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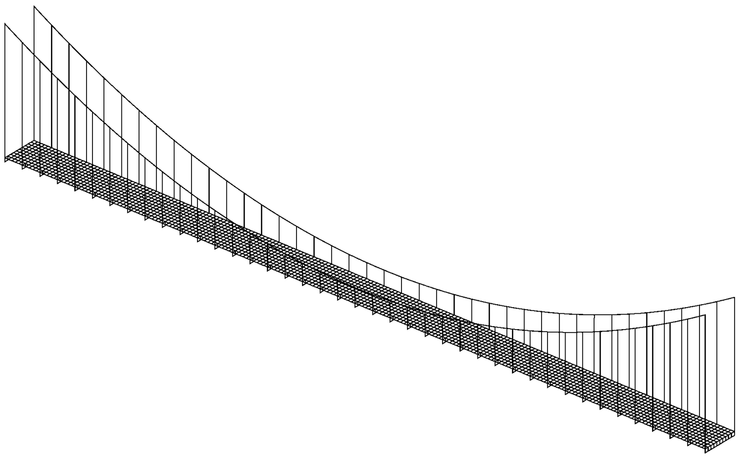

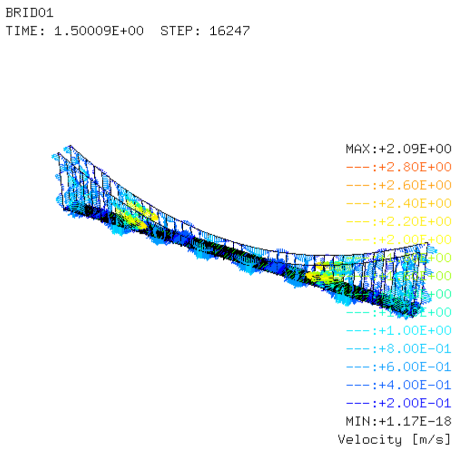

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Fluid-Structure Interaction with 3D beam and bar elements in EUROPLEXUS

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Contents

List of Tables

List of Figures

List of Algorithms

1 Introduction

This report presents the generalization of some existing Fluid-Structure Interaction (FSI) models of EUROPLEXUS and the development of a new drag-based FSI model for use in combination with 3D beam or bar elements.

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. As concerns post-processing of EPX results, the ParaView software [3] is sometimes used in the present report as an alternative to the built-in OpenGL-based visualizer of EPX.

EPX has a rich panoply of FSI models. Here we focus on models of the so-called *embedded* or *immersed* type, see [4] for a partial overview. In these models, the fluid and the structure sub-domains are fully non-conforming and are meshed independently from each other. Then, the structure mesh is simply superposed to (embedded in) the "background" fluid mesh. In this approach, the fluid mesh is often built as a parallelepiped made of regular brick elements (typically cubes) for simplicity, although the code accepts also a fully non-structured (irregular) fluid mesh. To achieve accuracy of FSI detection and enforcement, often Adaptive Mesh Refinement (AMR) or *adaptivity* is employed to refine the fluid mesh close to the structure. These techniques allow to cope with large motions, in particular large rotations, of the structure and with structural failure and erosion.

Two types of (pre-existing) embedded FSI algorithms are considered in the following. The `FLSR` algorithm uses a strong coupling approach based on Lagrange multipliers and is used in conjunction with Finite Element (FE) formulations of the fluid sub-domain. The `FLSW` algorithm uses a weak approach, based on direct transmission of pressure forces, and is used in conjunction with Cell-Centred Finite Volume (CCFV) formulations of the fluid sub-domain. Yet another type of embedded FSI algorithm, the `FLSX` model, has been recently formulated and implemented in EPX but it will not be considered in the present work.

The above mentioned FSI algorithms were developed and tested over the years with a variety of structural element types. Most often the structure is represented by shell elements, but also continuum elements are used sometimes. The case of 3D beam or bar elements is somewhat special (for the reasons that will be highlighted below), and it had never been considered prior to this work. The main goal here is therefore to extend the use of `FLSR` and `FLSW` algorithms in combination with 3D beam/bar elements, i.e. elements whose topological shape is a 2-node segment in 3D space.

Finally, a new model of FSI specific for 3D beam and bar elements is developed. This is based on the use of empirical drag coefficients and is implemented in a new type of decoupled constraint, the `LINK DECO DRAG` model.

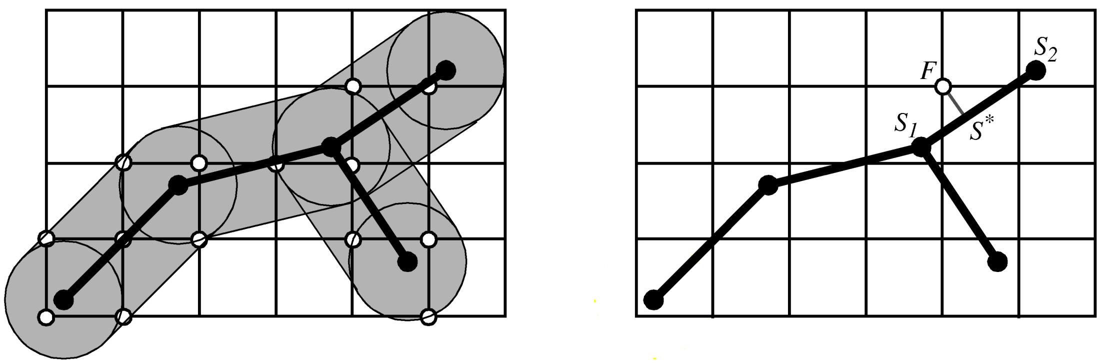
The most relevant Cast3m and EPX input files used to build the examples shown in this report are listed in the Appendix and are also available as a zipped folder (`FSI_BEAM_3D_Inputs.zip`) together with this report. Another available zipped folder (`FSI_BEAM_3D_Inputs_Extra.zip`) contains additional input files (only for post-processing), almost identical to the ones in the Appendix, which were not included in the Appendix for brevity but can be taken from the zipped folder to quickly re-run the examples in case of need.

2 The `FLSR` model

The `FLSR` model [5–7] establishes a *strong* coupling (by Lagrange multipliers) between a fluid and an immersed structure. The fluid is typically discretized by Finite Elements (FE), where the velocities and other kinematic variables are located at the element nodes.

2.1 The basic `FLSR` algorithm

The structural *influence domain*, built around the structure, is shown in grey in Figure 1(a). This consists of spheres of a certain radius R attached at the structural nodes (solid black circles) and of other more complex shapes (quadrilaterals in 2D, prisms, hexahedra or truncated cones in 3D) that join the spheres. All fluid nodes (hollow circles) located within the structural influence domain are considered to be coupled with the structure.



(a) Influence domain (b) F-S coupling

Figure 1: The FLSR algorithm (from [4]).

By following reference [4], let F be a coupled fluid node, see Figure 1(b). The closest point of the structure S^* (*not* a node, in general) is found and then suitable constraints are imposed on particle velocities. Two alternatives are available.

The first one corresponds to the input keyword `FSCP 0` (the default) and couples the two subdomains only along the (unit) local normal direction $\hat{\boldsymbol{n}}_S$:

$$\boldsymbol{v}_F \cdot \hat{\boldsymbol{n}}_S = \boldsymbol{v}_{S^*} \cdot \hat{\boldsymbol{n}}_S = (N_1 \boldsymbol{v}_{S_1} + N_2 \boldsymbol{v}_{S_2}) \cdot \hat{\boldsymbol{n}}_S \tag{1}$$

where $\boldsymbol{v}$ is the velocity and N_I are the shape functions.

Note that in the present case (unlike the case of conforming FSI meshes) the normal $\hat{\boldsymbol{n}}_F$ to the fluid domain F cannot be defined, so we use the normal $\hat{\boldsymbol{n}}_S$ to the structure S at point S^* instead (by tacitly assuming that such a normal can be computed). This form of the constraint aims at leaving the fluid free to slide along the structure. However, numerical examples have shown that sometimes this may produce fluid leakage, i.e. spurious (non-physical) passage of fluid across the structure.

The second alternative form of the constraint, obtained by the input keyword `FSCP 1`, reads simply:

$$\boldsymbol{v}_F = \boldsymbol{v}_{S^*} = N_1 \boldsymbol{v}_{S_1} + N_2 \boldsymbol{v}_{S_2} \tag{2}$$

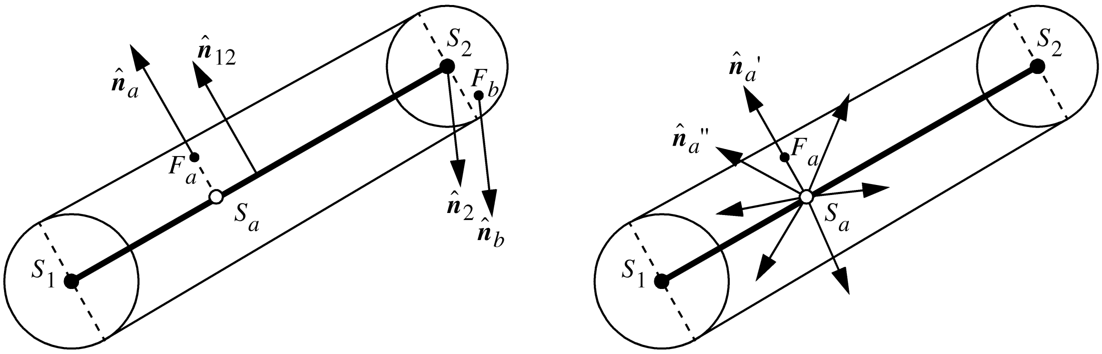
i.e. the fluid is tied to the structure in all directions (both along the normal and along the tangent). This condition is "stronger" than (1) and may lead to some non-physical loading of the structure along the tangent direction, but it has the advantage that it better avoids fluid leakage. Another practical advantage is that the computation of the local normal is not required in this case.

The actual coupling algorithm is slightly more complex than the summary given above. Much of the complexity comes from the calculation of the local normal(s). First of all, the (fast) search for the closest structural point S^* to a coupled fluid node F follows some rules. The sphere influence domains have the precedence over other types of domains. So, if a fluid node F is found to lie within a sphere, the search is interrupted and S^* is set at the structural point (a node) at the centre of the sphere. If the search over all sphere fails, it continues by considering the other types of domains. For example, if the point F lies within a quadrilateral (but not in a sphere) as shown in Figure 1(b), then S^* is found by projecting F onto the structural face associated with the quadrilateral (i.e., onto segment S_1S_2 in the example).

Next, the local normals to all influence sub-domains are computed. The normals to the face sub-domains (i.e. the quadrilaterals in Figure 1(b)) are computed first as the geometrical normals to such faces. Then, the normals to the node sub-domains (i.e. to the spheres) are computed by composing the normals of all faces adjacent to the node under consideration. In case of junctions, one may obtain more than one normal at a node. The maximum number of (independent) normals is equal to D, the space dimension (2 or 3 in EPX). When the number of normals $n_N = D$, the fluid is coupled along the structure along all spatial dimensions and the constraints are written along the global axes for simplicity.

2.2 Extension of the FLSR algorithm to 3D beams/bars

Upon its formulation and development, the FLSR model had been implemented for all relevant structural element types, namely for shells and continuum elements in both 2D and 3D, but the case of 3D beams/bars had been left behind. The reason was simply that it is not at all evident how to compute "the" normal to a 2-node segment (SEG2 geometrical shape) in 3D space.



(a) 2D space (b) 3D space

Figure 2: A SEG2 structural element.

Consider a SEG2 of structural nodes S_1 and S_2 as shown in Figure 2. The influence domain consists of two circles/spheres at the nodes (of different radii for full generality) and of a quadrangle/cone attached to the face. Let F_b be a fluid node embedded in one of the nodal domains (S_2) in the example and let F_a be a node embedded in the face domain (but not in any sphere).

The situation in 2D space is shown in Figure 2(a). For node F_b the closest structural point is, by definition, the centre S_2 of the circle, while for node F_a it is S_a, the projection of F_a onto the face. The normals are well-defined in the 2D case: at F_b the normal is $\hat{\boldsymbol{n}}_b \equiv \hat{\boldsymbol{n}}_2$, which results from the composition of the normals to all faces adjacent to the node (only one of these faces is actually shown in the drawing), while at F_a the normal is $\hat{\boldsymbol{n}}_a \equiv \hat{\boldsymbol{n}}_{12}$, i.e. the normal to the segment (face), which is geometrically well-defined in 2D.

The situation in 3D space is shown in Figure 2(b). The closest structural point S_a to a node such as F_a is obtained, like in 2D, by projecting F_a onto the segment. However, now the normal to S_a is no longer uniquely defined: any unit vector with origin in S_a and lying in the plane normal to the segment and passing through S_a is an acceptable normal. Some examples ($\hat{\boldsymbol{n}}'_a$, $\hat{\boldsymbol{n}}''_a$, etc.) are shown in the drawing. This indetermination is due to the fact that the normal to a 3D segment is not uniquely defined geometrically. Furthermore, since the normals to the faces are not defined, the normals to the nodes (e.g. S_2) are also undefined.

To cope with the possible presence of 3D beams/bars in the general `FLSR` algorithm, we must admit that some structural influence domains, more precisely nodal sphere and segment (truncated cone) domains, might have no geometrically valid normals, a possibility that was not allowed in the data structure prior to this development. The constraint expression in the case `FSCP 1` as given by Eq. (2) is still valid. However, we must find another reasonable way of writing the constraint in the case `FSCP 0`, which requires the definition of a normal as shown in Eq. (1). We tentatively explore several alternative possibilities:

1. At first sight one might be tempted to define the normal at F_a as the line joining S_a and F_a, i.e:

$$\hat{\boldsymbol{n}}_a = \frac{\vec{S_a F_a}}{||\vec{S_a F_a}||} = \hat{\boldsymbol{n}}'_a \tag{3}$$

which coincides with $\hat{\boldsymbol{n}}'_a$ in Figure 2(b). However, this expression is invalid when the fluid node lies exactly on the segment and, more importantly, it does not account in any way for the fluid flow direction.

2. So a better (and more physical) expression, making use of the *relative velocity* between the fluid and the structure, could be as follows. First evaluate the relative velocity:

$$\boldsymbol{v}_{Ra} = \boldsymbol{v}_{Fa} - \boldsymbol{v}_{Sa} \tag{4}$$

where, as indicated, the fluid velocity is evaluated at the fluid node F_a while the structure velocity is evaluated at the structure point S_a (under the assumption that the two points are not too far from each other). Then, the relative velocity vector is decomposed into a vector $\boldsymbol{v}^{\parallel}_{Ra}$ parallel to the segment and another vector $\boldsymbol{v}^{\perp}_{Ra}$ normal to the segment:

$$\hat{\boldsymbol{s}} = \frac{\vec{S_1 S_2}}{||\vec{S_1 S_2}||} \qquad \boldsymbol{v}^{\parallel}_{Ra} = (\boldsymbol{v}_{Ra} \cdot \hat{\boldsymbol{s}}) \cdot \hat{\boldsymbol{s}} \qquad \boldsymbol{v}^{\perp}_{Ra} = \boldsymbol{v}_{Ra} - \boldsymbol{v}^{\parallel}_{Ra} \tag{5}$$

where, as indicated by the first expression, $\hat{\boldsymbol{s}}$ is a unit vector directed along the segment S_1S_2. Finally, the normal $\hat{\boldsymbol{n}}_a$ is obtained by normalizing the vector $\boldsymbol{v}^{\perp}_{Ra}$:

$$\hat{\boldsymbol{n}}_a = \frac{\boldsymbol{v}^{\perp}_{Ra}}{||\boldsymbol{v}^{\perp}_{Ra}||} \tag{6}$$

The procedure Eqs. (4–6) fails if either the relative velocity vanishes ($\boldsymbol{v}_{Ra} = \boldsymbol{0}$) in Eq. (4) or the normal component of such velocity vanishes ($\boldsymbol{v}^{\perp}_{Ra} = \boldsymbol{0}$) in Eq. (6). However, in both cases the "directional" constraint Eq. (1) is already satisfied and needs not be imposed.

3. A third and final possibility, equivalent in practice to the previous one but slightly simpler to implement is that of considering not one but *two* distinct (mutually perpendicular) normals to the segment, denoted hereafter as $\hat{\boldsymbol{n}}'$ and $\hat{\boldsymbol{n}}''$, lying in the plane π perpendicular to the segment itself, see Figure 3. Such two vectors uniquely define the π plane and any couple of mutually perpendicular vectors in that plane may be chosen to this end. Hence not one, but two distinct

constraints of the form (1) are imposed. The result is that any "normal" fluid flow relative to the segment in the π plane is blocked, while any relative flow in the "tangent" direction (i.e., along the segment) is allowed without any restraint.

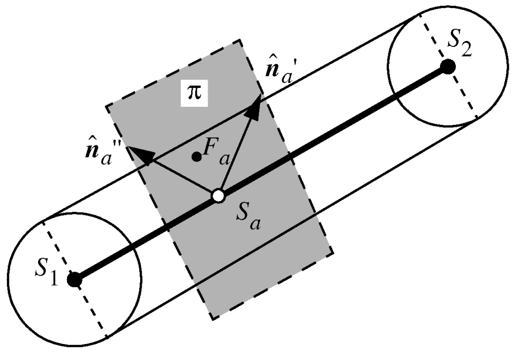


Figure 3: The two normals to a SEG2 structural element in 3D space.

The last strategy described above was chosen and implemented in EPX for the case `FSCP 1`. In order to uniquely compute the two normals $\hat{\boldsymbol{n}}'$ and $\hat{\boldsymbol{n}}''$ we use Algorithm 1 from reference [12], adapted from a procedure proposed by Hughes *et al.* [13, 14] for the evaluation of the nodal fiber basis in 3D shell element meshes.

Algorithm 1 Determination of the two normals to a 3D segment.

Compute an unit orthonormal basis (ξ, η, ζ) such that ζ is directed along a given segment $\vec{S_1S_2}$ in 3D space:

1. Let $\hat{\boldsymbol{g}}_i$, $i = 1, \cdots, 3$, denote the global unit vectors, that is $\hat{\boldsymbol{g}}_1 = (1, 0, 0)$, $\hat{\boldsymbol{g}}_2 = (0, 1, 0)$ and $\hat{\boldsymbol{g}}_3 = (0, 0, 1)$.
2. The $\boldsymbol{\zeta}$ vector is directed along the given segment, i.e. $\boldsymbol{\zeta} = \vec{S_1S_2}/||\vec{S_1S_2}||$.
3. Set a_i equal to the lengths of the global components of $\boldsymbol{\zeta}$, i.e. $a_i = |\zeta_i|$, $i = 1, \cdots, 3$.
4. Set $j = 1$.
5. If $a_1 > a_3$ then set $a_3 = a_1$ and $j = 2$.
6. If $a_2 > a_3$ then set $j = 3$.
7. Compute the $\boldsymbol{\eta}$ vector, which coincides with the second normal: $\boldsymbol{\eta} = \hat{\boldsymbol{n}}'' = (\boldsymbol{\zeta} \times g_j)/||\boldsymbol{\zeta} \times g_j||$.
8. Compute the $\boldsymbol{\xi}$ vector, which coincides with the first normal: $\boldsymbol{\xi} = \hat{\boldsymbol{n}}' = \boldsymbol{\eta} \times \boldsymbol{\zeta}$.

The orthonormal basis obtained satisfies the condition that, if $\boldsymbol{\zeta}$ is "close" to $\hat{\boldsymbol{g}}_3$, then $\boldsymbol{\xi}$ and $\boldsymbol{\eta}$ will be "close" to $\hat{\boldsymbol{g}}_1$ and $\hat{\boldsymbol{g}}_2$, respectively.

2.2.1 Dealing with FSI-driven adaptivity

Some special measures must be taken in treating FSI-driven adaptivity in conjunction with 3D beam/bar elements. The FSI-driven fluid mesh refinement algorithm is summarized in Figure 4, taken from report [10] (which should be consulted for further details).

The key point here is that in the standard algorithm, at the end of the refinement process the code uses the *finest* influence domain (corresponding to an influence diameter $D_3 = D_1/4$ in the example) to locate the fluid entities (here the FE fluid nodes) which have to be coupled with the structure, as it is shown in the last drawing of Figure 4.

This is the correct behaviour with shell or continuum structural elements, because it minimizes the amount of fluid that will be eventually "attached" to the structure. However, in the case of 3D beam/bar elements this choice is inappropriate, since the amount of fluid interacting with the structure must be constant in such a case and is ruled by the diameter of the beam or bar, which does not change with adaptivity in the fluid (nor with adaptivity in the structure, should this be applied).

Therefore, where the structure consists of 3D beam/bar elements, the *coarsest* (original) influence domain (corresponding to the input influence diameter D_1 in the example) should be used to locate the coupled fluid nodes, as shown in Figure 5.

By comparing this Figure with the last drawing of Figure 4, we see that many more fluid nodes (all the nodes located inside the *original* user-specified influence domain radius, that should correspond

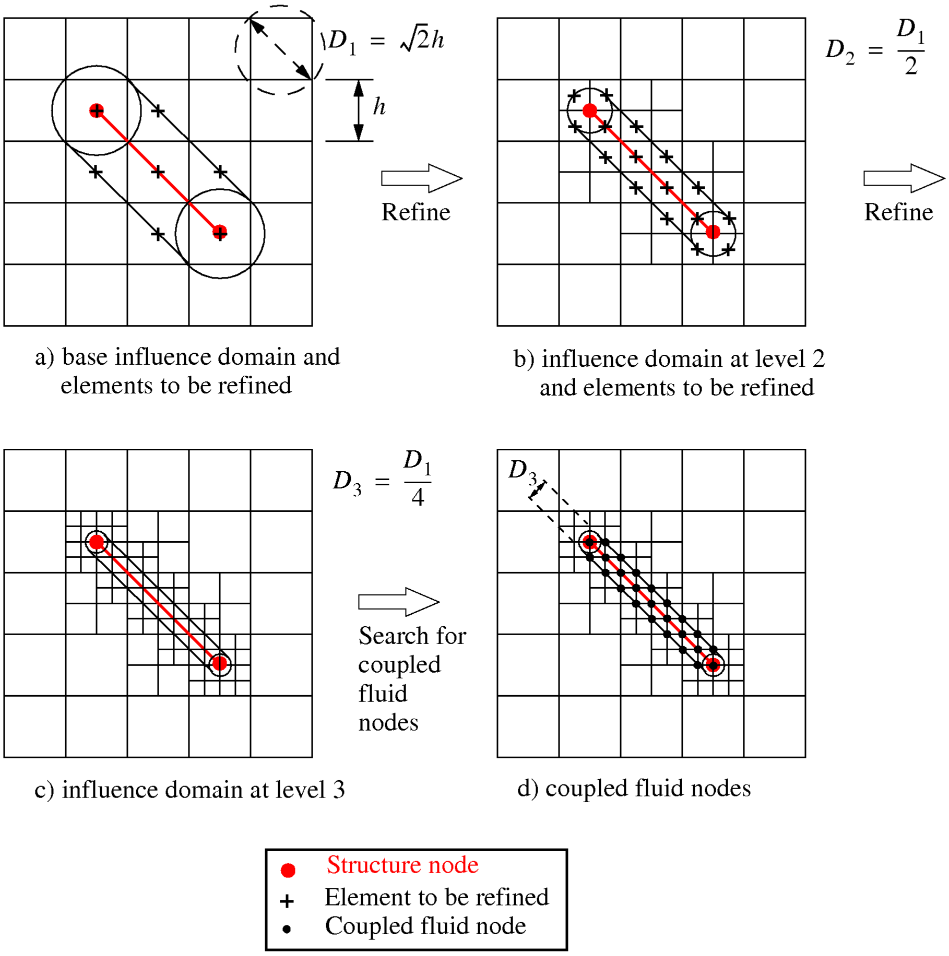


Figure 4: FSI-driven adaptivity (from [10]).

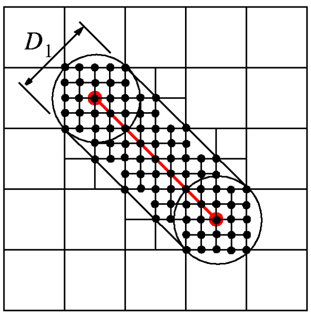


Figure 5: Corrected FSI-driven adaptivity in conjunction with 3D beam/bar elements.

with the physical radius of the beam/bar) are coupled with the structure than with the previous algorithm.

The implementation of the correction consists in letting the code scale down *all* FSI influence domains, including those attached to 3D beam/bar elements, in order to do the automatic fluid mesh adaptation (in subroutine ADAPT_FLSR). Then, however, in subroutine LINK_FLSR, the FSI influence domains attached to 3D beam/bar elements are scaled back up to their original size before searching for the coupled fluid nodes, and finally re-scaled down to the adapted size after the constraints have been written. This approach minimizes the number of changes to be made in the standard FSI-driven adaptivity routines and thus reduces the possibility of errors.

In order to identify the influence domains attached to 3D beam/bar elements, a new attribute `HAS_SEG2_3D` is added to the derived type `FLSR_DOMAIN` defined in module `M_LINK_FLSR_DATA`:

```
TYPE FLSR_DOMAIN
```

```
    INTEGER :: N_NODES               ! N. OF NODES (1, 2, 3 OR 4)
    INTEGER, POINTER :: NODES(:)     ! NODES OF THE DOMAIN
    REAL(8), POINTER :: RADII(:)     ! NODAL RADII
    INTEGER :: N_NORMALS             ! N. OF DISTINCT NORMALS
                                     ! ATTENTION: 3D BEAM/BAR ELEMENT
                                     ! (SEG2) DOMAINS HAVE 2 NORMALS
                                     ! IN THE PLANE PERP. TO THE SEGMENT
    REAL(8), POINTER :: NORMALS(:,:) ! DISTINCT NORMALS (NORMALIZED)
    INTEGER :: N_FACES               ! N. OF FACES FOR THE NORMAL(S)
    INTEGER, POINTER :: FACES(:)     ! FACES FOR THE NORMAL(S)
    LOGICAL :: IS_ERODED             ! EROSION FLAG
    LOGICAL :: BLOQ_FLUX             ! BLOCK FLUXES
    LOGICAL :: DEACT_VOFIRE          ! DEACTIVATE VOFIRE
    LOGICAL :: HAS_SEG2_3D           ! IS DOMAIN ATTACHED TO A SEG2 IN 3D?
                                     ! .TRUE. FOR 2-NODE FACE DOMAINS OF
                                     ! A 3D SEG2 (BEAM/BAR ELEMENT IN 3D)
                                     ! AND FOR NODAL SPHERES ATTACHED TO
                                     ! A 3D SEG2 NODE. THESE DOMAINS MUST
                                     ! BE SCALED/UNSCALED IN FSI-DRIVEN
                                     ! ADAPTIVITY (SEE LINK_FLSR) WHEN
                                     ! SEARCHING FOR COUPLED FLUID NODES
  END TYPE FLSR_DOMAIN
```

The new attribute is set to `.TRUE.` during the construction of the influence domains, for face domains (truncated cones) attached to a SEG2 element shape in 3D. At the same time, the attribute is set to `.TRUE.` also for any nodal domain (sphere) that is attached to a node belonging to a SEG2.

At the end of the domains construction phase, the SEG2 face domains (truncated cones) receive two normals as detailed in Algorithm 1, while the SEG2 nodal domains (spheres) receive either two or three normals, depending upon the number and orientation of the SEG2 faces that insist on each node. For example, a node belonging to (only) two SEG2 aligned with each other will have two normals (the same as those of each SEG2), while a node belonging to two SEG2 connected at a right angle will have three normals, i.e. the fluid will completely stick to the structure along all three global directions.

For completeness, it should also be mentioned that in module `M_LINK_FLSR_DATA` the description of the array `FLSR_SFACE_NORMALS` is also modified in order to allow for a face to have 0 normals (i.e. the geometric normal to the face is undetermined).

```
  PUBLIC ::
 >  FLSR_SPHERE,        ! INDEX OF FLSR SPHERE AT A GLOBAL NODE (0=NONE)
 >  N_FLSR_SFACES,      ! NUMBER OF FLSR STRUCTURAL FACES
 >  FLSR_SFACES,        ! ARRAY  OF FLSR STRUCTURAL FACES
 >  FLSR_SFACE_NORMALS, ! ARRAY  OF FLSR STRUCTURAL FACE NORMALS
                        ! (***NOT*** NORMALIZED !!!)
                        ! A 2-NODE (SEG2) FACE IN 3D HAS NO GEOMETRIC
                        ! NORMALS SO ITS 'NORMAL' IS SET TO (0,0,0)
 >  N_FLSR_SCORNERS,    ! NUMBER OF FLSR STRUCTURAL CORNERS
 >  FLSR_SCORNERS       ! ARRAY  OF FLSR STRUCTURAL CORNERS
```

This applies to 3D segment faces in array `FLSR_FACES` and should not be confused with the face-related FLSR influence domains (`FLSR_DOMAINS`) which have been described previously, and which indeed receive two normals each.

2.2.2 Visualization issues

As a consequence of the correction to the FSI-driven adaptivity algorithm detailed in the previous Section, the OpenGL visualization of `FLSR` influence domains in EPX also had to be corrected.

In routines RENDER_FDOM and RENDER_FDOM_PART the radii of influence domains (both truncated cones and spheres) attached to 3D beam/bar elements are scaled up to their original size for visualization, in order to be consistent with the corresponding coupled fluid nodes (should these be visualized as well).

3 Numerical examples with `FLSR`

We now consider some numerical examples in order to validate the developments described in the previous Sections. We start by the `FLSR` model of FSI that was described in Section 2.

3.1 Free beam under blast loading

We consider a preliminary test, aiming at checking only qualitatively the FSI in conjunction with beam elements. A straight beam is embedded in a parallelepiped of fluid. A high-pressure gas occupies the left region of the fluid domain while the rest is at lower pressure. The fluid envelope is blocked (`FSR` condition), except the right wall which is absorbing.

The blast-like wave generated by the initial pressure difference hits the beam and produces different (qualitative) effects depending upon the beam orientation (either horizontal, i.e. parallel to the fluid flow, or vertical, i.e. perpendicular to the flow) and on the setting of the `FSCP` coupling parameter (either 1, i.e. full coupling, or 0, i.e. normal coupling). The four performed simulations are summarized in Table 1.

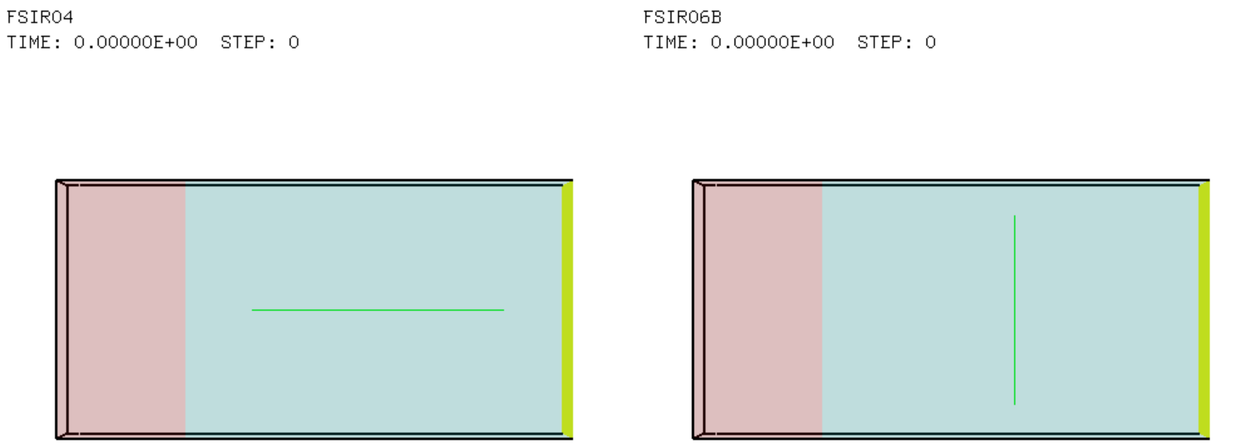
Case	Mesh	Description	Final time [ms]	Steps	CPU [s]	Computer
FSIR04	4 POUT	Horizontal beam, `FSCP 1`	20	186	3.6	M6700
FSIR05	4 POUT	Horizontal beam, `FSCP 0`	20	182	3.5	M6700
FSIR06	3 POUT	Vertical beam, `FSCP 1`	20	198	3.9	M6700
FSIR07	3 POUT	Vertical beam, `FSCP 0`	20	198	3.9	M6700

Table 1: Calculations for the free beam under blast loading.

Note that in these tests the beam is not expected to be loaded significantly in either configuration (other than as an almost rigid body) so the tests do not verify the POUT element employed, but only the macroscopic effects of FSI.

3.1.1 Cases FSIR04 to FSIR07

In the first test case, FSIR04, the beam lies horizontally in the fluid and we use full coupling (`FSCP 1`). The initial geometry is shown in Figure 6(a).



(a) Cases FSIR04 and FSIR05 (b) Cases FSIR06 and FSIR07

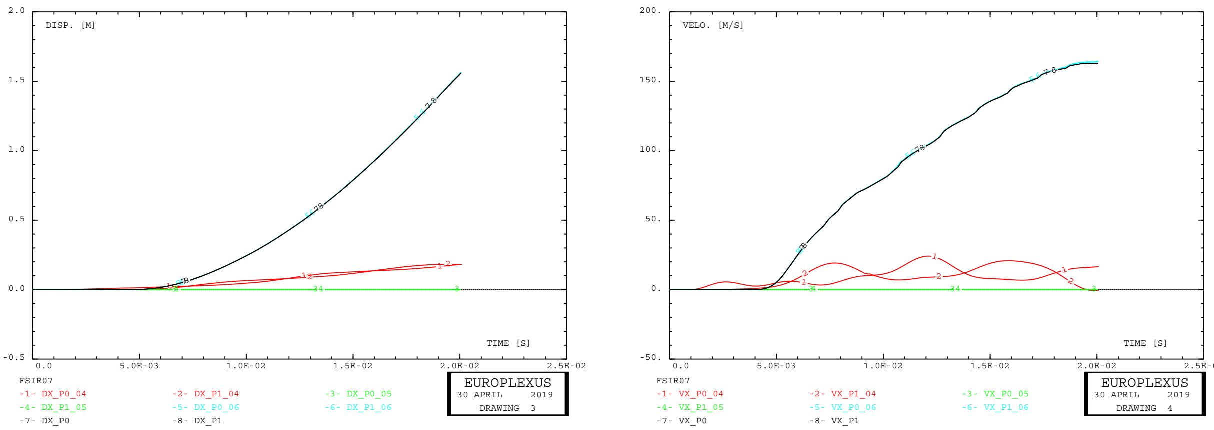
Figure 6: Initial geometries for tests FSIR04 to FSIR07.

We expect the fluid flow to exert a modest (but non-zero) drag on the beam, due to the fact that coupling occurs in all three spatial directions, including the horizontal one.

Case FSIR05 is the same as FSIR04 but we set `FSCP 0`, thus activating only normal coupling. In this case the fluid is free to flow along the beam (i.e. in the horizontal direction) and we expect the drag force to be exactly zero.

The next two cases, FSIR06 and FSIR07, are repetitions of FSIR04 and FSIR05, respectively, but the beam is placed vertically as shown in Figure 6(b). Since the fluid flow occurs transversally with respect to the beam, in both cases we expect a strong drag force on the beam, and (almost) independent from the setting of the `FSCP` parameter.

The results of these four calculations in terms of beam tip displacement and velocity are summarized and compared in Figure 7. The qualitatively expected patterns are confirmed: the displacements in case FSIR04 (red curves) are modest but non-zero, those in case FSIR05 (green curves) are strictly zero, while those in cases FSIR06 and FSIR07 (cyan and black curves, respectively) are much larger and almost identical to each other.



(a) Beam tip displacement (b) Beam tip velocity

Figure 7: Comparison of results in tests FSIR04 to FSIR07.

3.2 Cantilever beam with initial velocity in vacuum

Before doing the actual FSI tests, we want to check the use of beam elements in EPX. A simple cantilever beam in vacuum (no fluid, no FSI) is considered to this end. The beam is subjected to a uniform initial velocity of 10 m/s, except at the blocked end. The beam is 0.8 m long and has a square cross-section of 0.04×0.04 m. The material of the cantilever is chosen linear elastic ($\rho = 2000$, $E = 2.0 \times 10^9$, $\nu = 0.3$) for simplicity.

Solutions with continuum elements are obtained first and are then compared with solutions using beam elements (POUT). The scope is to quantify the dependence of the structural response upon the discretization used for the beam. All solutions are summarized in Table 2.

Case	Mesh	Description	Final time [ms]	Steps	CPU [s]	Computer
STRU01	20 CUB8	Structure only, coarse continuum mesh	20	1019	1	M6700
STRU02	160 CUB8	Structure only, fine continuum mesh	20	2041	2	M6700
STRU03	10 POUT	Structure only, coarse beam mesh	20	1022	1	M6700
STRU04	20 POUT	Structure only, fine beam mesh	20	4087	1	M6700

Table 2: Calculations for the cantilever beam with initial velocity (no fluid).

3.2.1 Purely structural cases STRU01 to STRU04

In order to trigger some deformations in the absence of blast loading, the beam is clamped at its lower extremity and is subjected to an initial uniform velocity in the x-direction of 10 m/s (in all nodes except those on the lower extremity, which are blocked). The response is therefore expected to be different from (although hopefully qualitatively similar to) that of the actual blast tests that will be considered in the next Sections. In the first test (STRU01), we use only 20 CUB8 elements (one element only in the beam's cross-section).

The next test, STRU02, uses 160 elements CUB8 of half size with respect to the previous case (2×2 elements in the beam's cross-section).

Next, we consider discretizations of the beam by means of dedicated 3D beam elements. In EPX the only available 3D beam element (which includes bending effects in addition to membrane effects) is the POUT element. In test STRU03 the beam is discretized by using 10 POUT elements. Each element has the shape of a 2-node segment.

```
STRU03
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     NGRO 2 'nblo' LECT p0 TERM
            'ntop' LECT p1 TERM
     COUL VERT LECT stru TERM
MATE LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123456 LECT nblo TERM
INIT VITE 1 10.0 LECT stru DIFF nblo TERM
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

The characteristics of the beams are set by means of the `COMP GEOP` directive. Here a rectangular (actually, square) cross-section is prescribed by means of the `RECT` keyword. Next, one has to define the local reference frame of the beam. By convention, the local ξ-axis is directed along the beam, i.e. along the line connecting the first and the second node of each beam element. In the present example, this coincides with the global z-axis.

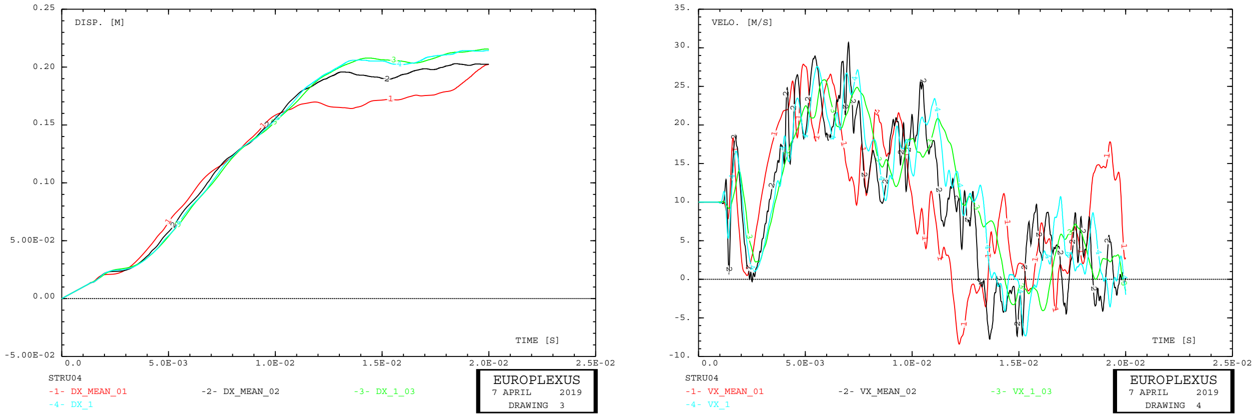
To uniquely define the local frame, a (provisional) local η-axis must be defined by the user by means of its three global components `VX`, `VY` and `VZ`. This vector *must not* be co-linear with the beam (ξ) local axis, but it does not need to be unitary nor exactly normal to the ξ local axis. These two axes define a plane. The final η-axis is then constructed by EPX as lying on this plane, normal to the ξ local axis and of unit length. The local ζ-axis finally results as the vector product of the ξ and η local axes.

In the present example, the local η axis must lie in the global plane xy, which is normal to the beam segment. For simplicity, we will take it coincident with the global y axis. Therefore, the η-axis has components $(0, 1, 0)$ as shown in the input. Next, the lengths of the sides of the rectangular cross-section of the beam `AY` (along η) and `AZ` (along ζ) are given, which in this case are both equal to 0.04 m. These characteristics are associated to all elements of the beam (`stru`) in this particularly simple case.

The next and final test, STRU04, uses a twice finer discretization than in case FLSR03, i.e. 20 beam elements POUT of half length with respect to the previous case (but with the same cross-section, of course).

The results of these four calculations in terms of beam tip displacement and velocity are summarized and compared in Figure 8. It can be seen that the results depend only slightly upon the discretization and the type of elements used. In particular, the solutions with beam elements are in very good agreement with the solution using the finer continuum mesh.

This is confirmed also by Figure 9, which depicts the final shape of the deformed beam in the four test cases.



(a) Beam tip displacement (b) Beam tip velocity

Figure 8: Comparison of results in tests STRU01 to STRU04.

(a) STRU01 (b) STRU02 (c) STRU03 (d) STRU04

Figure 9: Final shape of the beam in cases STRU01 to STRU04.

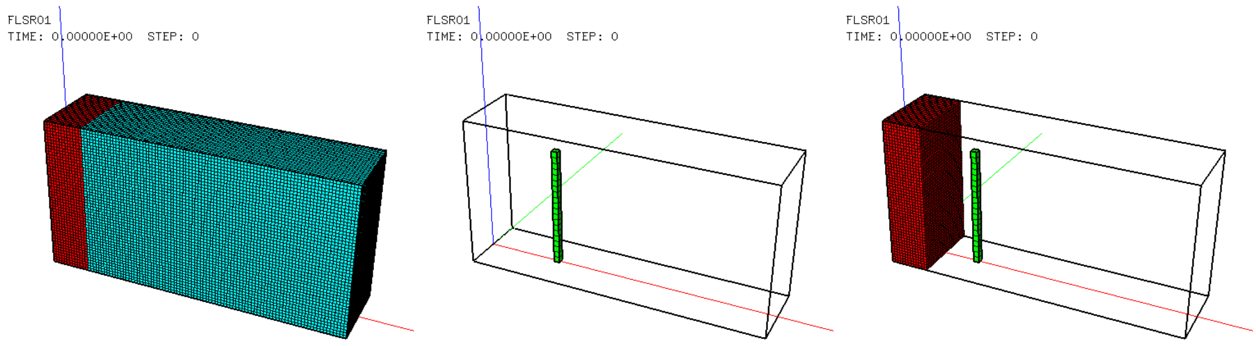
3.3 Cantilever beam under blast loading with continuum elements

We consider a relatively simple academic problem, a cantilever beam subjected to blast loading. A slender cantilever beam is blocked at one extremity and is immersed in a box filled with fluid and with rigid walls. At one extremity of the box a region is filled by high-pressure air while the rest is at atmospheric conditions. The pressure waves generated by the sudden release of the high-pressure gas hit the beam and deform it.

The initial geometry of the problem is sketched in Figure 10. The fluid box measures $2.0 \times 0.5 \times 1.0$ m, the cantilever, fixed at the bottom, measures $0.04 \times 0.04 \times 0.8$ m and is located at 0.5 m from the left extremity of the box. The high-pressure gas, shown in red, fills the first 0.25 m of the box.

The material of the cantilever is chosen linear elastic ($\rho = 2000$, $E = 2.0 \times 10^9$, $\nu = 0.3$) for simplicity. The boundary conditions of the fluid box are set as rigid, also for modelling simplicity (although the resulting physical response of the cantilever will be relatively complicated due to wave reflections). Considering open inlet / outlet flow conditions instead of rigid walls would be closer to the real application (shock tube) and would produce a simpler behaviour of the cantilever, but it would also introduce additional uncertainties in the modelling, especially in view of comparing different types of fluid formulations (FE *vs.* VFCC).

The high-pressure air is modelled as a perfect gas at an initial pressure of 8 bar ($\rho = 10.0$, $i = 2.0 \times 10^5$, $\gamma = 1.4$), while the rest of the air has atmospheric conditions with an initial pressure of 0.8 bar ($\rho = 1.0$, $i = 2.0 \times 10^5$, $\gamma = 1.4$). The final time of the simulation is set to 20 ms, sufficient for observing several reflections of the pressure waves inside the box. It should be noted that the actual intended pressures were 10 bar and 1 bar, respectively, which would correspond to a specific internal energy $i = 2.5 \times 10^5$ and not $i = 2.0 \times 10^5$ as typed by mistake in the first input file. The input error was detected after several lengthy test had been already run, so it was decided to keep



(a) Whole model (b) Structure (c) Structure and explosive

Figure 10: Geometry of the cantilever beam under blast problem.

these somewhat strange values (especially the "atmospheric" pressure of 0.8 bar) since they have no influence on the results comparisons with different methods that will be performed in the report.

Before attempting solutions with beam elements, we obtain reference solutions by discretizing the cantilever via continuum elements and by using the standard FSI algorithms available in EPX prior to the present work. These calculations require a very fine mesh and are therefore relatively expensive. They are summarized in Table 3.

Case	Mesh	Description	Final time [ms]	Steps	CPU [s]	Computer
FLSR01	FL38, CUB8	FE fluid, `FLSR`, coarse mesh	20	1720	1035	M6700
FLSR02	FL38, CUB8	FE fluid, `FLSR`, fine mesh	20	3522	15 180	EVICOM
FLSR03	FL38, CUB8	FE fluid, `FLSR`, adaptive mesh	20	7506	88 304	EVICOM

Table 3: Reference calculations for the cantilever beam under blast loading with `FLSR`.

3.3.1 Case FLSR01

The first solution uses a uniform mesh size of 0.02 m in the fluid and of 0.04 m in the structure, as depicted in Figure 10. The fluid consists of 125 000 cube elements of type FL38 while the beam is discretized by a single row of 20 elements CUB8.

```
FLSR01
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui CUB8 stru TERM
COMP GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT stru TERM COND Z LT 0.001
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT stru TERM COND Z GT 0.799
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
```

The calculation is declared ALE, with the structure `stru` treated as Lagrangian and the fluid `flui` treated as Eulerian. The `nfsr` object is extracted as the nodes on the envelope (`ENVE`) of the fluid domain `flui`.

```
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
```

```
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
```

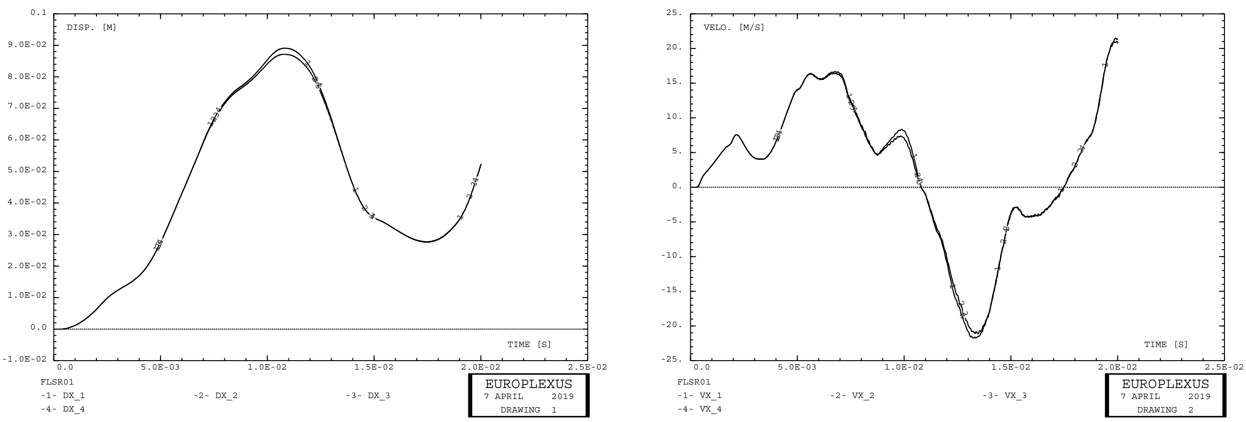
The FLUT material is used for the fluids and the LINE material is used for the structure.

```
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          HGRI 0.041 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

The base of the cantilever beam nblo is completely blocked. The rigid walls of the fluid box are modelled by the FSR condition applied to the nfsr object previously described. Finally, the FLSR interaction model is applied to the entire cantilever stru embedded in the fluid flui. The radius R of the structural influence domain is set so as to encompass at least one fluid element and the fast search grid HGRI is set so as to encompass at least one structure element. Full coupling between fluid and structure along all spatial directions is prescribed (FSCP 1) instead of the default behaviour (coupling only along the normal direction).

Upon a first attempt of running the case with the default stability safety coefficient (CSTA 0.8) very strange results were obtained, showing a sort of hourglassing in the structure (incipient instability). By reducing CSTA to the more prudent value of 0.5 the problem is avoided and the results are consistent. The calculation was run on the M6700 laptop PC under Windows 7 and took 1720 time steps and 1035 s of CPU to reach the final time of 20 ms.

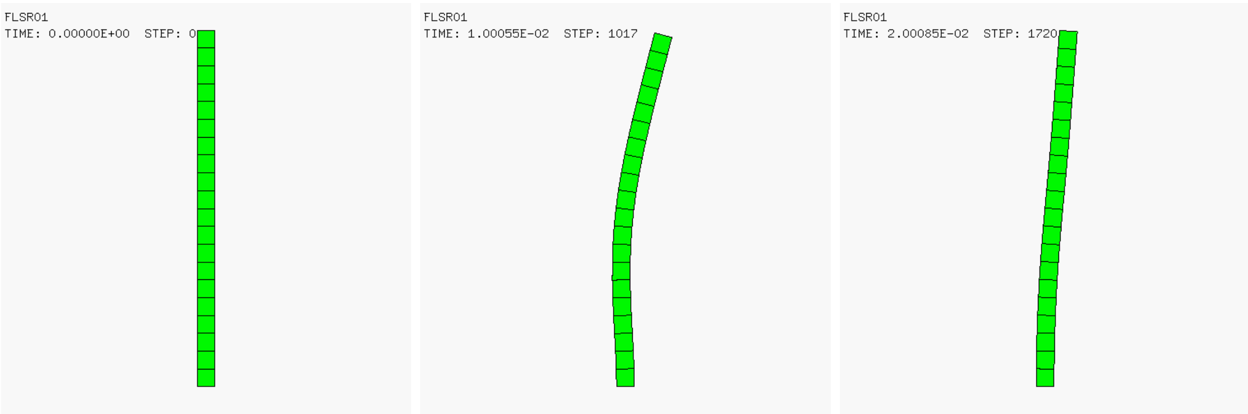
Figure 11 shows the x-displacement and the x-velocity of the four nodes at the tip of the cantilever beam. The small spread between the curves is physical and is due to the finite rotation of the beam.



(a) Beam tip displacement (b) Beam tip velocity

Figure 11: Some results of test FLSR01.

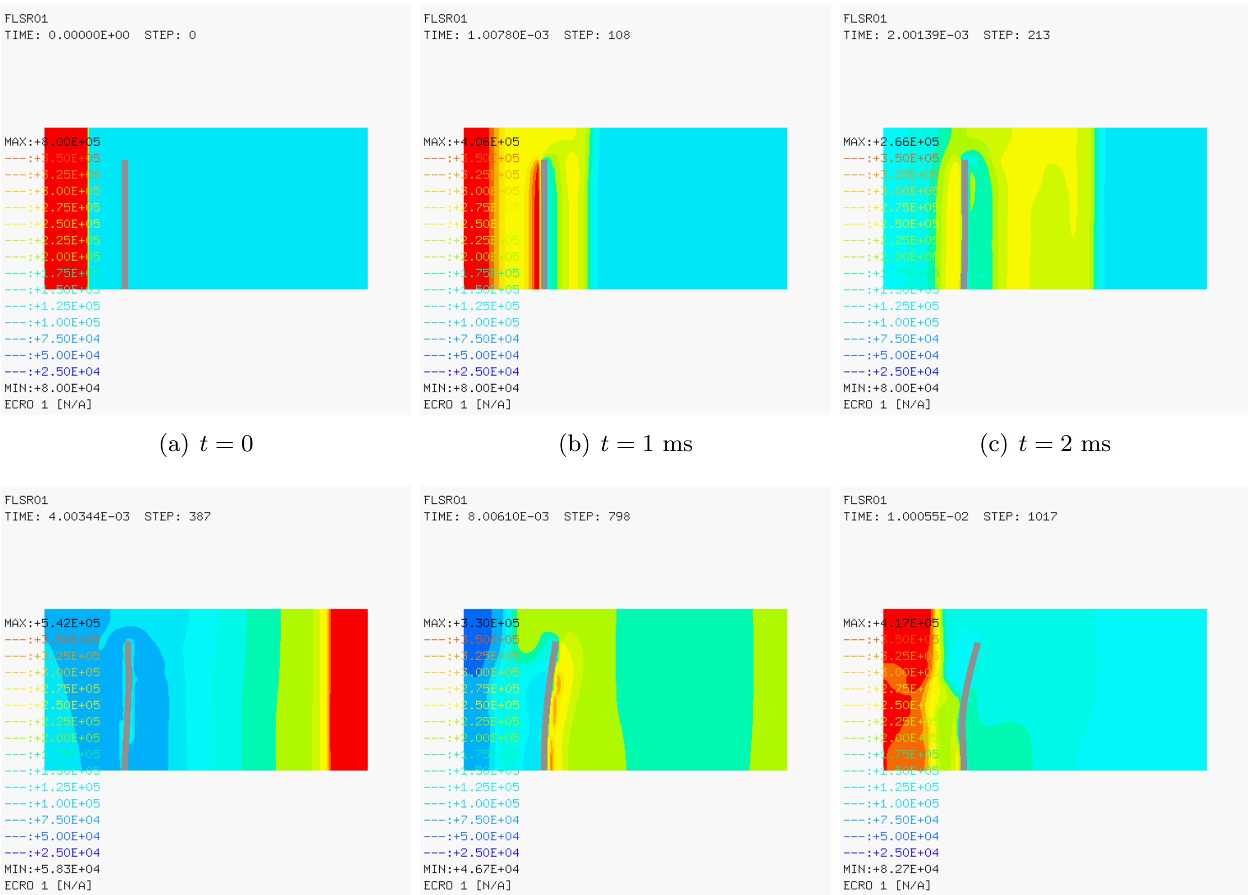
The deformed shape of the beam is shown in Figure 12 at some representative time instants.



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

Figure 12: Deformed beam shape in test FLSR01.

Figure 13 presents the fluid pressures and the deformed cantilever shape seen from the side on 1/2 of the model for insight into what is happening in the interior. At 1 ms the pressure waves are impinging on the beam, at 4 ms the wave hits the right wall of the box and is reflected, at 8 ms the reflected wave strikes again on the beam and at 10 ms it is eventually reflected back from the left extremity of the box.

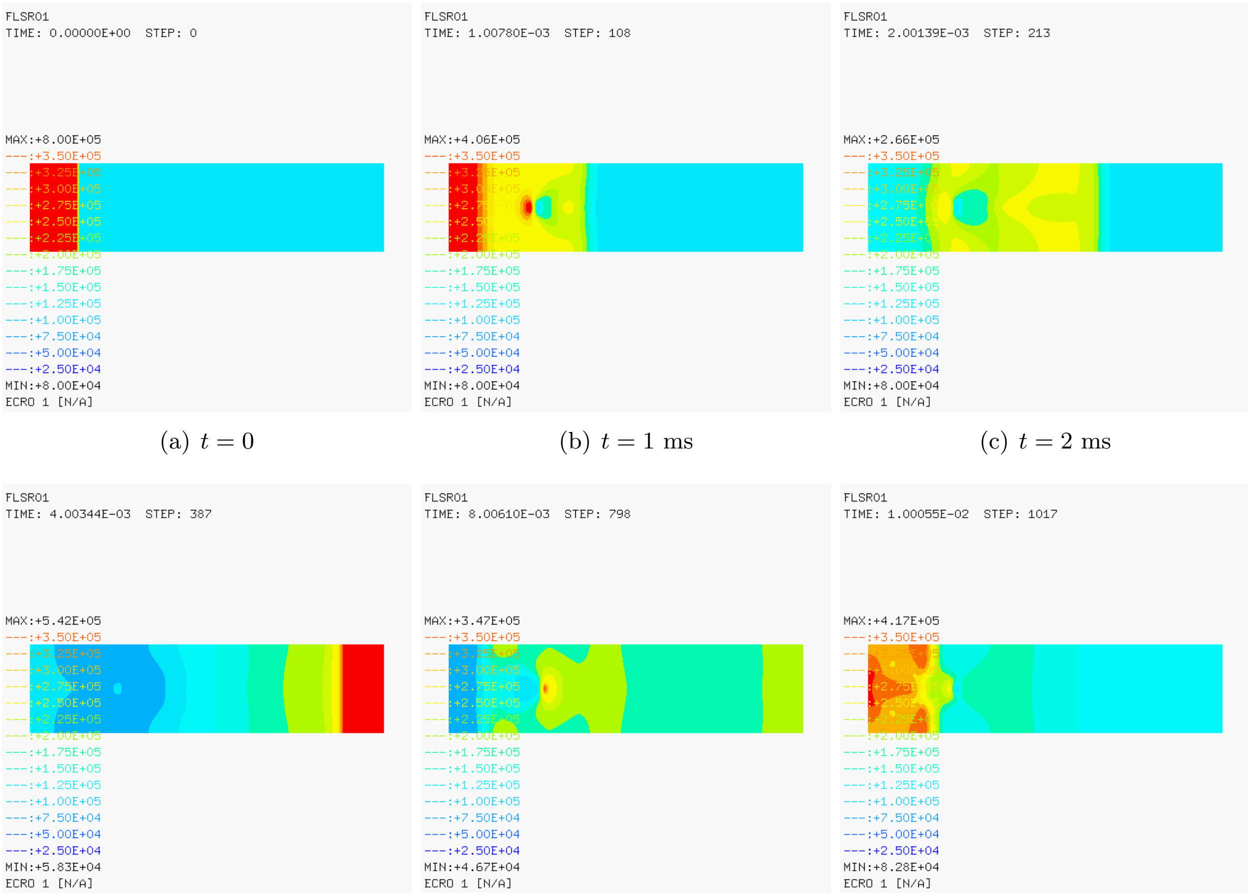


(a) $t = 0$ (b) $t = 1$ ms (c) $t = 2$ ms

(d) $t = 4$ ms (e) $t = 8$ ms (f) $t = 10$ ms

Figure 13: Fluid pressures in test FLSR01 (side view).

Figure 14 shows the same pressure results but seen from below, in the whole model. Note how the pressure wave impinges on the beam creating a stagnation pressure and a side flow around the obstacle. This phenomenon can also be appreciated in Figure 15, which shows the fluid velocities.



(a) $t = 0$ (b) $t = 1$ ms (c) $t = 2$ ms

(d) $t = 4$ ms (e) $t = 8$ ms (f) $t = 10$ ms

Figure 14: Fluid pressures in test FLSR01 (bottom view).

3.3.2 Case FLSR02

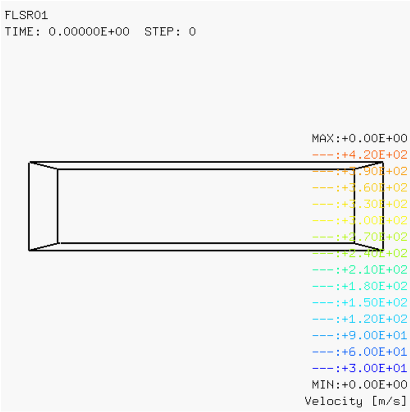
The next solution uses a mesh twice finer with respect to the previous solution, in order to investigate possible mesh dependency effects. The beam is discretized by 80 CUB8 elements of size 0.02 m and the fluid uses 1 000 000 elements of type FL38 and size 0.01 m.

The calculation was run on the EVICOM PC under Windows 10 (which is used for longer runs) and took 3522 time steps and 15 180 s of CPU to reach the final time of 20 ms.

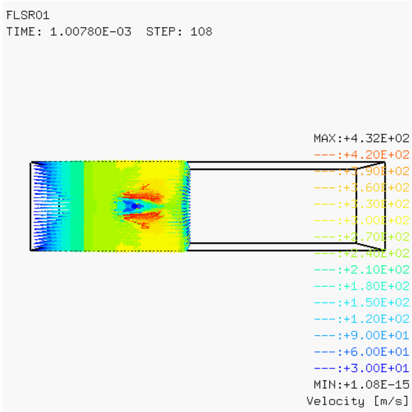
Figure 16 shows the x-displacement and the x-velocity of the nine nodes at the tip of the cantilever beam. The small spread between the curves is physical and is due to the finite rotation of the beam.

The displacements and velocities (shown in black) are compared in Figure 17 with those obtained in the previous solution FLSR01 (shown in red). For each solution, only one curve is shown, obtained as the arithmetic mean (`MEAN` operator in EPX) of the curves presented previously and relative to all points at the tip of the beam. The behaviour has some similarities but large differences are observed in the values. Part of these discrepancies are thought to be due to the (twice) finer discretization of the beam, and the rest to the fact that the influence domain of the structure is twice smaller in the second simulation, thanks to the twice fine fluid mesh, so that FSI spatial resolution is much better.

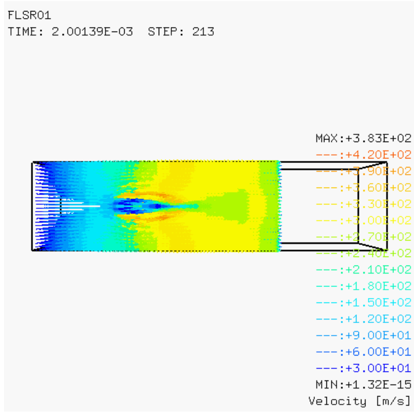
A priori it is hard to tell which of these two factors has a larger influence on the results. However, the previous series of purely structural tests (STRUxx) presented in Section 3.2 may help to clarify this point. From those results, it may be concluded that most of the discrepancies observed in Figure 17 for the blast loaded beam are due to the FSI effect, in particular to the use of a different value of the influence domain radius in the two simulations presented in that Figure. One might tentatively say that when the influence radius is larger (red curve in Figure 17(a)) more fluid is “attached”



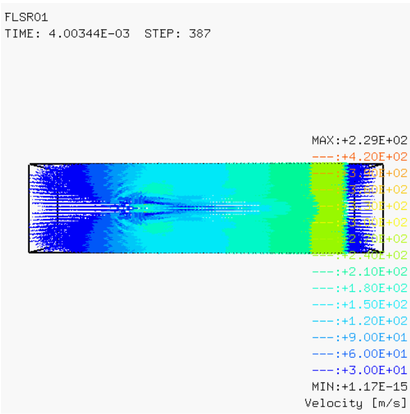
(a) $t = 0$



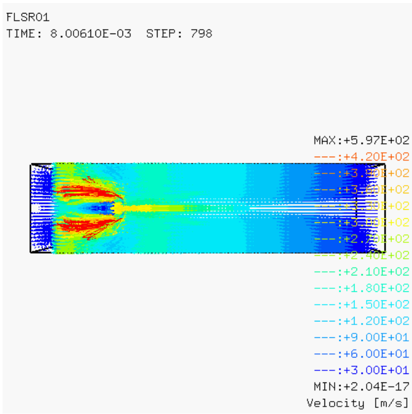
(b) $t = 1$ ms



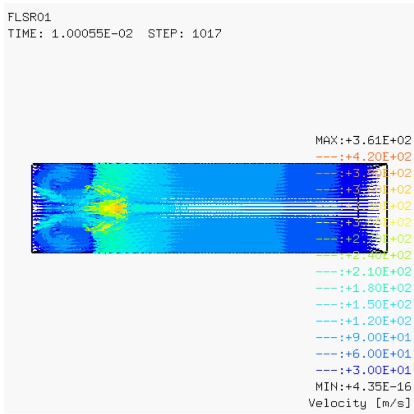
(c) $t = 2$ ms



(d) $t = 4$ ms

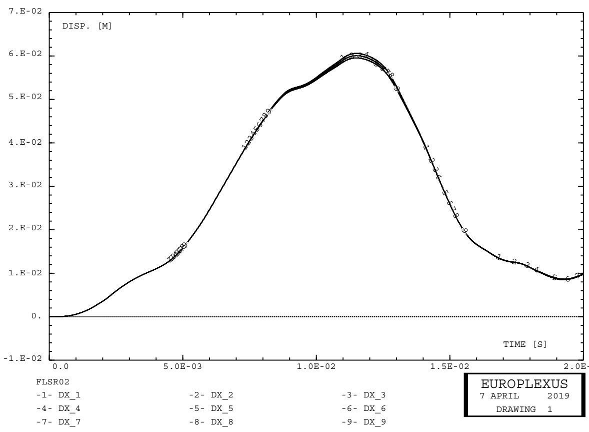


(e) $t = 8$ ms

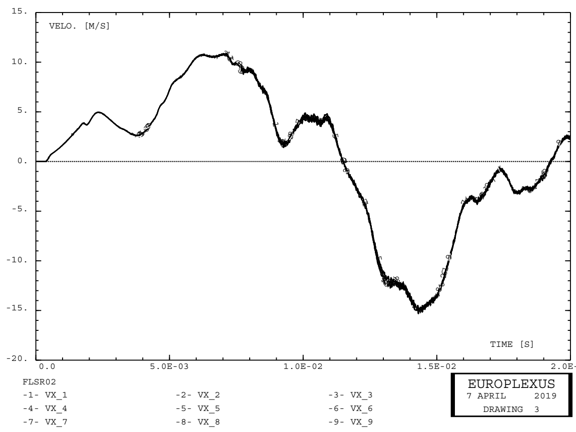


(f) $t = 10$ ms

Figure 15: Fluid velocities in test FLSR01 (bottom view).



(a) Beam tip displacement



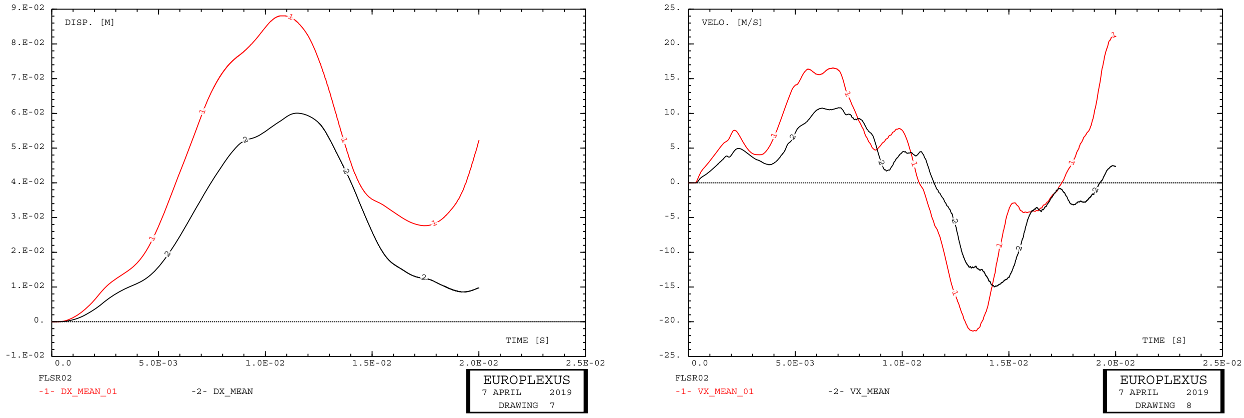
(b) Beam tip velocity

Figure 16: Some results of test FLSR02.

to the structure and therefore the force exerted on the structure is larger, thus leading to a larger deformation.

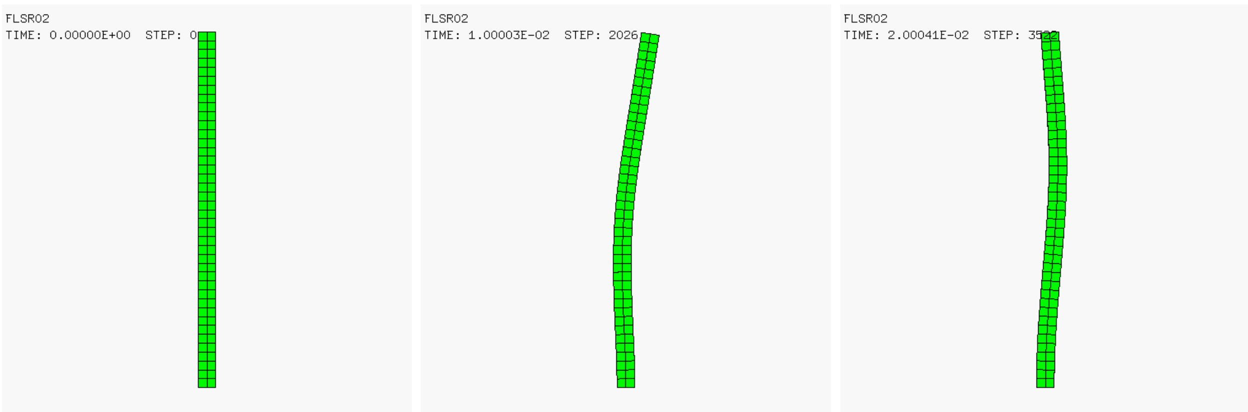
The deformed shape of the beam is shown in Figure 18 at some representative time instants.

Figure 19 presents the fluid pressures and the deformed cantilever shape seen from the side on 1/2 of the model for insight into what is happening in the interior. At 1 ms the pressure waves are impinging on the beam, at 4 ms the wave hits the right wall of the box and is reflected, at 8 ms the reflected wave strikes again on the beam and at 10 ms it is eventually reflected back from the left



(a) Beam tip displacement (b) Beam tip velocity

Figure 17: Comparison of results in tests FLSR01 and FLSR02.



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

Figure 18: Deformed beam shape in test FLSR02.

extremity of the box.

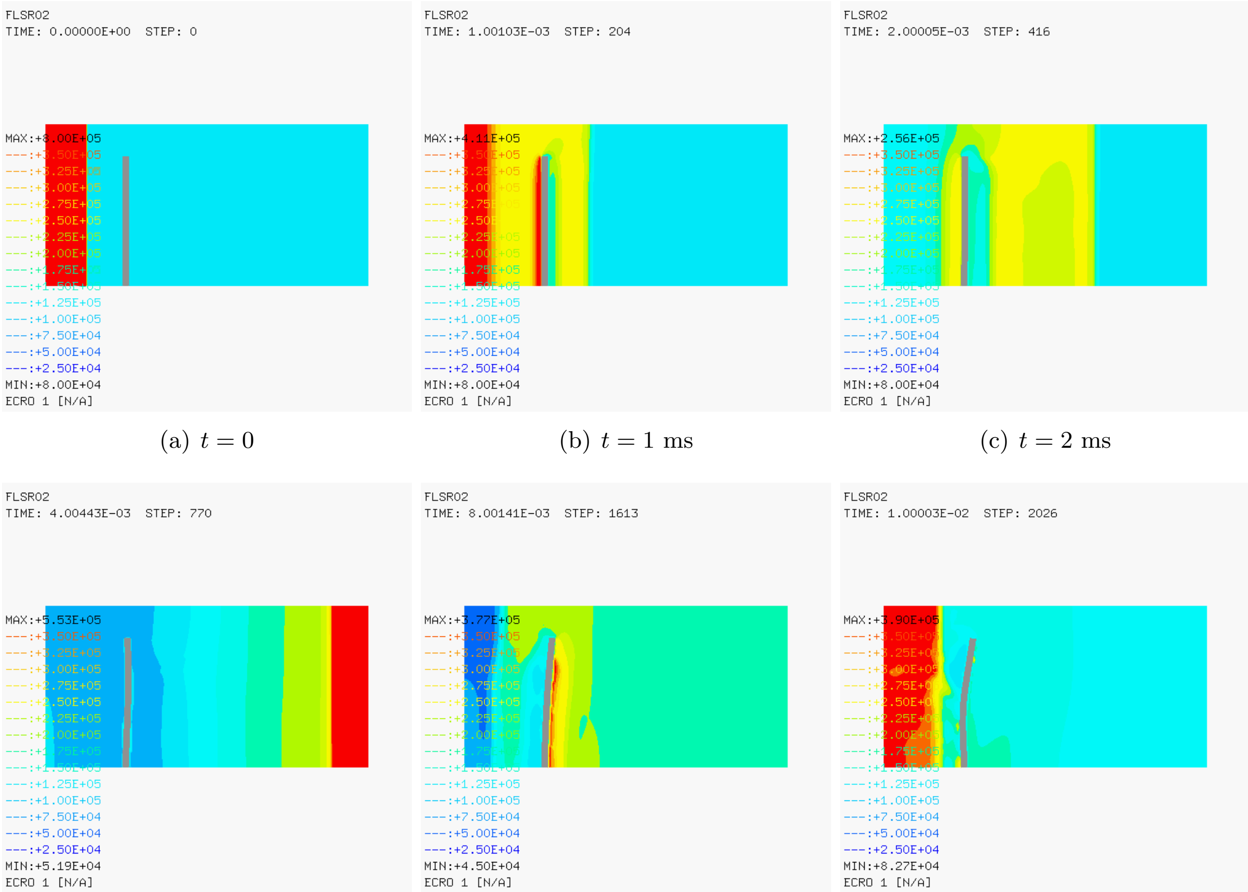
Figure 20 shows the same pressure results but seen from below, in the whole model. Note how the pressure wave impinges on the beam creating a stagnation pressure and a side flow around the obstacle. This phenomenon can also be appreciated in Figure 21, which shows the fluid velocities.

3.3.3 Case FLSR03

The next solution uses the same coarse base mesh as case FLSR01. However, FSI-driven adaptation of the fluid mesh is added in order to increase the accuracy of FSI detection near the embedded structure.

The modifications needed in the input file are highlighted below.

```
FLSR03
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME ADAP NPOI 100000 FL38 100000 ENDA TERM
GEOM FL38 flui CUB8 stru TERM
COMP GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT stru TERM COND Z LT 0.001
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT stru TERM COND Z GT 0.799
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air _fl38 TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          HGRI 0.041 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
```



(a) $t = 0$ (b) $t = 1$ ms (c) $t = 2$ ms

(d) $t = 4$ ms (e) $t = 8$ ms (f) $t = 10$ ms

Figure 19: Fluid pressures in test FLSR02 (side view).

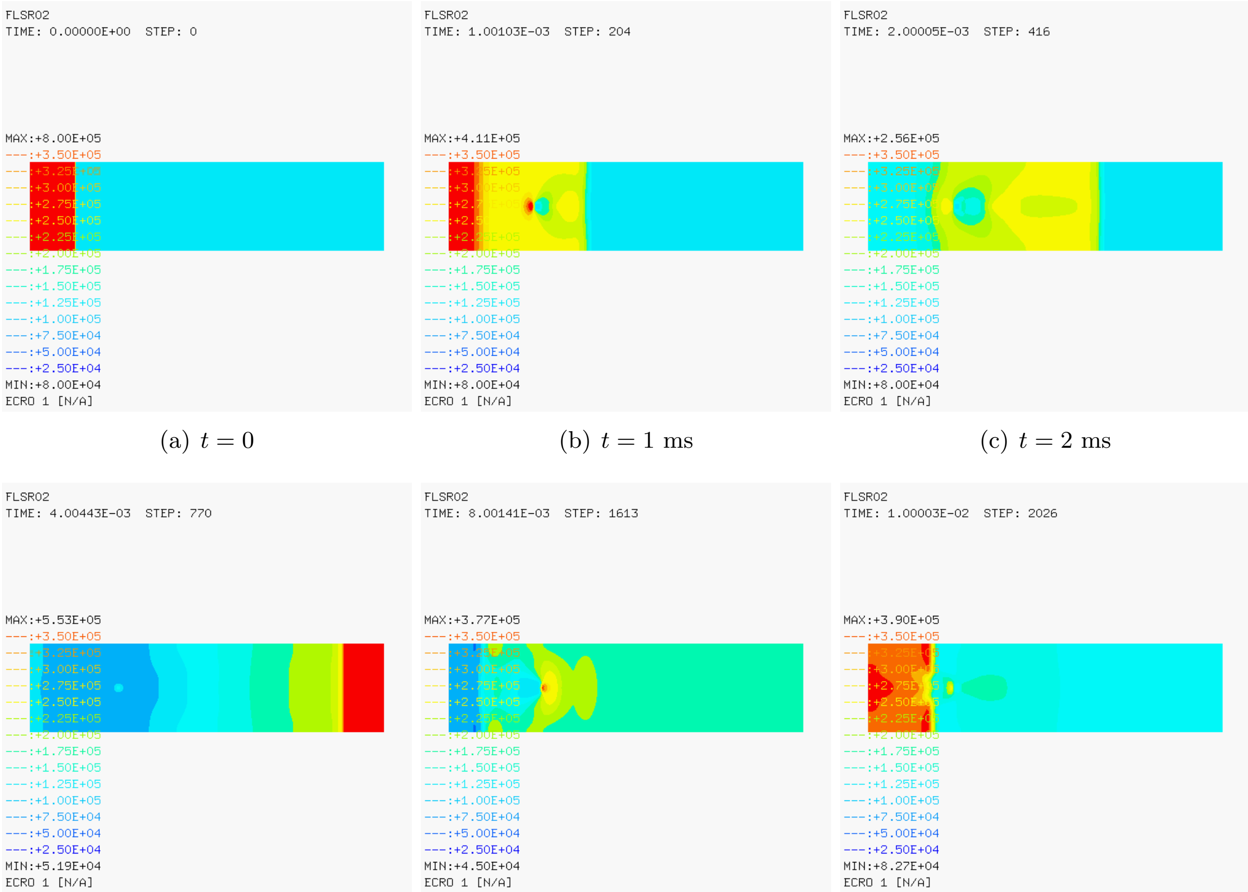
```
        FSCP 1
        ADAP LMAX 3 SCAL 2.0
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

Some dimensioning is needed for the adaptivity. Here we choose a maximum of 100 000 nodes and 100 000 FL38 elements in the memory extension zone. The material FLUT is assigned to the descendent FL38 elements (object `_fl38`). Finally and most importantly, the `ADAP` sub-keyword is added to the `FLSR` directive to activate FSI-driven adaptivity, with a maximum refinement level `LMAX 3` (2 successive refinements) and a scaling factor `SCAL 2.0` in order to double the size of the mesh transition zone.

The calculation required 7506 time steps and 88 304 s (24.5 hours) on the EVICOM machine to reach the final time of 20 ms. The results in terms of beam tip displacement and velocity are compared in Figure 22 agains those of cases FLSR01 (in red) and FLSR02 (in green). The agreement with respect to case FLSR02, which used a static fine mesh (no adaptivity) is relatively good. However, it is not clear (and it should be investigated) why this simulation took almost 6 times the CPU of case FLSR02.

The final shape of the cantilever beam in the three solutions is compared in Figure 23.

Figure 24 compares the fluid pressures at 8 ms, when the reflected wave hits the back side of the beam. Figure 25 compares the same results seen from the bottom of the fluid box. Finally, Figure 26 compares the fluid velocities seen from the bottom of the fluid box.



(a) $t = 0$ (b) $t = 1$ ms (c) $t = 2$ ms

(d) $t = 4$ ms (e) $t = 8$ ms (f) $t = 10$ ms

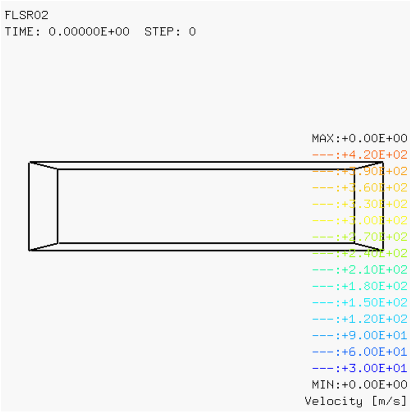
Figure 20: Fluid pressures in test FLSR02 (bottom view).

3.4 Cantilever beam under blast loading with beam elements

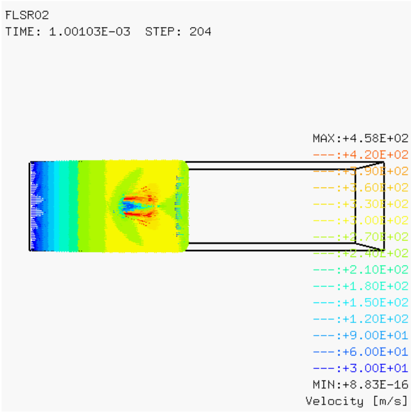
We now present some FSI simulations where the beam is discretized by means of POUT elements and the interaction with the surrounding fluid is modelled by the FLSR method, according to the previously presented new developments in EPX. They are summarized in Table 4.

Case	Mesh	Description	Steps	CPU [s]	Computer
POUT01	FL38, 10 POUT	`FLSR` with $R = 1.74$ cm	1655	904	M6700
POUT01blo	FL38, 10 POUT	`FLSR` with $R = 1.74$ cm, fully blocked	1635	891	M6700
POUT02	FL38, 10 POUT	`FLSR` with $R = 1.74$ cm, `ADAP LMAX 3`	3643	5088	M6700
POUT03	FL38, 10 POUT	`FLSR` with $R = 1.74$ cm, `ADAP LMAX 2`	1953	1656	M6700
POUT04	FL38, 10 POUT	`FLSR` with $R = 4.00$ cm	1768	1015	M6700
POUT05	FL38, 10 POUT	`FLSR` with $R = 2.00$ cm	1633	971	M6700
POUT06	FL38, 20 POUT	`FLSR` with $R = 2.00$ cm	4083	2125	M6700
POUT07	FL38, 10 POUT	`FLSR` with $R = 8.00$ cm, `ADAP LMAX 3`, `SOLV PARD`	6928	39 180	M6700
		After correction of FSI-driven adaptivity:			
POUT08	FL38, 10 POUT	`FLSR` with $R = 2.00$ cm, `ADAP LMAX 2`, `SOLV PARD`	3551	3586	EVICOM
POUT09	FL38, 10 POUT	`FLSR` with $R = 3.42$ cm, `ADAP LMAX 2`, `SOLV PARD`	3350	4652	EVICOM
POUT12	FL38, 10 POUT	`FLSR` with $R = 1.74$ cm, `ADAP LMAX 3`, `SOLV PARD`	4569	18 460	EVICOM
POUT13	FL38, 10 POUT	`FLSR` with $R = 1.74$ cm, `ADAP LMAX 2`, `SOLV PARD`	2936	3200	EVICOM
POUT21	FL38, 10 POUT	`FLSR` with $R = 1.74$ cm, `FSCP 0`	1639	911	M6700

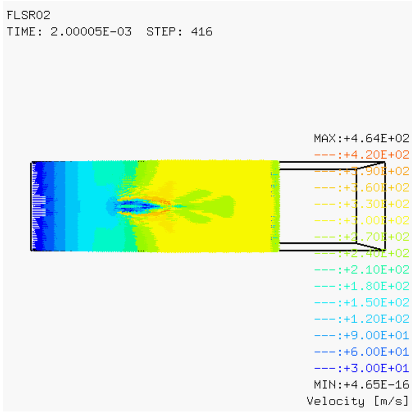
Table 4: Calculations for the cantilever beam under blast loading with POUT elements and `FLSR`.



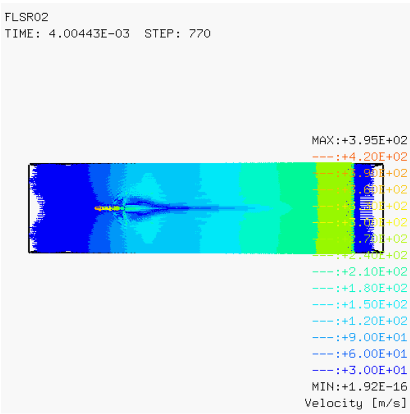
(a) $t = 0$



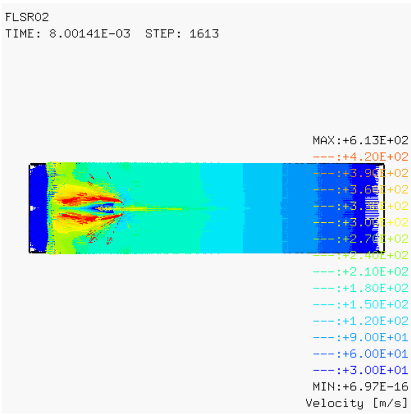
(b) $t = 1$ ms



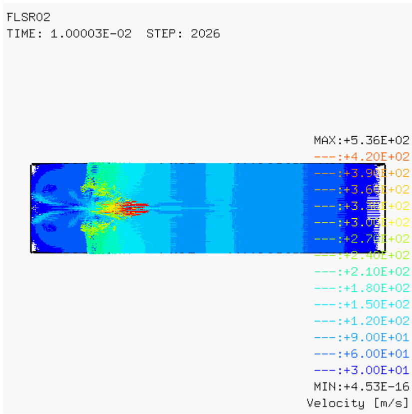
(c) $t = 2$ ms



(d) $t = 4$ ms

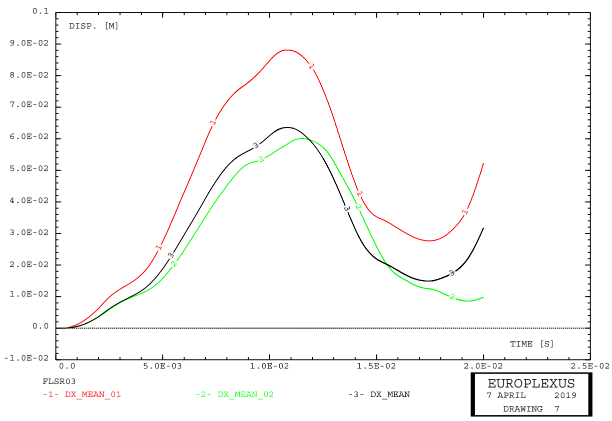


(e) $t = 8$ ms

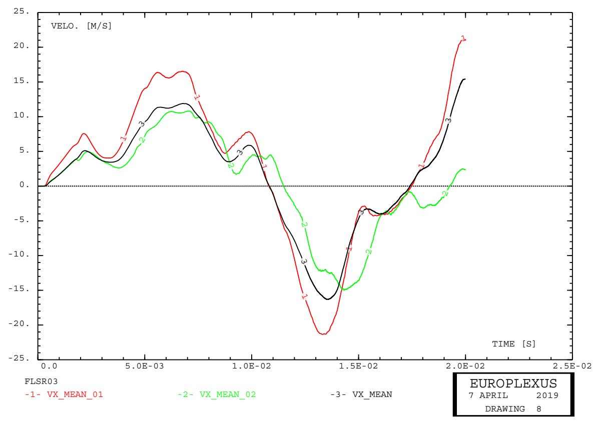


(f) $t = 10$ ms

Figure 21: Fluid velocities in test FLSR02 (bottom view).



(a) Beam tip displacement



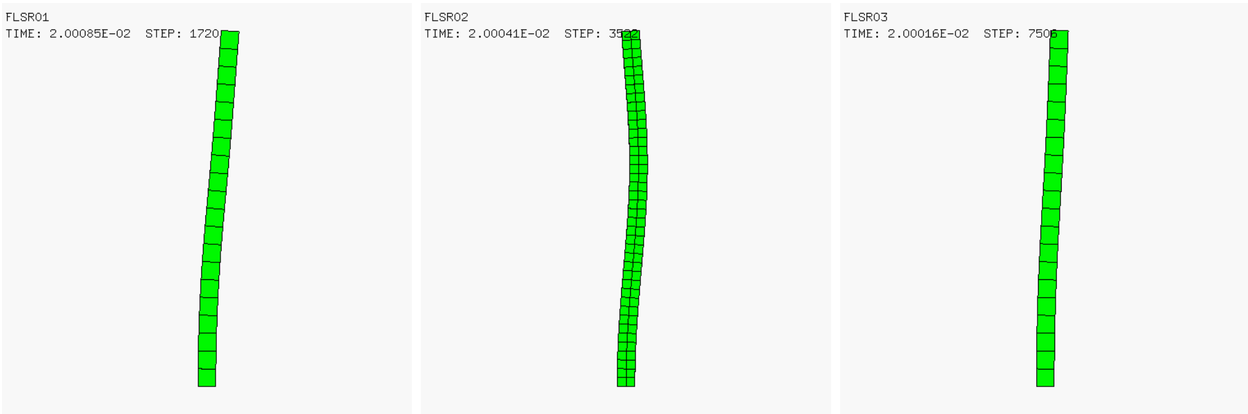
(b) Beam tip velocity

Figure 22: Comparison of results in tests FLSR01, FLSR02 and FLSR03.

3.4.1 Case POUT01

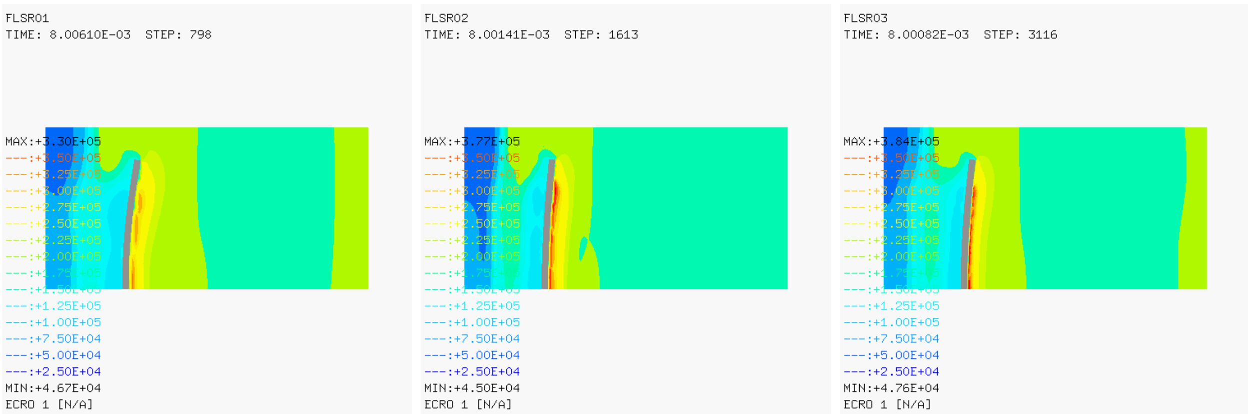
The first simulation POUT01 uses 10 POUT elements to discretize the beam.

```
POUT01
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
      LECT stru TERM
GROU 2 'expl' LECT flui TERM COND XB LT 0.25
       'air'  LECT flui DIFF expl TERM
NGRO 3 'nblo' LECT p0 TERM
       'nfsr' LECT flui TERM COND ENVE
       'ntop' LECT p1 TERM
COUL ROUG LECT expl TERM
```



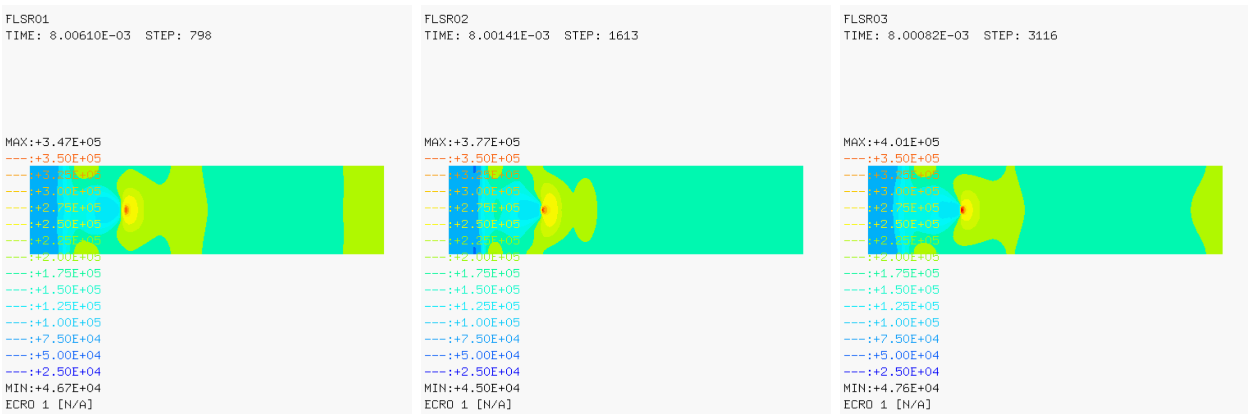
(a) FLSR01 (b) FLSR02 (c) FLSR03

Figure 23: Comparison of final beam shape in tests FLSR01, FLSR02 and FLSR03.



(a) FLSR01 (b) FLSR02 (c) FLSR03

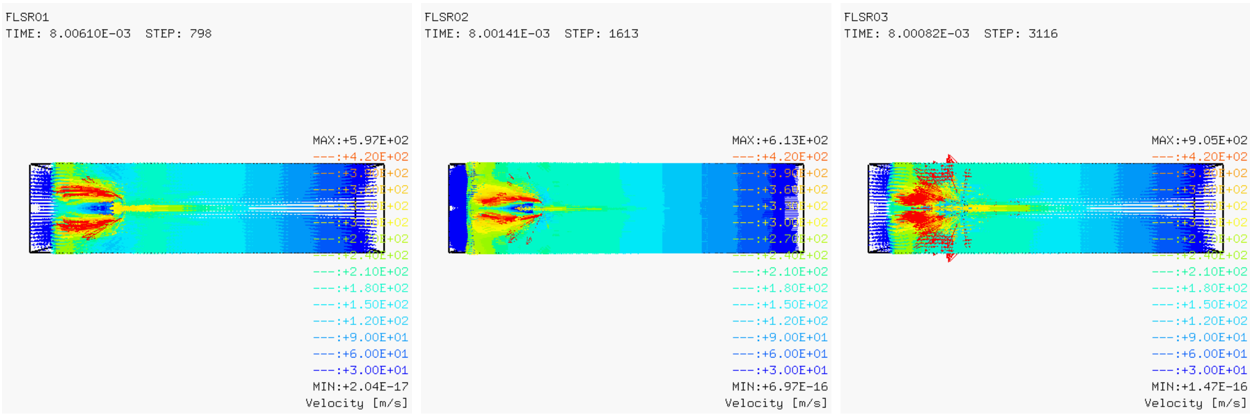
Figure 24: Comparison of fluid pressures at $t = 8$ ms in tests FLSR01, FLSR02 and FLSR03.



(a) FLSR01 (b) FLSR02 (c) FLSR03

Figure 25: Comparison of fluid pressures at $t = 8$ ms in tests FLSR01, FLSR02 and FLSR03 (bottom view).

```
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
```



(a) FLSR01 (b) FLSR02 (c) FLSR03

Figure 26: Comparison of fluid velocities at $t = 8$ ms in tests FLSR01, FLSR02 and FLSR03 (bottom view).

```
FLSR STRU LECT stru TERM
     FLUI LECT flui TERM
     R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
     !R 5.00E-2
     HGRI 0.081 ! HGRI > max (h_fluid, h_stru)
     DGRI
     BFLU 0
     FSCP 1
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

The geometrical characteristics of the beam elements are set by the `COMP GEOP` directive already discussed in test STRU01. FSI is modelled by the `FLSR` directive. In this first tentative simulation with the updated `FLSR` model, the radius R of the structure influence domain is tentatively set by following the standard rule of `FLSR`, that is, based on the size of the fluid mesh encompassing the immersed structure (but we will see later on that this is inappropriate in the case of a 3D beam/bar structure). For a fluid mesh size h, the recommended value in 3D calculations is $R = 0.87h$. In this case it is $h = 0.02$ m, so we set $R = 0.87 \times 0.02 = 1.74 \times 10^{-2}$ m.

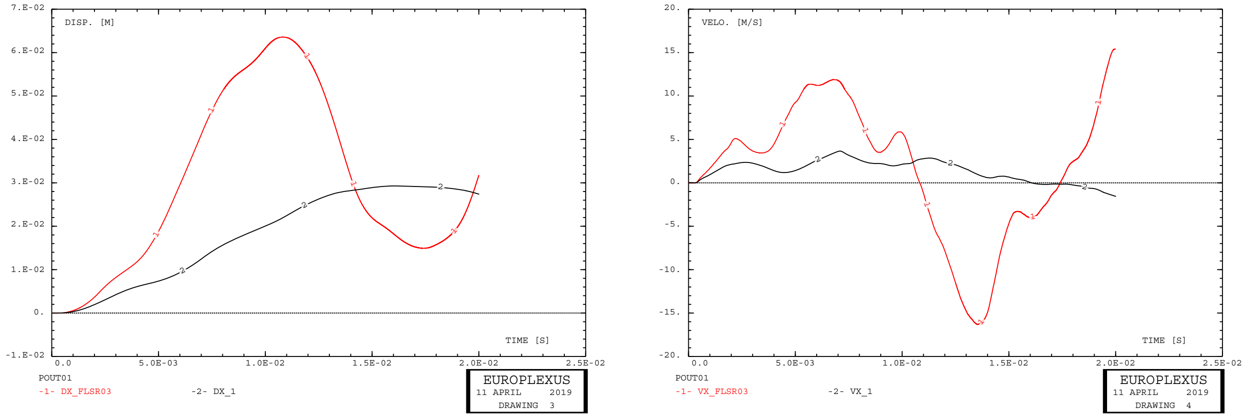
The grid size H for fast search of the coupled fluid nodes is set according to the maximum between the fluid and the structure mesh size. In this case the structure mesh size is larger than the fluid mesh size and equal to 0.08 m, so we set $H = 0.081$ m. The `BFLU` flux-blocking parameter is set to `0` (which is the default, meaning no blocked fluxes) since anyway it has no influence on the present calculation. In fact, this parameter is used only in conjunction either with node-centred Finite Volumes (NCFV) or with CEA's fluid FE (e.g. CUBE), but not with the JRC's fluid FE (FLxx) used here. Finally, we activate full coupling (along all spatial directions) between the structure and the fluid by setting `FSCP 1`. This is in order to avoid, at least for the moment, the uncertainties related to the evaluation of "the" normal to a 3D segment (which is geometrically undetermined).

Figure 27 shows the x-displacement and the x-velocity of the tip node of the cantilever beam. It can be observed that the beam displacement is lower than that obtained in the solutions using continuum elements in the beam (FLSRxx) and *the general shape of the curve is quite different* (the red curve shown in the picture is the solution of case FLSR03).

3.4.2 Analysis of solution mismatch

The reason for this large qualitative difference was discovered long after running this and most of the following test cases using beam elements. The boundary conditions at the foot of the cantilever beam are set differently: completely blocked (`BLOQ 123`) in the continuum model, but only simply blocked (again, `BLOQ 123`) in the beam model, which also has rotational degrees of freedom `456`. In other words, the rotation of the beam foot was (unintentionally) left free and this of course had a large influence on the result. The beam reacts in a much weaker way to the lateral blast load and, in fact, the frequency of the observed oscillations is lower.

One should rather have used `BLOQ 123456` in order to completely block the beam foot in the models



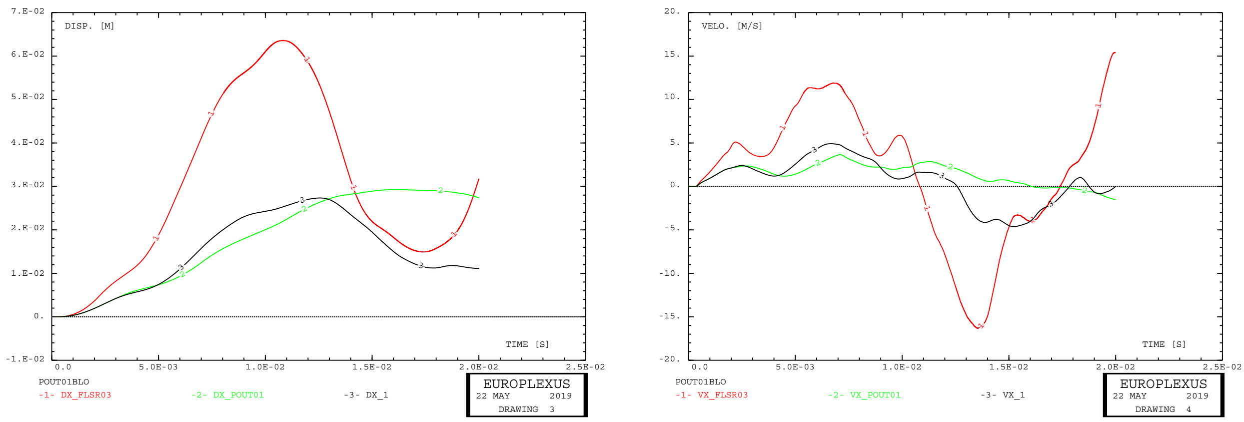
(a) Beam tip displacement

(b) Beam tip velocity

Figure 27: Some results of test POUT01 compared with FLSR03.

with POUT elements, in order to achieve similar conditions to the continuum solutions. However, re-running all the POUT cases in this report with the "correct" conditions was considered too time consuming. There is no real error in these cases. One should simply recognize that the problem solved is different and therefore no direct comparison with the continuum solutions should be made (but comparisons between solutions with beam elements are still valid, of course).

Just a few of the POUT test cases in the report are (re-)run with complete foot blockage, in order to show the difference. For example, the case POUT01 is re-run as POUT01blo. Figure 28 shows the results. The fully blocked beam solution (black curve) is still quantitatively much lower than the continuum solution (red curve), but qualitatively much closer to it than the green curve, which is the solution with simply blocked beam foot.



(a) Beam tip displacement

(b) Beam tip velocity

Figure 28: Some results of test POUT01blo compared with FLSR03a nd POUT01.

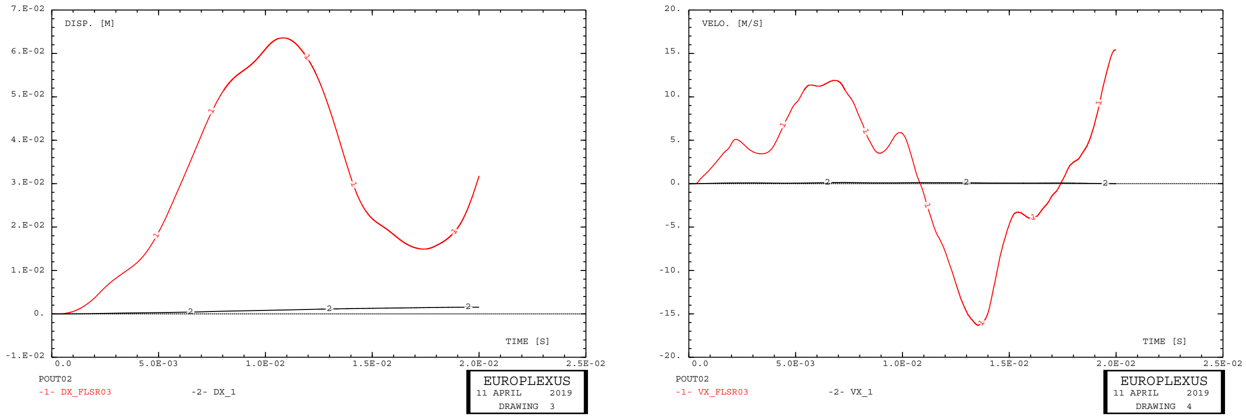
3.4.3 Case POUT02

This test is similar to POUT01 but we activate FSI-driven adaptivity in the fluid by the `FLSR` ... `ADAP LMAX 3 SCAL 2.0` directive.

Figure 29 shows the x-displacement and the x-velocity of the tip node of the cantilever beam. The beam displacement is much lower than in the previous simulation and the solution looks much worse than the previous one, despite the use of a finer fluid mesh.

The reason for this becomes apparent when the structure influence domain (after fluid mesh adaptation) is visualized. In fact, the standard FSI-driven adaptivity model automatically reduces the size of the structure influence domain as the fluid mesh is being refined. This behaviour is correct when the structure is meshed by shell or continuum elements, but it is inappropriate for 3D beam/bar elements because this action effectively reduces the “FSI diameter” of the beam and thus it reduces the volume of fluid coupled with the beam (or the beam surface exposed to fluid pressure drop).

Following this observation, the corrections for the adaptive case detailed in section 2.2.1 were introduced in the code.



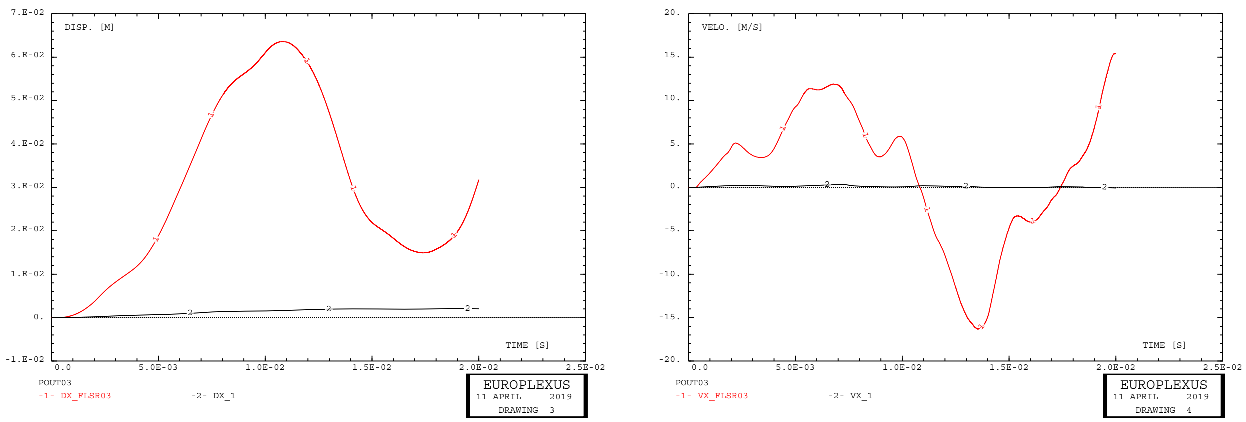
(a) Beam tip displacement (b) Beam tip velocity

Figure 29: Some results of test POUT02 compared with FLSR03.

3.4.4 Case POUT03

This test is similar to POUT02 (and uses the same version of the code, prior to the corrections detailed in Section 2.2.1), but we set `LMAX 2` instead of `LMAX 3` in the `FLSR` ... `ADAP` directive.

Figure 30 shows the x-displacement and the x-velocity of the tip node of the cantilever beam. Again, the beam displacement is lower than in the reference simulation FLSR03 although not as much as in the previous case POUT02.



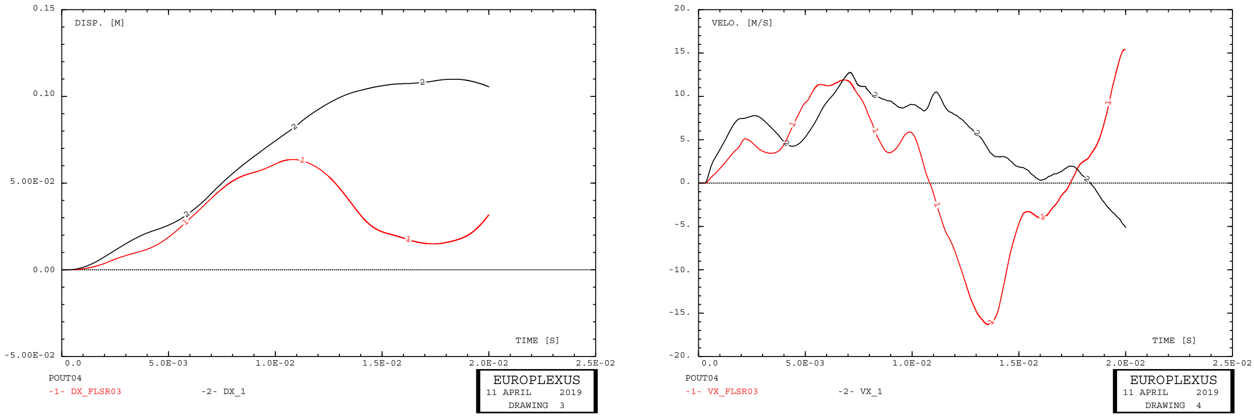
(a) Beam tip displacement (b) Beam tip velocity

Figure 30: Some results of test POUT03 compared with FLSR03.

3.4.5 Case POUT04

In the light of the previous considerations, we return for the moment to solutions without adaptivity, since a modification in the FSI-driven adaptivity model is needed for use in conjunction with 3D beam/bar elements (see Section 2.2.1). This test is similar to POUT01 but we use $R = 4.0$ cm as influence domain radius, i.e. the same value as the side of the square cross-section of the beam in discretizations with continuum elements. Note, however, that this corresponds to a diameter of the influence domain of 8 cm.

Figure 31 shows the x-displacement and the x-velocity of the tip node of the cantilever beam. Now at least the order of magnitude of displacement and velocity is correct, although there remains a large discrepancy between the shape of the solution with respect to the reference.



(a) Beam tip displacement

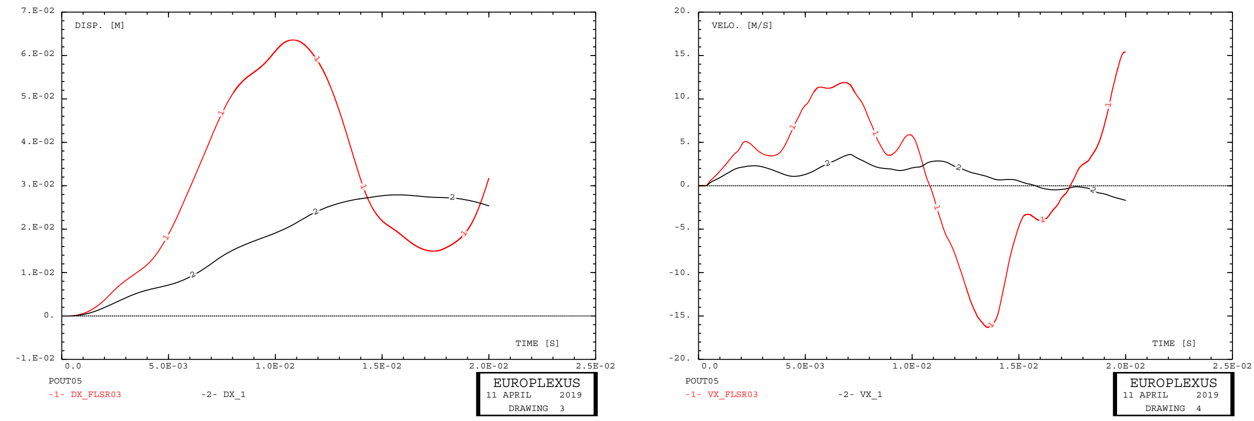
(b) Beam tip velocity

Figure 31: Some results of test POUT04 compared with FLSR03.

3.4.6 Case POUT05

This test is a repetition of case POUT04 (no adaptivity) but with an influence domain radius $R = 2.0$ cm (corresponding to a diameter of 4.0 cm) which seems more appropriate since it is comparable with the physical diameter of the bar (4.0 cm).

Figure 32 shows the x-displacement and the x-velocity of the tip node of the cantilever beam. The displacement is underestimated with respect to the reference and the shape of the signal is still inappropriate.



(a) Beam tip displacement

(b) Beam tip velocity

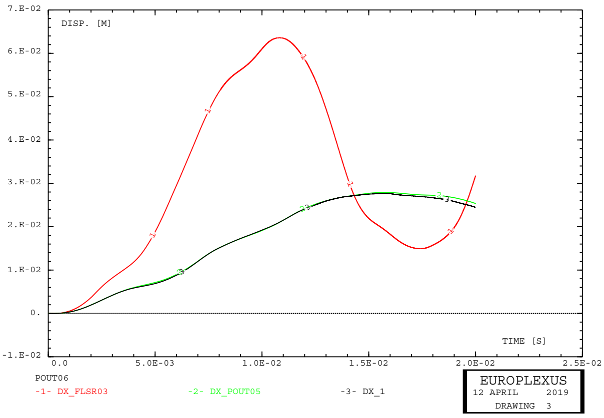
Figure 32: Some results of test POUT05 compared with FLSR03.

In order to obtain better solutions with POUT elements it will probably be necessary to use adaptivity, but this requires a correction of the FSI-driven adaptivity model. The correction, detailed Section 2.2.1, consists in avoiding the automatic scaling of the structural influence domain around 3D beam/bar structures.

3.4.7 Case POUT06

This test is similar to case POUT05 but uses a finer mesh for the structure, namely 20 POUT elements of length 0.04 m each, instead of 10 elements of length 0.08 m. Consequently, the grid size `HGRI` is set to 0.041 m.

The resulting beam displacement (black curve) is almost identical to that of case POUT05 (green curve) and still far from the reference FLSR03 (red curve), indicating that the bad agreement with the reference is not due to an insufficient discretization of the structure.



(a) Beam tip displacement (b) Beam tip velocity

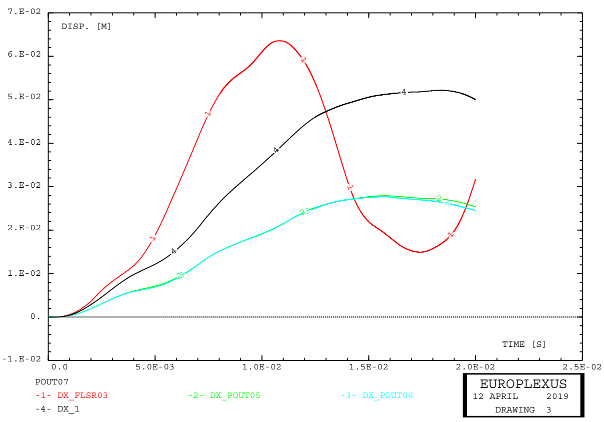
Figure 33: Some results of test POUT06 compared with FLSR03 and POUT05.

3.4.8 Case POUT07

We return to solutions with mesh adaptivity (in the fluid). The base mesh is taken from case POUT05 and we add `ADAP LMAX 3 SCAL 1.0` in the `FLSR` directive to activate FSI-driven adaptivity.

The calculation is done before the correction mentioned in Section 2.2.1. Therefore, in an attempt to compensate for the error introduced by this fact, we set $R = 0.08$ m in the `FLSR` directive. Solution is very slow, using around 50 s of CPU per step, but this is reduced to 10 s per step by activating the optional Pardiso solver for the links (`SOLV PARD`).

Results are shown in Figure 34. The beam tip displacement is larger than previous solutions and its maximum is in better agreement with the reference (FLSR03), but the shape of the curve is still far from the reference.



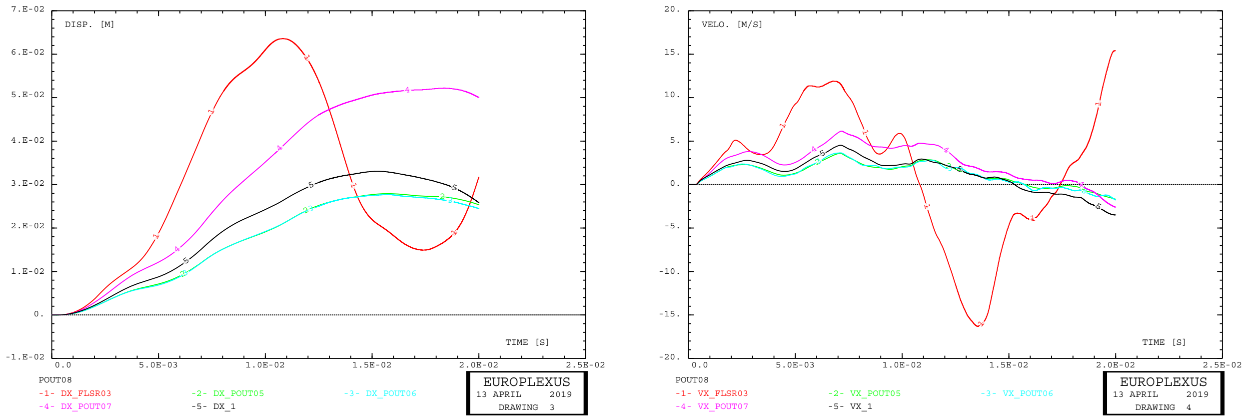
(a) Beam tip displacement (b) Beam tip velocity

Figure 34: Some results of test POUT07 compared with FLSR03, POUT05 and POUT06.

3.4.9 Case POUT08

This solution is similar to case POUT07 but uses the new executable including the correction mentioned in Section 2.2.1. Therefore, the radius is set to $R = 0.02$ m and the grid size is set to $h = 0.04$ m. We use `ADAP LMAX 2` (not 3) and `SCAL 2.0` in order to contain the CPU time needed for the solution.

The solution (black curve), shown in Figure 35, is slightly higher than cases POUT05 and POUT06 (green and cyan curves) but lower than case POUT07 (magenta curve).

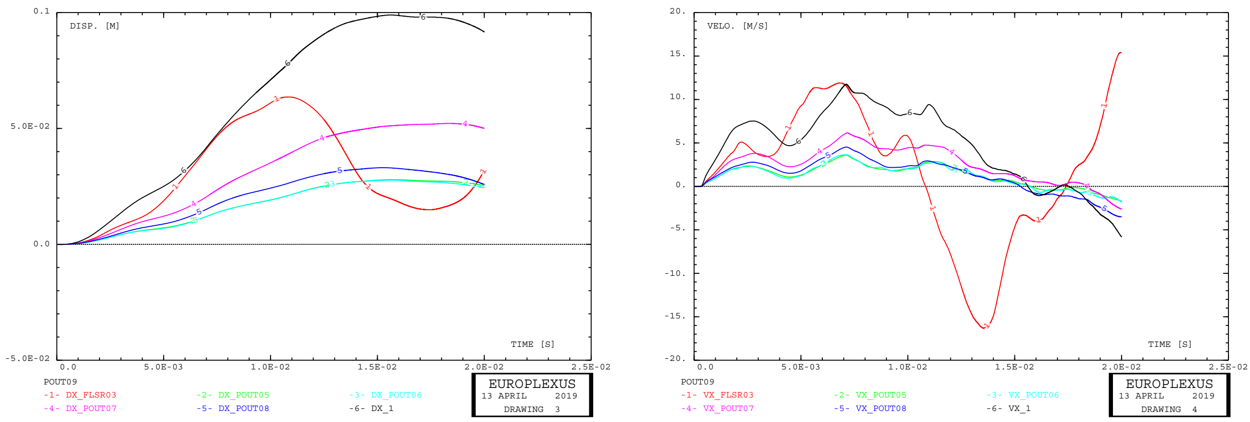


(a) Beam tip displacement (b) Beam tip velocity

Figure 35: Some results of test POUT08 compared with FLSR03 and POUT05 to POUT07.

3.4.10 Case POUT09

This calculation is a repetition of case POUT08 by tentatively increasing the influence domain radius R according to the drag coefficient ratio between a face-on long rectangular member ($C_D = 2.05$, see e.g. Figure 60) and a side-on circular cylinder ($C_D = 1.20$). Therefore we set $R = 0.02 \times 2.05/1.20 = 0.01 \times 1.71 = 0.0342$ m and $h = 0.0684$ m.



(a) Beam tip displacement (b) Beam tip velocity

Figure 36: Some results of test POUT09 compared with FLSR03 and POUT05 to POUT08.

The solution (black curve), shown in Figure 36, is too high with respect to the reference and still has a different shape from it. It seems that changing the influence radius has a more than linear effect on the numerical result in terms of displacement.

3.4.11 Case POUT12

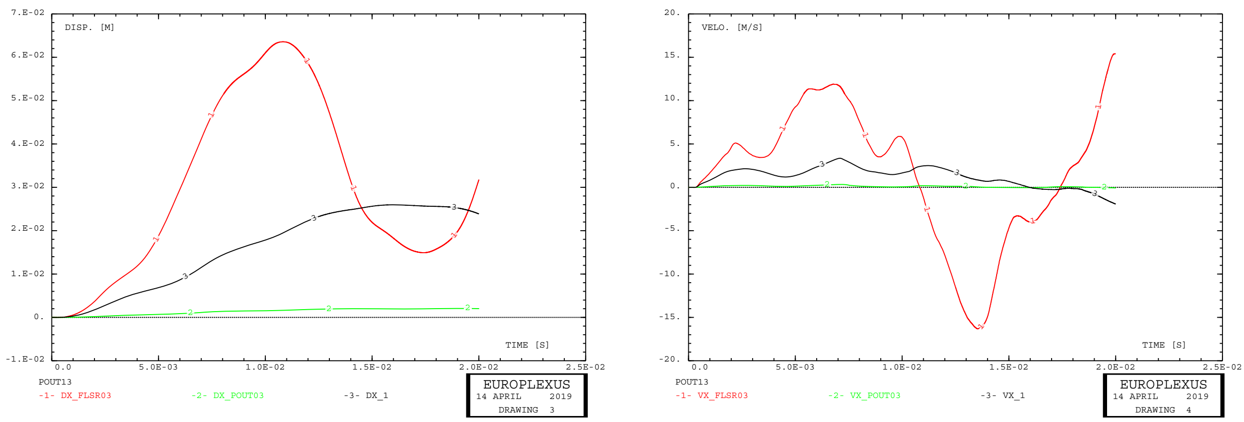
This is simply a repetition of case POUT02 by using the newer executable including the correction for the adaptive case. The `SOLV PARD` is activated to reduce the CPU time since with the above mentioned correction the number of links is much higher than in case POUT02.

The beam tip does not move, like if no FSI would take place. This strange behaviour will have to be investigated.

3.4.12 Case POUT13

This is a repetition of case POUT03 by using the newer executable including the correction for the adaptive case. The `SOLV PARD` is activated to reduce the CPU time since with the above mentioned correction the number of links is much higher than in case POUT02.

The solution (black curve), shown in Figure 37, is much higher than POUT03 but still lower than (and different in shape from) the reference FLSR03.



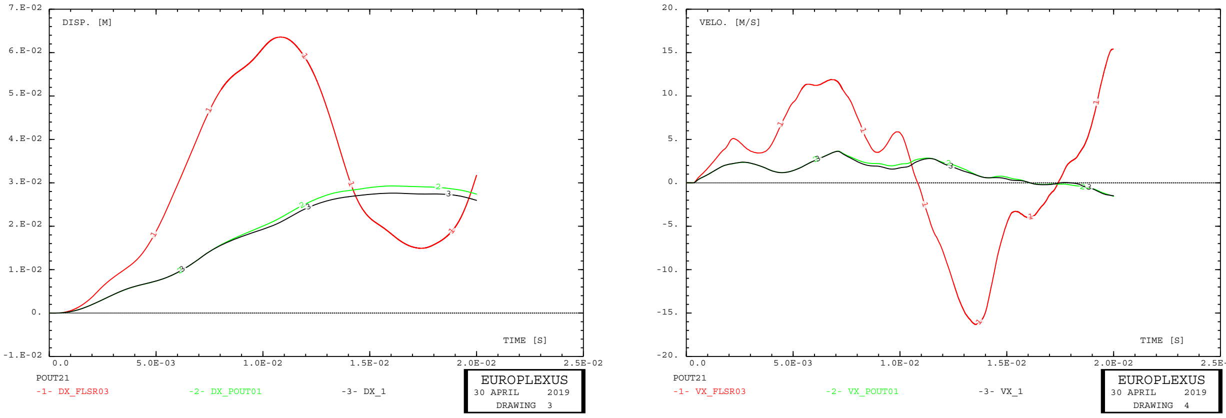
(a) Beam tip displacement (b) Beam tip velocity

Figure 37: Some results of test POUT13 compared with FLSR03 and POUT03.

3.4.13 Case POUT21

This test is a repetition of case POUT01 from Section 3.4.13 but by setting `FSCP 0` instead of `FSCP 1` in the `FLSR` directive. The FSI coupling therefore acts only along the normal(s) to the structure. The fluid is free to flow along the direction of the beam elements.

Figure 38 shows the x-displacement and the x-velocity of the tip node of the cantilever beam compared with the reference (case FLSR03) and with the solution using complete coupling (POUT01). The beam displacement (black curve) is even slightly less than in case POUT01 (green curve), which makes sense since the fluid is less tied to the structure, and the shape of the signal is still far from the reference (red curve). Thus, the discrepancy between solutions obtained with beam elements and with continuum elements in the bar remains so far unexplained.



(a) Beam tip displacement

(b) Beam tip velocity

Figure 38: Some results of test POUT21 compared with FLSR03 and POUT01.

4 The `FLSW` model

The `FLSW` model [8, 9] establishes a *weak* coupling (by direct transmission of pressure forces) between a fluid and an immersed structure. The fluid is typically discretized by Cell-Centred Finite Volumes (VFCC), where the velocities and other kinematic variables are located at the element centroid, together with the state variables.

4.1 The basic `FLSW` algorithm

The structure influence domain is built up exactly like for the strong algorithm (FLSR). However, instead of searching for fluid nodes, it is convenient to search directly for the element-to-element interfaces—indicated simply as faces in the following for brevity—located within the influence domain (coupled faces), see Figure 39(a). The numerical fluxes are evaluated in this case at face centres, marked by small squares in Figure 39.

According to the weak approach, the forces generated by fluid pressure have to be computed and transmitted to the structure. With reference to Figure 39(b), for each coupled face f located between two volumes V_1, V_2 currently at pressures p_1, p_2, the pressure drop force $\boldsymbol{f}_{\Delta p}$ is evaluated as:

$$\boldsymbol{f}_{\Delta p} = (p_1 - p_2)\, L \boldsymbol{n}_f \tag{7}$$

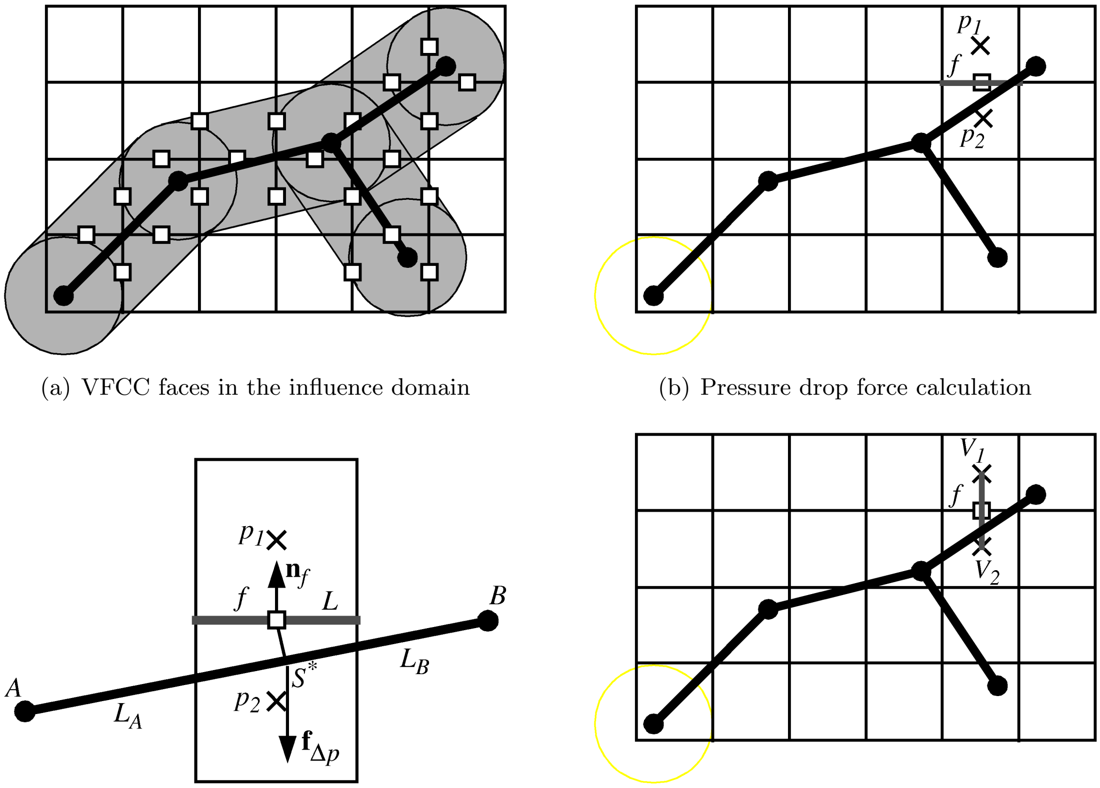
where L is the length (area, in 3D) of the face and $\boldsymbol{n}_f$ is the unit normal to the face. Then, as shown in Figure 39(c), the point S^* of the structure closest to the face centre is computed. The force (7) is supposed to act at this point S^* and is distributed on the structure nodes A, B according to the following expression (in 2D), where $L_S = L_A + L_B$:

$$\boldsymbol{f}_{\Delta p,A} = (L_B/L_S)\, \boldsymbol{f}_{\Delta p} \qquad \boldsymbol{f}_{\Delta p,B} = (L_A/L_S)\, \boldsymbol{f}_{\Delta p} \tag{8}$$

Then, in order to avoid spurious fluid leakage across the structure it is necessary to inhibit the mass and energy numerical fluxes at each coupled face, as illustrated in Figure 39(d) (thick shaded line). Note that expression (7) is the weak equivalent of (2), i.e. the fluid and the structure are coupled in all directions. Alternatively, one may project the pressure drop force along the normal to the structure $\boldsymbol{n}_s$ (assuming that this can be computed), obtaining the weak equivalent of (1). However, like in the strong case, such an expression risks to produce fluid leakage.

4.2 Extension of the `FLSW` algorithm to 3D beams/bars

The extension to 3D beams/bars of the `FLSW` algorithm follows the same lines as for the `FLSR` algorithm, which were presented in Section 2.2. In fact, the construction of the structural influence domains and



(a) VFCC faces in the influence domain (b) Pressure drop force calculation

(c) VFCC faces in the influence domain (d) Pressure drop force calculation

Figure 39: The FLSW algorithm (from [4]).

of the normals is practically identical in the two models. The same applies to the case of FSI-driven adaptivity already described in Section 2.2.1 for the `FLSR` case.

As concerns visualization, similar corrections to those detailed in Section 2.2.2 for the `FLSR` case are applied, but now in routines RENDER_FDOMW and RENDER_FDOMW_PART.

5 Numerical examples with `FLSW`

We now repeat by the `FLSW` model of FSI the most relevant test cases presented in Section 3 with the `FLSR` model.

5.1 Cantilever beam under blast loading with continuum elements

We consider again the cantilever beam subjected to blast loading of Section 3.3. The fluid will now be discretized using VFCC instead of FE, and `FLSW` weak coupling will be applied. The simulations are summarized in Table 5.

Case	Mesh	Description	Final time [ms]	Steps	CPU [s]	Computer
FLSW01	CUVF, CUB8	VFCC fluid, `FLSW`, coarse mesh	20	1378	1048	EVICOM
FLSW02	CUVF, CUB8	VFCC fluid, `FLSW`, fine mesh	20	2789	16 268	EVICOM
FLSW03	CUVF, CUB8	VFCC fluid, `FLSW`, adaptive mesh	20	4857	6961	EVICOM

Table 5: Reference calculations for the cantilever beam under blast loading with `FLSW`.

5.1.1 Case FLSW01

This test uses the same relatively coarse mesh as case FLSR01 of Section 3.3.1.

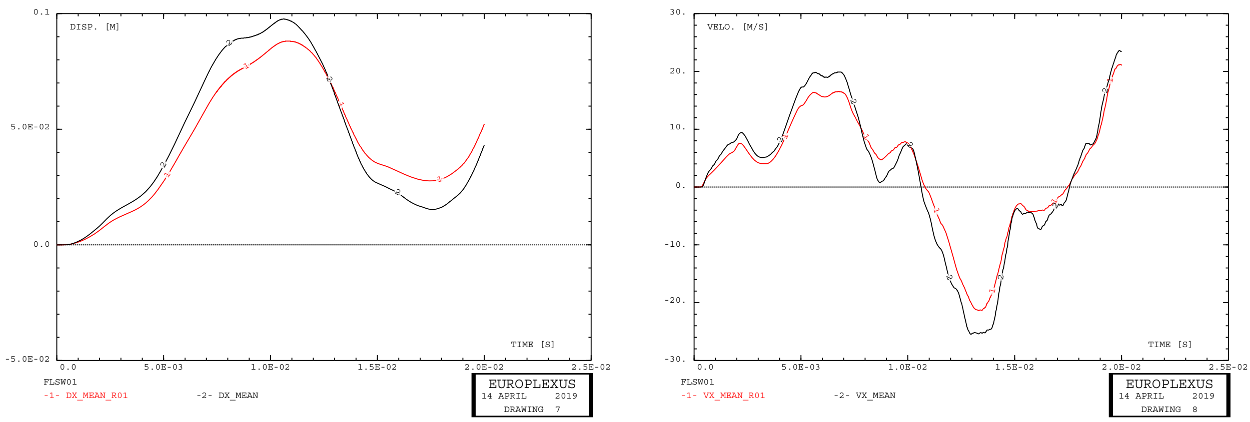
```
FLSW01
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM CUVF flui CUB8 stru TERM
COMP GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 2 'nblo' LECT stru TERM COND Z LT 0.001
            'ntop' LECT stru TERM COND Z GT 0.799
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
          EULE LECT flui TERM
MATE GAZP RO 10.0 PINI 8.0E5 GAMM 1.4 PREF 0.8E5
          LECT expl TERM
     GAZP RO 1.0 PINI 0.8E5 GAMM 1.4 PREF 0.8E5
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
LINK DECO FLSW STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          HGRI 0.041 ! HGRI > max (h_fluid, h_stru)
          DGRI
          FACE
          BFLU 1
          FSCP 1
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 6
          ORDR 2
          OTPS 2
          RECO 1
CALC TINI 0. TEND 20.E-3
FIN
```

The CUVF element replaces FL38 and the GAZP material replaces FLUT (with equivalent settings). The `LINK DECO FLSW` directive is used for FSI and there is no need to constrain the external nodes of the fluid domain (`FSR`). The `FACE` keyword couples the structure directly with VFCC interfaces (rather than volumes).

It is important to notice that the `BFLU` parameter has been set to 1 and not to 0 (the default) like in FE solutions, in order to actually block the fluxes across the coupled interfaces. Failing to do so would effectively remove any FSI coupling.

Finally, some options are set specifically for the VFCCs (`OPTI VFCC`). The `FCON 6` option chooses the HLLC flux solver (which is the default anyway), while the following options choose second order solution in time and in space.

Figure 40 shows the x-displacement and the x-velocity of the tip node of the cantilever beam, compared with case FLSR01. The correspondence is relatively good, considering that the mesh is coarse.



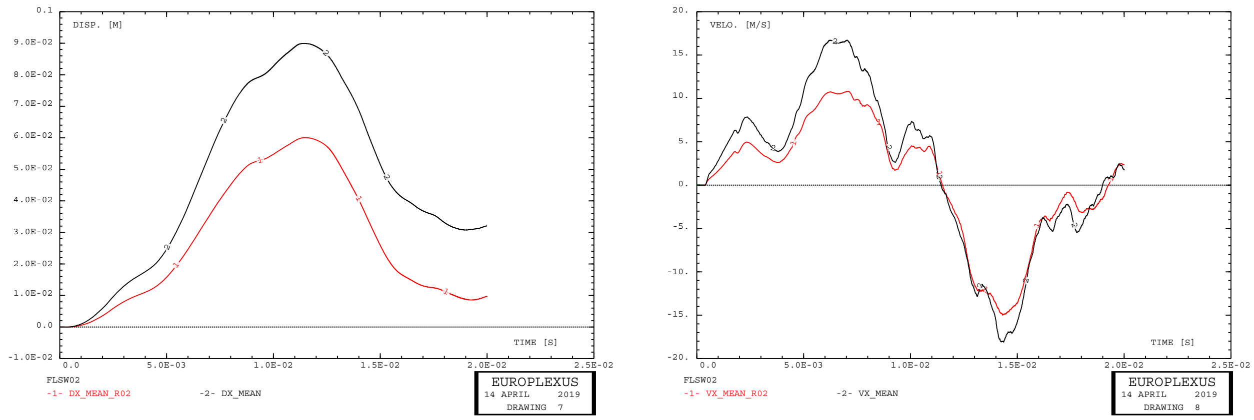
(a) Beam tip displacement (b) Beam tip velocity

Figure 40: Some results of test FLSW01 compared with FLSR01.

5.1.2 Case FLSW02

This test uses the same twice finer mesh as case FLSR02 of Section 3.3.2. Upon first running, the calculation stopped with a `TILT` message after 4.6 ms of physical time. To avoid the problem, the `NTIL` option was added in the input section dedicated to VFCC options and the calculation was re-run, now completing successfully.

Figure 41 shows the x-displacement and the x-velocity of the tip node of the cantilever beam, compared with case FLSR02. The correspondence is much worse than in cases FLSW01/FLSR01, which is a bit surprising since the mesh is finer.



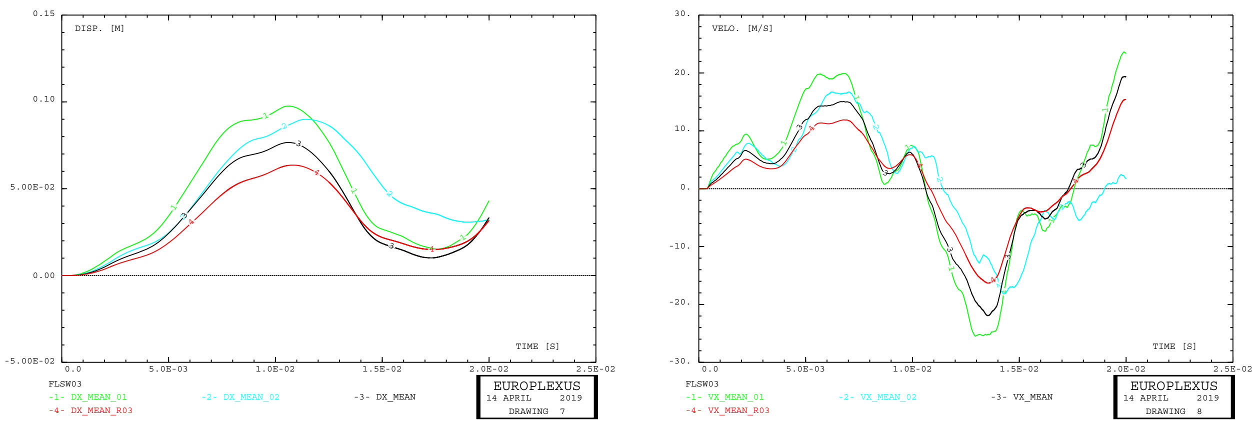
(a) Beam tip displacement (b) Beam tip velocity

Figure 41: Some results of test FLSW02 compared with FLSR02.

5.1.3 Case FLSW03

This test uses the same coarse base mesh as FLSW01 but the fluid mesh is adaptively refined by adding the directive `FLSW ... ADAP LMAX 3 SCAL 2.0`, similarly to case FLSR03 of Section 3.3.3. Also in this case it was necessary to add the `NTIL` option in order to avoid a tilt error message at 1.85 ms.

Figure 42 shows the x-displacement and the x-velocity of the tip node of the cantilever beam (in black), compared with case FLSR03 (in red). The solutions for cases FLSW01 (in green) and FLSW02 (in cyan) are also included for comparison. The solutions spread is relatively important. The present solution compares fairly with the corresponding `FLSR` solution, but not very well with the other two `FLSW` solutions.



(a) Beam tip displacement (b) Beam tip velocity

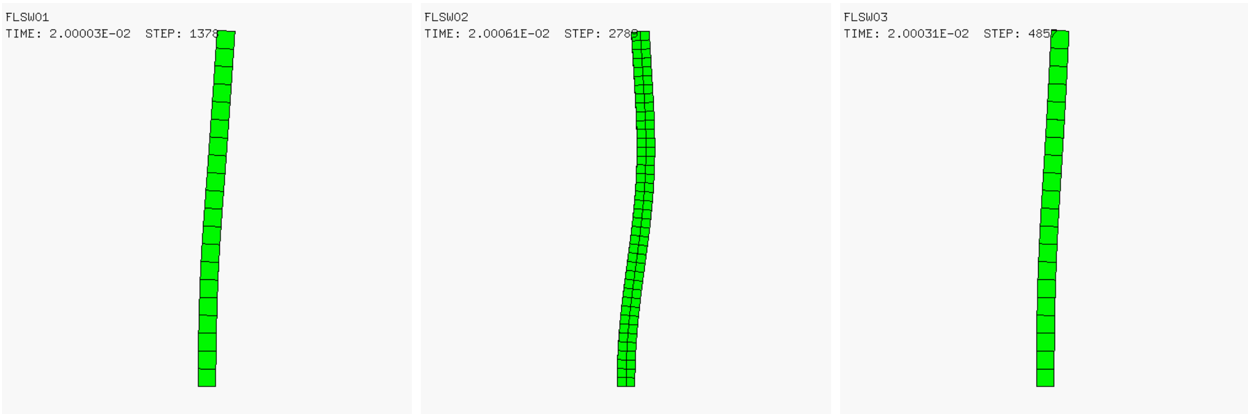
Figure 42: Some results of test FLSW03 compared with FLSR03, FLSW01 and FLSW02.

The final shape of the cantilever beam in the three solutions with `FLSW` is compared in Figure 43.

Figure 44 compares the fluid pressures at 8 ms, when the reflected wave hits the back side of the beam. Figure 45 compares the same results seen from the bottom of the fluid box. Finally, Figure 46 compares the fluid velocities (at the cell centroids) seen from the bottom of the fluid box.

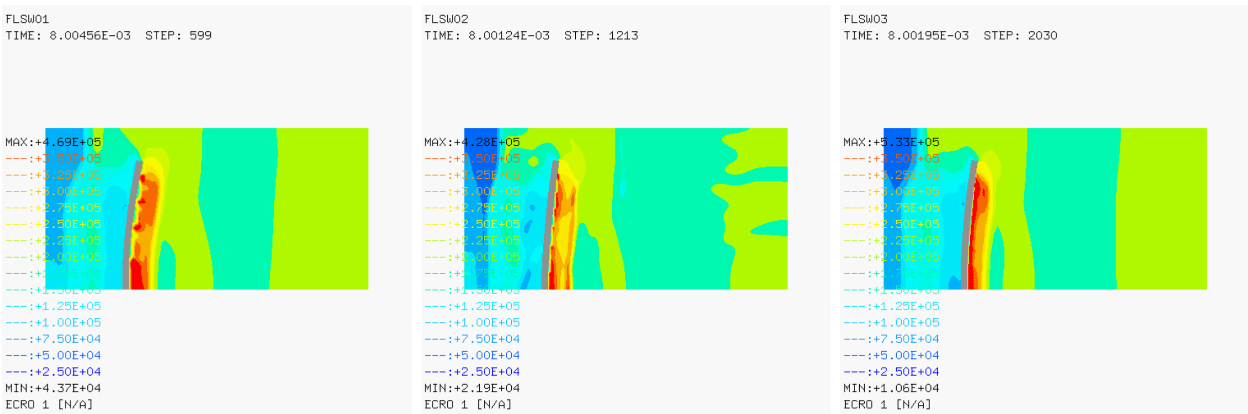
5.2 Cantilever beam under blast loading with beam elements

We now present some FSI simulations where the beam is discretized by means of POUT elements, the fluid is discretized by VFCC volumes and the interaction is modelled by the `FLSW` method, according to the previously presented new developments in EPX.



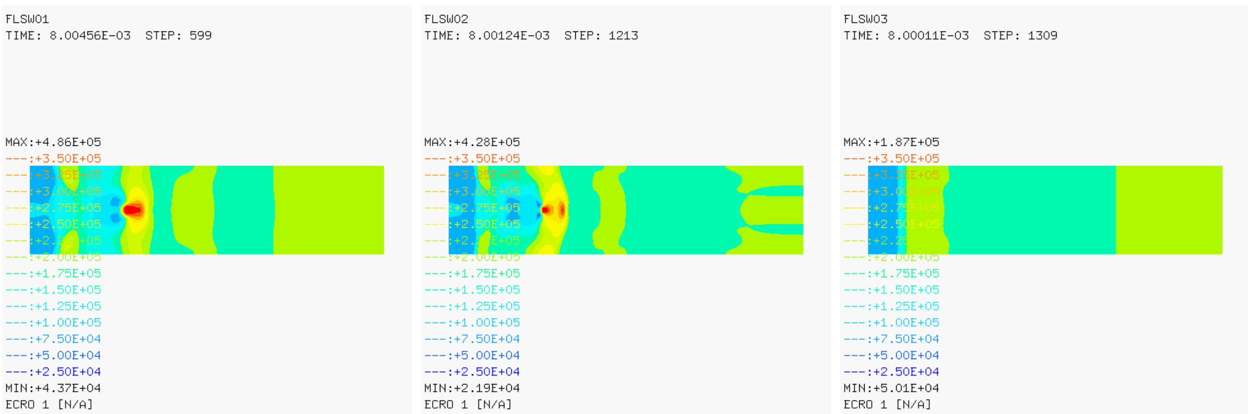
(a) FLSW01 (b) FLSW02 (c) FLSW03

Figure 43: Comparison of final beam shape in tests FLSW01, FLSW02 and FLSW03.



(a) FLSW01 (b) FLSW02 (c) FLSW03

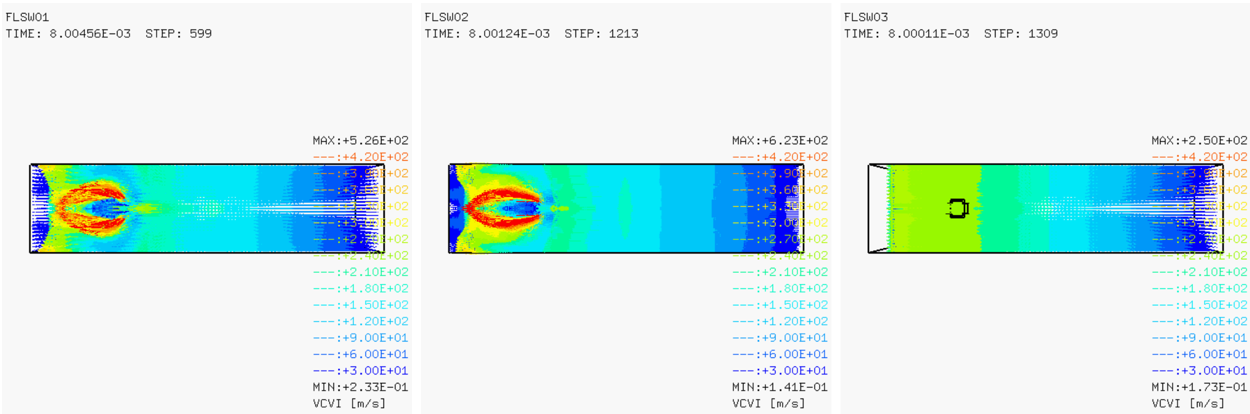
Figure 44: Comparison of fluid pressures at $t = 8$ ms in tests FLSW01, FLSW02 and FLSW03.



(a) FLSW01 (b) FLSW02 (c) FLSW03

Figure 45: Comparison of fluid pressures at $t = 8$ ms in tests FLSW01, FLSW02 and FLSW03 (bottom view).

All calculations were performed with an executable encompassing the correction on FSI-driven adaptivity. They are summarized in Table 6.



(a) FLSW01 (b) FLSW02 (c) FLSW03

Figure 46: Comparison of fluid velocities at $t = 8$ ms in tests FLSW01, FLSW02 and FLSW03 (bottom view).

Case	Mesh	Description	Steps	CPU [s]	Computer
POUW01	CUVF, 10 POUT	`FLSW` with $R = 1.74$ cm	1491	1092	M6700
POUW12	CUVF, 10 POUT	`FLSR` with $R = 1.74$ cm, `ADAP LMAX 3`	4903	4590	EVICOM
POUW13	CUVF, 10 POUT	`FLSR` with $R = 1.74$ cm, `ADAP LMAX 2`	2179	1902	EVICOM
POUW21	CUVF, 10 POUT	`FLSW` with $R = 1.74$ cm, `FSCP 0`	1459	1074	M6700

Table 6: Calculations for the cantilever beam under blast loading with POUT elements and `FLSW`.

5.2.1 Case POUW01

The first simulation POUW01 is analogous to case POUT01 of Section 3.4.1 and uses 10 POUT elements to discretize the beam.

```
FLSW01
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM CUVF flui CUB8 stru TERM
COMP GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 2 'nblo' LECT stru TERM COND Z LT 0.001
            'ntop' LECT stru TERM COND Z GT 0.799
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE GAZP RO 10.0 PINI 8.0E5 GAMM 1.4 PREF 0.8E5
          LECT expl TERM
     GAZP RO 1.0 PINI 0.8E5 GAMM 1.4 PREF 0.8E5
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
LINK DECO FLSW STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          HGRI 0.041 ! HGRI > max (h_fluid, h_stru)
          DGRI
          FACE
          BFLU 1
          FSCP 1
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 6
          ORDR 2
          OTPS 2
          RECO 1
          NTIL
CALC TINI 0. TEND 20.E-3
FIN
```

Like in case FLSW01 of Section 5.1.1, the CUVF element replaces FL38 and the GAZP material replaces FLUT (with equivalent settings). The `LINK DECO FLSW` directive is used for FSI and there is no need to constrain the external nodes of the fluid domain (`FSR`). The `FACE` keyword couples the structure directly with VFCC interfaces (rather than volumes).

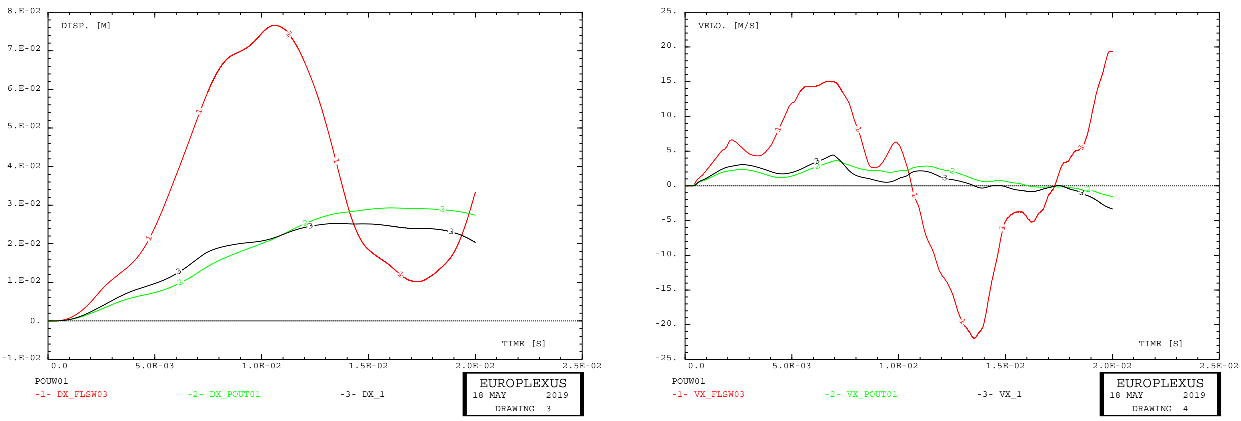
It is important to notice that the `BFLU` parameter has been set to 1 and not to 0 (the default) like in FE solutions, in order to actually block the fluxes across the coupled interfaces. Failing to do so would effectively remove any FSI coupling.

Finally, some options are set specifically for the VFCCs (`OPTI VFCC`). The `FCON 6` option chooses the HLLC flux solver (which is the default anyway), while the following options choose second order solution in time and in space.

A first attempt of running the test failed at step 1079, $t = 15.54$ ms, having used 942 s of CPU time, with a tilt message. The `NTIL` option was added and the calculation completed succesfully.

Figure 47 shows the x-displacement and the x-velocity (black curves) of the tip node of the cantilever beam. It can be observed that the beam displacement is lower than that obtained in the solutions using continuum elements in the beam (FLSWxx) and the general shape of the curve is quite different. The red curve shown in the picture is the solution of case FLSW03. The same observation had been raised also for calculations with the `FLSR` model.

Interestingly, the current solution is very close to that of case POUT01 (green curve) by using POUT elements and `FLSR`. This seems to indicate that the nature of the solutions using either continuum or beam elements for the structure is different, and this independently of the fluid formulation (FE or VFCC) and of the FSI model (`FLSR` or `FLSW`). However, blaming the structure model for this discrepancy seems inappropriate, in the light of the purely structural comparison tests (beam with initial velocity in vacuum) performed with either CUB8 or POUT elements in Section 3.2.



(a) Beam tip displacement

(b) Beam tip velocity

Figure 47: Some results of test POUW01 compared with FLSW03 and POUT01.

5.2.2 Case POUW12

This test is a repetition of case POUT12 by using `FLSW` instead of `FLSR`. It is similar to POUW01 but FSI-driven adaptivity is activated by the directive `FLSW` ... `ADAP LMAX 3 SCAL 2.0`.

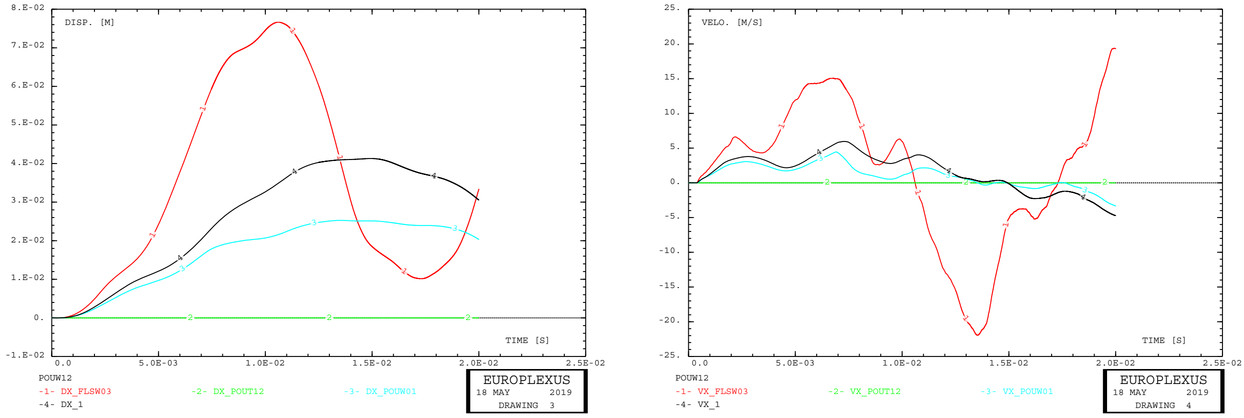
Figure 48 shows the x-displacement and the x-velocity (black curves) of the tip node of the cantilever beam. The beam displacement is substantially larger than that obtained in case POUW01 (cyan curve), and thus closer (but only as far as the maximum displacement is concerned) to the reference solution FLSW03 (red curve) that uses continuum elements in the structure. The solution of case POUT12 (green curve) is weird (practically no displacement at all), as mentioned in Section 3.4.11, and is included only for completeness of information.

5.2.3 Case POUW13

This test is a repetition of case POUT13 by using `FLSW` instead of `FLSR`. It is similar to POUW01 but FSI-driven adaptivity is activated by the directive `FLSW` ... `ADAP LMAX 2 SCAL 2.0`.

Figure 49 shows the x-displacement and the x-velocity (black curves) of the tip node of the cantilever beam. The beam displacement is substantially larger than that obtained in cases POUT13 (green curve) and POUW01 (cyan curve), and thus closer (but only as far as the maximum displacement is concerned) to the reference solution FLSW03 (red curve) that uses continuum elements in the structure.

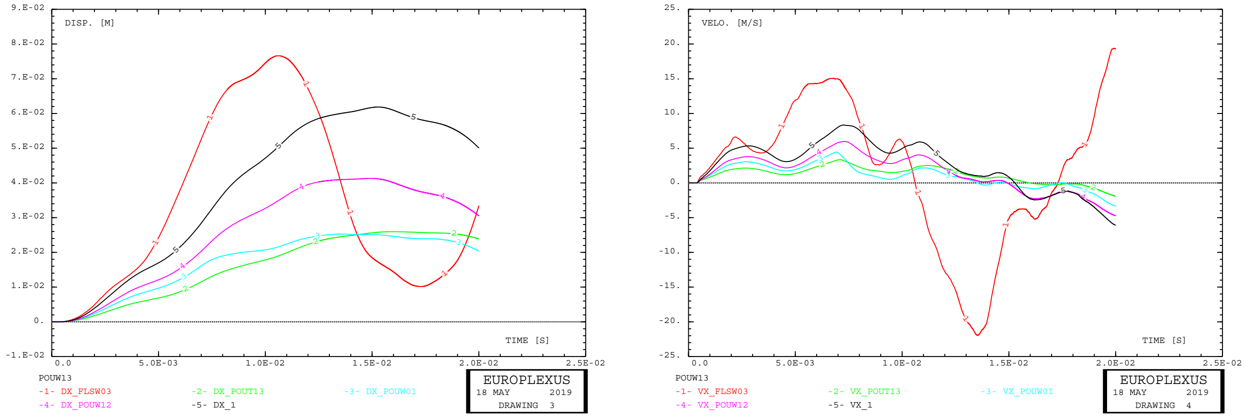
However, it is strange that the displacement obtained in this case, with `LMAX 2`, is larger than that of case POUW12, which uses `LMAX 3`. In other words, the obtained displacement does not seem to grow monotonically by increasing the refinement of the fluid mesh.



(a) Beam tip displacement

(b) Beam tip velocity

Figure 48: Some results of test POUW12 compared with FLSW03, POUT12 and POUW01.



(a) Beam tip displacement

(b) Beam tip velocity

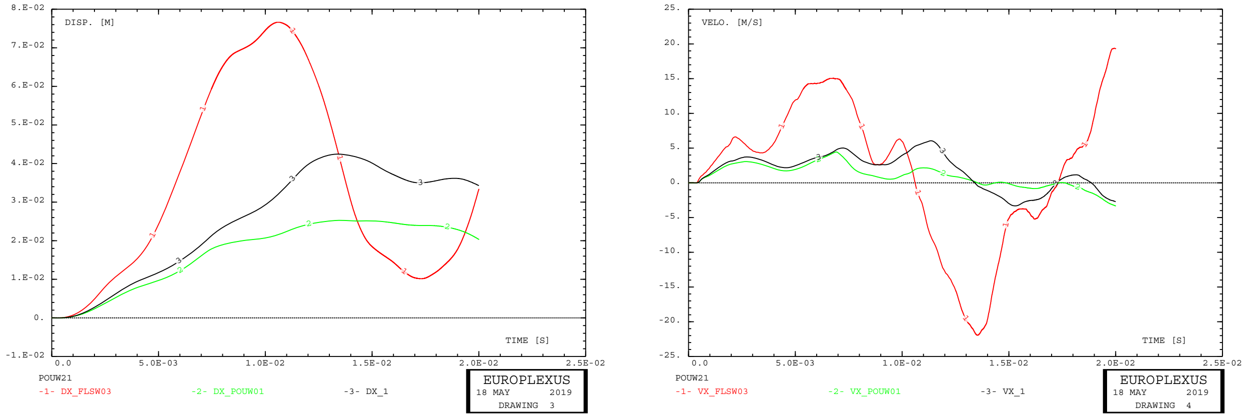
Figure 49: Some results of test POUW13 compared with FLSW03, POUT13, POUW01 and POUW12.

5.2.4 Case POUW21

This simulation is identical to case POUW01 but uses `FSCP 0` so that the FSI coupling occurs only along the normal to the structure.

Figure 50 shows the x-displacement and the x-velocity (black curves) of the tip node of the cantilever beam. The beam displacement is substantially larger than that obtained in case POUW01 (green curve). This is counter-intuitive since the coupling with `FSCP 0` should be weaker than with `FSCP 1` (as confirmed e.g. by comparing solutions POUT01 and POUT21 using `FLSR` in Section 3.4.13).

The implementation of `FSCP 0` for the `FLSW` model (a combination which is rarely used in applications) will have to be carefully checked to exclude any bugs.



(a) Beam tip displacement

(b) Beam tip velocity

Figure 50: Some results of test POUW21 compared with FLSW03 and POUW01.

6 A new drag-based FSI model for 3D beam/bar elements

We now explore the possibility of setting up a new model of FSI specifically for 3D bar/beam elements, based on empirical expressions of *drag coefficients* that can be found in the literature.

6.1 Provisional algorithm

The procedure resembles that used in EPX to treat so-called *flying debris*, see Section 2 of reference [11], with the notable difference that the debris particles are always assumed to be spherical while for 3D beams/bars a more complex shape (a long cylinder or prismatic bar) should be used to determine the drag coefficient.

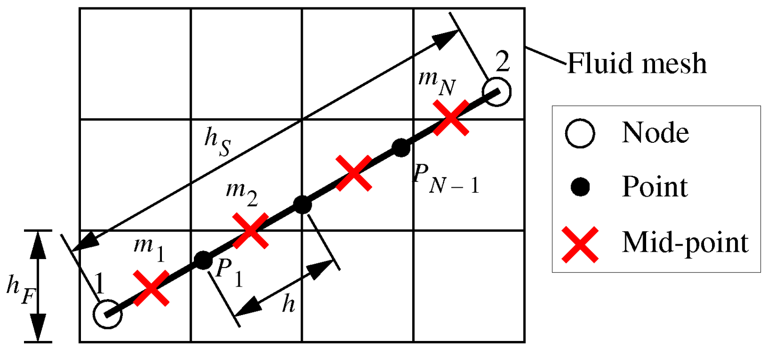


Figure 51: Geometry for the drag-based FSI model.

With reference to Figure 51 (drawn in 2D for simplicity) consider a beam/bar element (a segment) of nodes 1 and 2, embedded in a fluid mesh. Let $h_S = ||\vec{12}||$ be the size (length) of the structural element, h_F the size of the fluid mesh. We assume the fluid mesh to be structured and of size h_F in every space direction, for simplicity. Typically, it should be $h_F < h_S$. Let us assume for the moment that the fluid mesh is composed of Finite Elements (FE). A first tentative procedure to compute the drag-based FSI could be as summarized in Algorithm 2 below.

6.2 Input syntax of the DRAG directive

The drag-based model is implemented as a form of *decoupled* (or weak) link in EPX, that is, as part of the LINK DECO directive. The input syntax is as follows (see [1] for further details):

```
LINK DECO
  ...
```

Algorithm 2 Provisional drag-based FSI algorithm for 3D beam/bar elements.

1. Compute the number N of fluid elements that fit along the structural segment:
   (a) If $(h_f \geq h_S)$ then $N = 1$ (degenerated case).
   (b) Else $N = \lceil h_S/h_F \rceil$, i.e. the ceiling of the ratio between the structure and fluid lengths. This is the typical case due to the assumption that $h_F < h_S$.
2. Subdivide the segment 12 into N equal parts each of length $h = h_S/N$. That is, construct the $N-1$ points P_i, $i = 1, \cdots, N-1$.
3. Construct the N mid-points of the parts: m_i, $i = 1, \cdots, N$.
4. For each mid-point m_i, $i = 1, \cdots, N$:
   (a) Compute the normalized coordinate ψ_i of m_i with respect to the segment 12.
   (b) Compute the structure velocity at m_i: $\boldsymbol{v}_{Si} = N_1(\psi_i)\boldsymbol{v}_{S1} + N_2(\psi_i)\boldsymbol{v}_{S2}$, where N_I are the segment's shape functions.
   (c) Find the fluid Finite Element e_i into which the point m_i is embedded. A fast search bucket sort algorithm should be employed for this operation.
   (d) Compute the normalized coordinates ξ_i, η_i, ζ_i of m_i with respect to e_i.
   (e) Compute the fluid velocity at point m_i by interpolation from the nodal velocities of e_i: $\boldsymbol{v}_{Fi} = \sum_k N_k(\xi_i, \eta_i, \zeta_i)\boldsymbol{v}_{Fk}$, where N_k are e_i's shape functions.
   (f) Compute the relative velocity of the fluid with respect to the structure at m_i: $\boldsymbol{v}_{Ri} = \boldsymbol{v}_{Fi} - \boldsymbol{v}_{Si}$.
   (g) Split the relative velocity $\boldsymbol{v}_{Ri}$ into two contributions, a vector $\boldsymbol{v}_{Ri}^{\parallel}$ parallel to the segment and a vector $\boldsymbol{v}_{Ri}^{\perp}$ perpendicular to the segment: $\boldsymbol{v}_{Ri}^{\parallel} = (\boldsymbol{v}_{Ri} \cdot \hat{\boldsymbol{s}})\hat{\boldsymbol{s}}$ and $\boldsymbol{v}_{Ri}^{\perp} = \boldsymbol{v}_{Ri} - \boldsymbol{v}_{Ri}^{\parallel}$, where $\hat{\boldsymbol{s}}$ is the unit vector directed along the segment 12.
   (h) Compute the *drag pressure* exerted by the fluid on the i-th part of the structure segment at m_i: $p_i = C_d \frac{1}{2} \rho_F (\boldsymbol{v}_{Ri}^{\perp})^2$. Here C_d denotes the *drag coefficient*, which depends upon the shape of the bar as well as upon the Reynolds number Re and, for compressible flows, the Mach number M.
   (i) Compute the *drag force* exerted by the fluid on the i-th part of the structure segment at m_i: $\boldsymbol{F}_{di} = p_i h d_i \hat{\boldsymbol{n}}$ where $\hat{\boldsymbol{n}} = \boldsymbol{v}_{Ri}^{\perp}/||\boldsymbol{v}_{Ri}^{\perp}||$ is a unit vector in the direction of the normal relative velocity, h is the length of the segment's part as defined above and d_i is the transversal diameter of the beam/bar in the direction normal to $\boldsymbol{v}_{Ri}^{\perp}$, so that hd_i is the area of the bar "exposed to" (i.e. normal to) the relative fluid flow.
   (j) Add the drag force to the complementary forces acting on the structure (nodes 1 and 2).
   (k) Subtract the drag force from the complementary forces acting on the fluid (nodes of e_i).

```
DRAG <ROF rof> <VFX vfx> <VFY vfy> <VFZ vfz>
     STRU /LECTS/
    <FLUI /LECTF/>
    <(HF hf /LECTS2/)>
     (CD cd /LECTS3/)
    < $ HGRI hgri ; NMAX nmax ; DELE dele $ <DGRI> >
    < $ FBAC ; NOFB $ >
```

The various input parameters have the following meaning:

`rof`

Density of the (default) uniform fluid field in which the 3D beams/bars are embedded. This value is 0.0 by default, meaning that by default the 3D beams/bars move in vacuum (if they are not coupled with a discretized fluid domain by the `FLUI` keyword). Note that the drag force acting on a 3D beam/bar depends on the density but also on the drag coefficient (`CD`, see below).

`vfx, vfy, vfz`

Components of the velocity of the surrounding uniform fluid field. These values are 0.0 by default.

`STRU`

Introduces the `/LECTS/` of the 3D beam/bar elements. Only elements with a SEG2 geometrical shape are accepted.

`FLUI`

Introduces the `/LECTF/` of the discretized fluid domain with which the 3D beams/bars motion should be coupled. When a 3D beam/bar traverses this domain, the (local) fluid velocity and density are automatically computed by the code, instead of using the constant user-given values `rof`, `vfx`, `vfy`, `vfz` described above. A fast search algorithm based on a grid of cells (as in bucket sorting) is used to compute the fluid element (if any) encompassing each 3D beam/bar element.

`HF hf`

Size of the fluid elements coupled with each of the 3D beam/bar elements specified in the following /LECTS2/ directive in order to compute the local drag pressure and then the local drag force. As indicated by the parentheses, the `HF hf` sub-directive may be repeated as many times as necessary to assign a size `hf` to each one of the structure elements previously listed in the `STRU` directive. If omitted, the code computes automatically the local size of the coupled fluid elements to each structural beam/bar element.

`CD cd`

Drag coefficient C_d assigned to the 3D beam/bar elements specified in the following /LECTS3/ directive. As indicated by the parentheses, the `CD cd` sub-directive must be repeated as many times as necessary to assign a drag coefficient `cd` to each one of the structure elements previously listed in the `STRU` directive.

`HGRI`

Specifies the size of the grid cell for fast search operations. Each cell has the same size in all spatial directions and is aligned with the global axes. Note that the size of this grid is related to the size of the **structural** elements specified in `STRU`, not of the fluid elements specified in `FLUI`.

`NMAX`

Specifies the maximum number of cells along one of the global axes.

`DELE`

Specifies the size of the grid cell as a multiple of the diameter of the largest coupled **structural** element. Element "diameters" are computed only along each global spatial direction and the maximum is taken. For example, by setting `DELE 2` the size of the cell is twice the diameter of the largest coupled structural element declared in the `FLUI` directive. By default, i.e. if neither `HGRI`, nor `NMAX`, nor `DELE` are specified, the code takes `DELE 1.1`.

`DGRI`

Dump out the initial grid of cells used for fast searching on the listing. For brevity, the print is done only the first time that the grid is computed, that is, at step 0.

`FBAC`

Activate the feed-back mechanism whereby the drag forces generated by the fluid on the structure are also applied (with the minus sign) to the fluid itself. This is the default.

`NOFB`

Deactivate the feed-back mechanism whereby the drag forces generated by the fluid on the structure are also applied (with the minus sign) to the fluid itself.

6.3 Actual algorithm

In practice, the drag algorithm is slightly more complex than the provisional version outlined in Section 6.1. This is especially to take into account the possibility of mesh adaptivity in the fluid (in order to increase the resolution and the accuracy of the drag-based model) and possibly also in the structure (although this case should occur much less frequently since we are dealing here with beam/bar elements). Therefore, a more realistic (but still conceptual) version of the procedure looks like Algorithm 3 below.

This algorithm would be inefficient in large applications, unless a fast search procedure (e.g. a bucket-sort) is used to find all the candidate fluid elements "close" to each structural element, as informally indicated at point 3 of the listing. However, this changes the organization of the procedure. The main loop over all structural elements is replaced by a loop over the grid cells used for the search. For each cell, a list of candidate fluid elements λ_F is built formed by all elements whose centroid lies either in the cell itself or in a directly neighbouring cell (in 3D there are up to 26 neighbours for each cell). Then an (inner) loop is performed over the structural elements contained in the current cell λ_S, i.e. the elements whose centroid lies within the current cell.

For this strategy to work appropriately, the size h_C of the cells (assumed equal in each direction of the 3D space) must be larger than the maximum length $L_{\max}$ of all structural elements subjected to drag. By default, the code computes it automatically as: $h_C = 1.01L_{\max}$.

The actual procedure implemented in EPX (using fast search) is summarized in Algorithm 4 and is part of subroutine LINK_DRAG in module M_LINK_DRAG. Some details are not shown in the listing of the Algorithm, due to lack of space. The most important ones are the following:

- The algorithm shown is for the case that the fluid is discretized by Finite Elements. If the fluid is discretized by Cell-Centred Finite Volumes instead, the search is not made for fluid nodes (since all variables are expressed at the volume centroids) but rather for the interfaces between neighbouring cells, where numerical transport terms are computed.
- The case of structural elements (or of structural element parts) located outside the discretized fluid region must be properly treated. If a structural element's centroid is located outside the discretized fluid domain, the entire element is considered to be outside the fluid (without subdividing it into parts) and the drag force is computed (element-wise) based on the far-field conditions (if the user has provided a non-vanishing far-field fluid density in the input data).
- A structural element may have its centroid within the discrete fluid region yet some of its parts may be outside that region. In this case, the element is split into parts, the drag force of the outside parts is computed (part-wise) based on the far-field conditions while the drag force of the inside parts is computed normally.

Algorithm 3 Conceptual drag-based FSI algorithm for 3D beam/bar elements.

- Build up a list Λ_S of all *structural* (3D beam/bar) elements to be subjected to fluid-dynamic drag forces. If adaptivity in the structural elements has been activated, these will be all the *active descendants* of the (parent) structural elements declared in the coupling directive. Otherwise (no adaptivity in the structure), these will simply be the (parent) structural elements declared in the coupling directive. Any *eroded* (failed) 3D beam/bar elements are stripped from the list.
- Build up a similar list Λ_F of all *fluid* elements declared to be coupled to 3D beam/bar elements. Take into account adaptivity in the fluid (by extracting the active descendants) but not erosion since fluid elements are never eroded.
- Then, for each 3D beam/bar element in Λ_S, represented by a structural segment 12:
  1. Let $h_S = ||\vec{12}||$ be the size (length) of the structural element.
  2. Compute a pseudo-bounding box of the segment as the cube of side h_S, centred at the segment's centre and aligned with the global axes.
  3. Build the sub-list λ_F of all fluid elements from Λ_F that fit (i.e, whose centroid fits) into the segment's pseudo-bounding box. Use a bucket-sort **fast search** algorithm.
  4. Find the (current) local fluid mesh size h_F. If the user has specified a value in the input for the current structural element, take this value. Else, evaluate h_F as the minimum of the sizes of all fluid elements in λ_F.
  5. Compute the number N of (minimum-sized) fluid elements that would fit along the structural segment: $N = \lceil h_S/h_F \rceil$, i.e. the ceiling of the ratio between the structure and fluid lengths. This ensures that $N \geq 1$. The (degenerated) case $N = 1$ occurs when $h_S \leq h_F$, which should *not* typically be true.
  6. Subdivide the segment 12 into N equal parts each of length $h = h_S/N$. That is, construct the $N-1$ points P_i, $i = 1, \cdots, N-1$.
  7. Construct the N mid-points of the parts: m_i, $i = 1, \cdots, N$.
  8. For each mid-point m_i, $i = 1, \cdots, N$:
     (a) Compute the normalized coordinate ψ_i of m_i with respect to the segment 12.
     (b) Compute the structure velocity at m_i: $\boldsymbol{v}_{Si} = N_1(\psi_i)\boldsymbol{v}_{S1} + N_2(\psi_i)\boldsymbol{v}_{S2}$, where N_I are the segment's shape functions.
     (c) Find the fluid Finite Element e_i into which the point m_i is embedded. A fast search bucket sort algorithm is not needed for this operation, since the fluid element candidates to be considered are those in λ_F, not those in Λ_F.
     (d) Compute the normalized coordinates ξ_i, η_i, ζ_i of m_i with respect to e_i.
     (e) Compute the fluid velocity at point m_i by interpolation from the nodal velocities of e_i: $\boldsymbol{v}_{Fi} = \sum_k N_k(\xi_i, \eta_i, \zeta_i)\boldsymbol{v}_{Fk}$, where N_k are e_i's shape functions.
     (f) Compute the relative velocity of the fluid with respect to the structure at m_i: $\boldsymbol{v}_{Ri} = \boldsymbol{v}_{Fi} - \boldsymbol{v}_{Si}$.
     (g) Split the relative velocity $\boldsymbol{v}_{Ri}$ into two contributions, a vector $\boldsymbol{v}_{Ri}^{\parallel}$ parallel to the segment and a vector $\boldsymbol{v}_{Ri}^{\perp}$ perpendicular to the segment: $\boldsymbol{v}_{Ri}^{\parallel} = (\boldsymbol{v}_{Ri} \cdot \hat{\boldsymbol{s}})\hat{\boldsymbol{s}}$ and $\boldsymbol{v}_{Ri}^{\perp} = \boldsymbol{v}_{Ri} - \boldsymbol{v}_{Ri}^{\parallel}$, where $\hat{\boldsymbol{s}}$ is the unit vector directed along the segment 12.
     (h) Compute the *drag pressure* exerted by the fluid on the i-th part of the structure segment at m_i: $p_i = C_d \frac{1}{2} \rho_F (\boldsymbol{v}_{Ri}^{\perp})^2$. Here C_d denotes the *drag coefficient*, which depends upon the shape of the bar as well as upon the Reynolds number Re and, for compressible flows, the Mach number M.
     (i) Compute the *drag force* exerted by the fluid on the i-th part of the structure segment at m_i: $\boldsymbol{F}_{di} = p_i h d_i \hat{\boldsymbol{n}}$ where $\hat{\boldsymbol{n}} = \boldsymbol{v}_{Ri}^{\perp}/||\boldsymbol{v}_{Ri}^{\perp}||$ is a unit vector in the direction of the normal relative velocity, h is the length of the segment's part as defined above and d_i is the transversal diameter of the beam/bar in the direction normal to $\boldsymbol{v}_{Ri}^{\perp}$, so that hd_i is the area of the bar "exposed to" (i.e. normal to) the relative fluid flow.
     (j) Add the drag force to the complementary forces on the structure (nodes 1 and 2).
     (k) If the feed-back mechanism is active, subtract the drag force from the complementary forces on the fluid (nodes of e_i).

Algorithm 4 Actual drag-based FSI algorithm for 3D beam/bar elements (with fast search).

- Build up a list Λ_S of all *structural* (3D beam/bar) elements to be subjected to fluid-dynamic drag forces. If adaptivity in the structural elements has been activated, these will be all the *active descendants* of the (parent) structural elements declared in the coupling directive. Otherwise (no adaptivity in the structure), these will simply be the (parent) structural elements declared in the coupling directive. Any *eroded* (failed) 3D beam/bar elements are stripped from the list.
- Build up a similar list Λ_F of all *fluid* elements declared to be coupled to 3D beam/bar elements. Take into account adaptivity in the fluid (by extracting the active descendants) but not erosion since fluid elements are never eroded.
- Set up the cell grid that will be used for fast search. By default the code computes the grid size as $h_C = 1.01L_{\max}$, with $L_{\max}$ the maximum global projection of all structural elements in Λ_S.
- Loop on all cells of the grid. For each cell:
  - Build the sub-list λ_F of all fluid elements from Λ_F that fit (i.e, whose centroid fits) either into the current cell or in any of its (up to 26) direct neighbour cells.
  - Build the sub-list λ_S of all structural elements from Λ_S that fit (i.e, whose centroid fits) into the current cell.
  - Find the minimum and maximum local fluid mesh sizes h_F and $h_F^{\max}$ as the extreme sizes of all fluid elements in λ_F.
  - For each element (segment 12) e_j in λ_S:
    1. Let $h_S = ||\vec{12}||$ be the size (length) of the structural element.
    2. Build the sub-sub-list λ_{Fj} of all elements from λ_F whose centroid fits into the global b-box β_j of e_j, augmented by $h_F^{\max}/2$ in each (positive and negative) space direction.
    3. Compute the number N of (minimum-sized) fluid elements that would fit along the structural segment: $N = \lceil h_S/h_F \rceil$, i.e. the ceiling of the ratio between the structure and fluid lengths. This ensures that $N \geq 1$. The (degenerated) case $N = 1$ occurs when $h_S \leq h_F$, which should *not* typically be true.
    4. Subdivide the segment 12 into N equal parts of length $h = h_S/N$, i.e., construct the points P_i, $i = 1, \cdots, N-1$ and the mid-points m_i, $i = 1, \cdots, N$.
    5. For each mid-point m_i, $i = 1, \cdots, N$:
       (a) Compute the normalized coordinate ψ_i of m_i with respect to the segment 12.
       (b) Compute the structure velocity at m_i: $\boldsymbol{v}_{Si} = N_1(\psi_i)\boldsymbol{v}_{S1} + N_2(\psi_i)\boldsymbol{v}_{S2}$, where N_I are the segment's shape functions.
       (c) Find the fluid Finite Element e_i into which the point m_i is embedded. A fast search bucket sort algorithm is not needed for this operation, since the fluid element candidates to be considered are those in λ_{Fj}, not those in Λ_F or λ_F.
       (d) Compute the normalized coordinates ξ_i, η_i, ζ_i of m_i with respect to e_i.
       (e) Compute the fluid velocity at point m_i by interpolation from the nodal velocities of e_i: $\boldsymbol{v}_{Fi} = \sum_k N_k(\xi_i, \eta_i, \zeta_i)\boldsymbol{v}_{Fk}$, where N_k are e_i's shape functions.
       (f) Compute the relative velocity at m_i: $\boldsymbol{v}_{Ri} = \boldsymbol{v}_{Fi} - \boldsymbol{v}_{Si}$.
       (g) Split the relative velocity $\boldsymbol{v}_{Ri}$ into two contributions, a vector $\boldsymbol{v}_{Ri}^{\parallel}$ parallel to the segment and a vector $\boldsymbol{v}_{Ri}^{\perp}$ perpendicular to the segment: $\boldsymbol{v}_{Ri}^{\parallel} = (\boldsymbol{v}_{Ri} \cdot \hat{\boldsymbol{s}})\hat{\boldsymbol{s}}$ and $\boldsymbol{v}_{Ri}^{\perp} = \boldsymbol{v}_{Ri} - \boldsymbol{v}_{Ri}^{\parallel}$, where $\hat{\boldsymbol{s}}$ is the unit vector directed along the segment 12.
       (h) Compute the *drag pressure* exerted by the fluid on the i-th part of the structure segment at m_i: $p_i = C_d \frac{1}{2}\rho_F(\boldsymbol{v}_{Ri}^{\perp})^2$. Here C_d denotes the *drag coefficient*, which in principle depends upon the shape of the bar as well as upon the Reynolds number Re and, for compressible flows, on the Mach number M. In the current implementation C_d is considered constant.
       (i) Compute the *drag force* exerted by the fluid on the i-th part of the structure segment at m_i: $\boldsymbol{F}_{di} = p_i h d_i \hat{\boldsymbol{n}}$ where $\hat{\boldsymbol{n}} = \boldsymbol{v}_{Ri}^{\perp}/||\boldsymbol{v}_{Ri}^{\perp}||$ is a unit vector in the direction of the normal relative velocity, h is the length of the segment's part as defined above and d_i is the transversal diameter of the beam/bar in the direction normal to $\boldsymbol{v}_{Ri}^{\perp}$, so that hd_i is the area of the bar "exposed to" (i.e. normal to) the relative flow.
       (j) Add the drag force to the complementary forces on the structure (nodes 1 and 2).
       (k) If the feed-back mechanism is active, subtract the drag force from the complementary forces on the fluid (nodes of e_i).

7 Numerical examples with DRAG

The following numerical examples aim at checking the newly developed drag-based model (LINK DECO DRAG directive).

7.1 Consistency checks

Like for any completely new model, we start by some consistency checks. They are summarized in Table 7 and are described in the following sub-sections.

Case	Mesh	Description	Steps	CPU [s]	Computer
DRAG03	3 POUT	No discretized fluid, ROF 1.0 VFX 20.0	8001	2.6	M6700
DRAG04	3 POUT	Same as DRAG03, beam blocked at both ends	8001	2.6	M6700
DRAG05	3 POUT	Same as DRAG04, fluid velocity along beam	8000	2.6	M6700
DRAG08	4000 FL38 3 POUT	With discretized fluid (FL38)	327	4.5	M6700

Table 7: Consistency check calculations with the DRAG model.

7.1.1 Case DRAG03

This test includes a cantilever beam composed of 3 POUT elements, but no discretized fluid. The beam, initially placed vertically, is similar to those used in some previous tests (length 3.0 m, square cross-section of 0.04×0.04 m, elastic material) and is completely blocked (including rotations) at its lower extremity.

The LINK DECO DRAG directive is used to embed the cantilever in a uniform fluid flow with density $\rho_F = 1.0$ kg/m^3 and a horizontal (along x) velocity of 20 m/s. A drag coefficient $C_D = 1.0$ is assigned to all structural elements. The input data looks as follows:

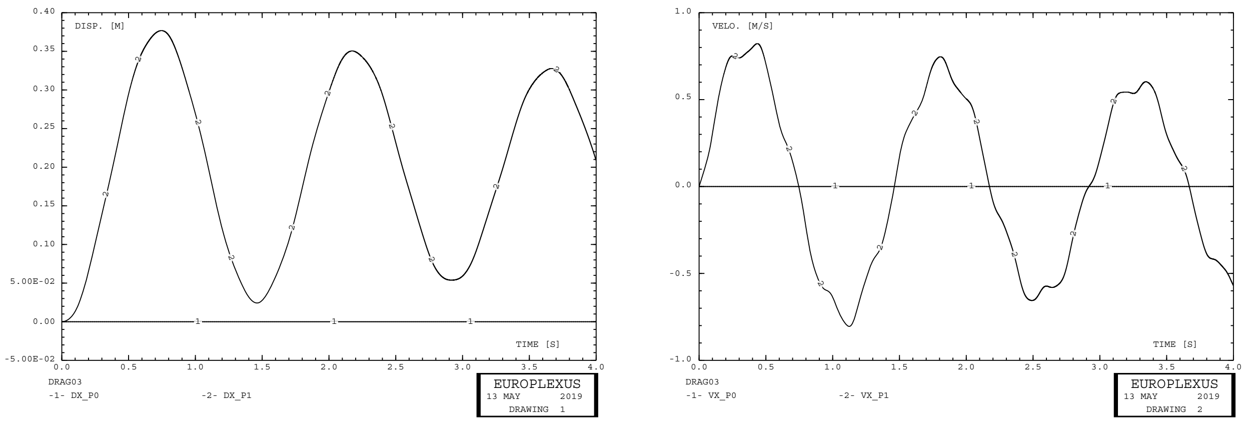
```
DRAG03
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     COUL VERT LECT stru TERM
MATE LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK DECO
     BLOQ 123456 LECT p0 TERM
     DRAG ROF 1.0 VFX 20.0
          STRU LECT stru TERM
          CD 1.0 LECT stru TERM
ECRI DEPL VITE TFRE 2.E-1
     NOEL POIN LECT p0 p1 TERM
     FICH ALIC TFRE 4.E-2
     FICH ALIC TEMP FREQ 1
          POIN LECT p0 p1 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 4.0
FIN
```

It should be noted incidentally that in the above input data set the blockage of the beam extremity (BLOQ) is inserted in the LINK DECO directive, together with the DRAG command. In other words, we use the *decoupled* form of the blockage command.

If one would use the *coupled* or strong form of the command (LINK COUP DECO) instead, results would not be completely correct. This is due to the fact that in EPX the coupled constraints are enforced first, and the decoupled constraints are enforced last (which is perhaps not the best possible strategic choice). Consequently, the beam extremity would not be perfectly blocked because the drag forces would be added *after* the calculation of the blocking forces.

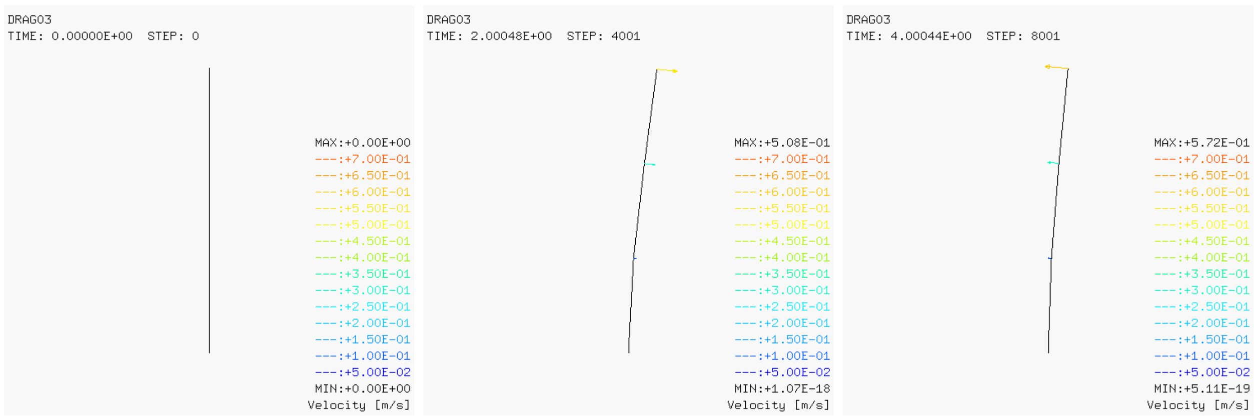
To solve this and similar problems that sometimes occur in applications, a new development would be needed in EPX allowing to apply strong (coupled) conditions *after* decoupled constraints, if so desired, but this remains to be done and is out of scope in the present work.

Figure 52 shows some results (beam tip displacement and velocity) of this simulation, which look plausible, until the chosen final time of 4.0 s. The beam oscillates elastically, with some damping. Figure 53 shows some snapshots of the deformed beam at various times.



(a) Beam tip displacement (b) Beam tip velocity

Figure 52: Some results of test DRAG03.



(a) $t = 0$ (b) $t = 2$ s (c) $t = 4$ s

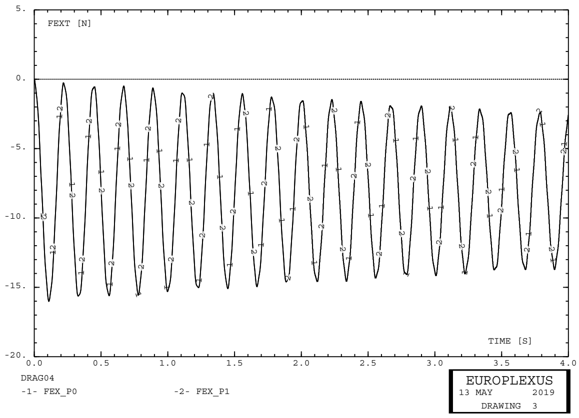
Figure 53: Beam deformed shape and velocity in test DRAG03.

7.1.2 Case DRAG04

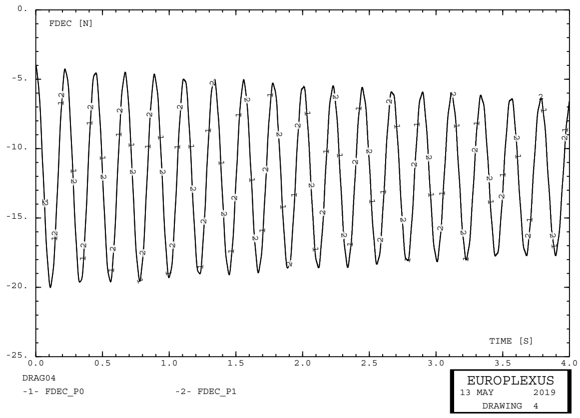
This test is similar to DRAG03 but we block both extremities of the beam. The purpose is that of checking that the overall drag force acting over the beam agrees with the value that can be computed analytically. Since under the chosen boundary conditions the beam deforms very little, the relative velocity is close to the fluid velocity ($v_R \approx v_f = 20.0$ m/s). The total drag force then should be $F_D = p_D A = 0.5 C_D \rho_F v_R^2 L d \approx 0.5 \times 1.0 \times 1.0 \times 20^2 \times 3 \times 0.04 = 24$ N.

Figure 54 shows the external force (`FEXT`) and the complementary force (`FDEC`) along x computed at the two extremities of the beam. The oscillations have a higher frequency with respect to the previous case, but this is normal since the beam is stiffer when both extremities are blocked. Under static (steady-state) conditions the expected *reaction* force at each extremity is $F_R = -F_D/2 = -12.0$ N. This seems to coincide fairly well with the mean value of the oscillating `FDEC`, but not with that of `FEXT`. These discrepancies stem from the way in which the various force components are treated in

EPX, which is not always completely intuitive. A revision of this subject in EPX would be highly desirable, along with the re-formulation of the precedence rules of coupled and decoupled links already mentioned in Section 7.1.1.



(a) External force



(b) Complementary force

Figure 54: Some results of test DRAG04.

7.1.3 Case DRAG05

This test is similar to DRAG04 but the fluid flow velocity is directed along the z direction, i.e. parallel to the beam. The scope is simply to verify that under such conditions the drag force on the beam vanishes, which is indeed the case. Results are not presented for brevity.

7.1.4 Case DRAG08

This test uses a discretized fluid domain similar to that of tests FLSRxx (Section 3.3), but the initial pressure is uniform everywhere (no explosive) and the fluid box is completely closed (no absorbing boundary). A beam is immersed in the fluid, with a given initial velocity. The purpose of the calculation is to compute the drag exerted by the fluid on the beam and also the feed-back effect produced by the beam motion on the fluid.

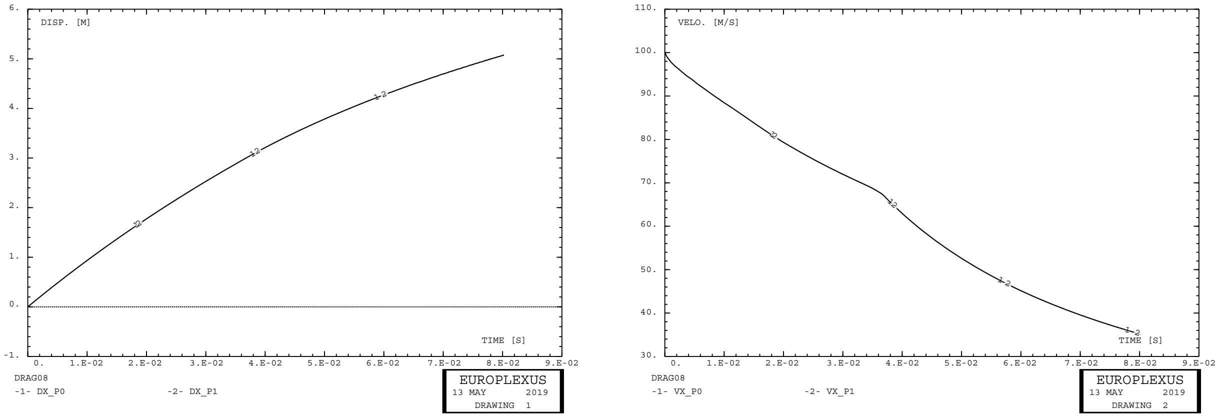
The beam has the same geometrical and material characteristics as in the previous examples. The boundary and initial conditions are as follows:

```
LINK COUP SPLT NONE
     FSR  LECT fsrn TERM
LINK DECO
     DRAG ROF 1.0
          STRU LECT stru TERM
          FLUI LECT flui TERM
          CD 50.0 LECT stru TERM
          DGRI
INIT VITE 1 100.0 LECT stru TERM
```

A far-field fluid density `ROF` of 1.0 kg/m^3 is set in order to compute the drag on the beam even when it eventually exits from the discretized fluid domain. A relatively high initial velocity (100 m/s) and an extremely high (un-realistic) drag coefficient (50.0) are assigned to the structure, in order to obtain rather strong drag forces that will produce evident effects on the structure motion even in a relatively short time period (80 ms).

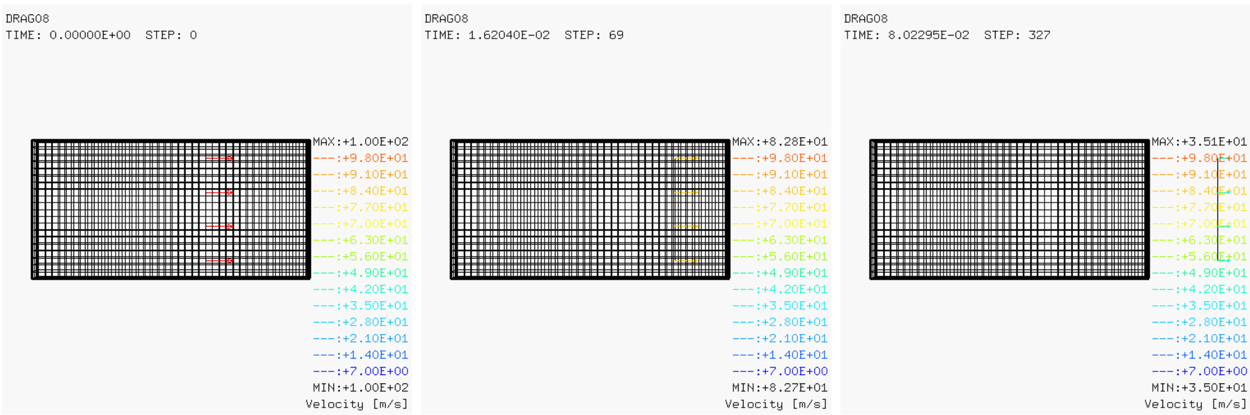
Figure 55 presents some results (beam displacement and velocity) of this simulation, until the chosen final time of 80 ms, showing strong deceleration of the beam motion. After a displacement of 3 m (which occurs at about 30 ms) the beam exits from the discretized fluid domain and one can observe a slight change of slope in the curves due to the idealized conditions assumed in the far field.

Figure 56 shows some snapshots of the deformed beam at various times, with the velocity vectors on the structure.



(a) Beam displacement (b) Beam velocity

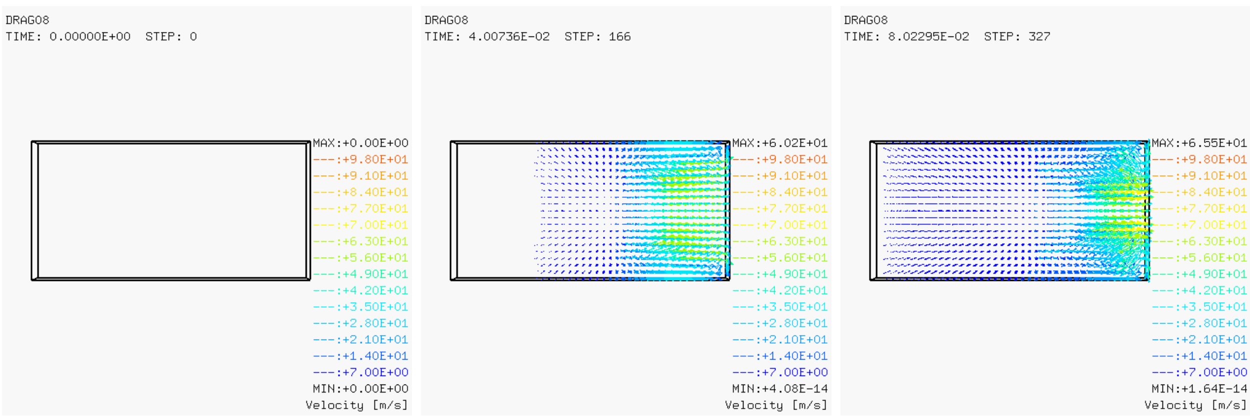
Figure 55: Some results of test DRAG08.



(a) $t = 0$ (b) $t = 16$ ms (c) $t = 80$ ms

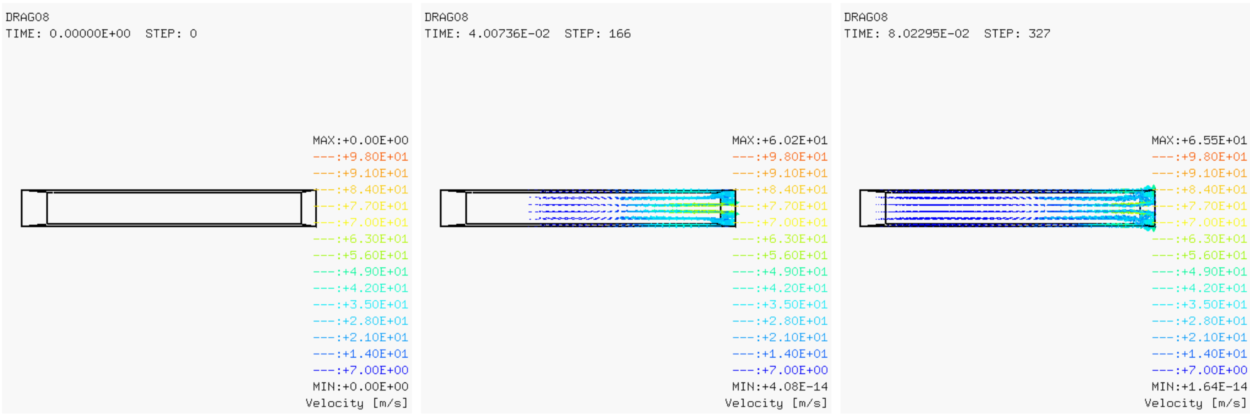
Figure 56: Beam deformed shape and velocity in test DRAG08.

Finally, Figures 57 and 58 present the fluid velocity field induced by the beam at various time instants (seen from the side and from the top, respectively).



(a) $t = 0$ (b) $t = 40$ ms (c) $t = 80$ ms

Figure 57: Fluid velocity in test DRAG08 (side view).



(a) $t = 0$ (b) $t = 40$ ms (c) $t = 80$ ms

Figure 58: Fluid velocity in test DRAG08 (top view).

7.2 Cantilever beam under blast loading with FE fluid

We now apply the `DRAG` model to the problem of the cantilever beam under blast loading already tackled with other methods in previous Sections 3.3 and 5.1. In this first series of calculations, the fluid domain is discretized by Finite Elements (type FL38).

The performed simulations are summarized in Table 8 and are described in the following subsections.

Case	Mesh	Description	Steps	CPU [s]	Computer
DRAG11	125000 FL38 10 POUT	`CD 1.00`	1440	593	M6700
DRAG12	125000 FL38 10 POUT	`CD 1.98`	1468	622	M6700
DRAG13	290264 FL38 10 POUT	Statically adapted fluid mesh	3443	29968	M6700
DRAG14	895000 FL38 10 POUT	Statically graded fluid mesh	3789	6676	EVICOM
DRAG15	16250 FL38 10 POUT	Twice coarser fluid mesh	1025	65	M6700
DRAG21	125000 FL38 10 POUT	`CD 1.00 NOFB`	1405	604	M6700
DRAG22	125000 FL38 10 POUT	`CD 1.98 NOFB`	1405	605	M6700
DRAG23	290264 FL38 10 POUT	Statically adapted fluid mesh `NOFB`	3254	23636	EVICOM
DRAG24	895000 FL38 10 POUT	Statically graded fluid mesh `NOFB`	3583	6324	EVICOM
DRAG25	16250 FL38 10 POUT	Twice coarser fluid mesh `NOFB`	1025	57	M6700

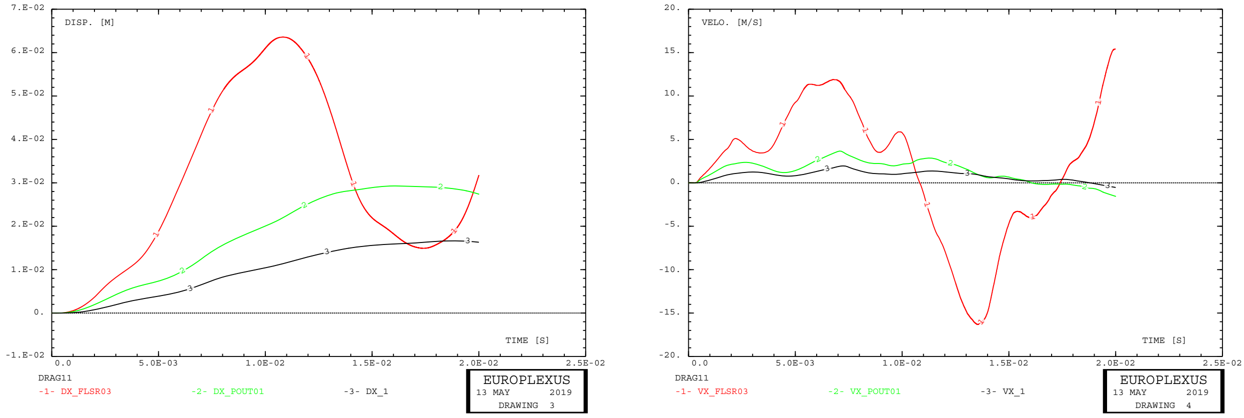
Table 8: Cantilever beam under blast loading calculations with the `DRAG` model and FE fluid.

7.2.1 Case DRAG11

This model is similar to case POUT01 presented in Section 3.4.1 but uses the `DRAG` model. We start by using a drag coefficient of 1.0.

```
LINK DECO
     DRAG STRU LECT stru TERM
          FLUI LECT flui TERM
          CD 1.0 LECT stru TERM
          DGRI
```

Figure 59 shows the x-displacement and the x-velocity of the tip node of the cantilever beam (in black), compared with cases FLSR03 (in red) and POUT01 (in green). The present solution is qualitatively in agreement with the POUT01 solution, which used the `FLSR` model and beam elements and differs from FLSR03, which used `FLSR` with continuum elements. The quantitative difference between DRAG11 and POUT01 might be due to the choice of the drag coefficient.



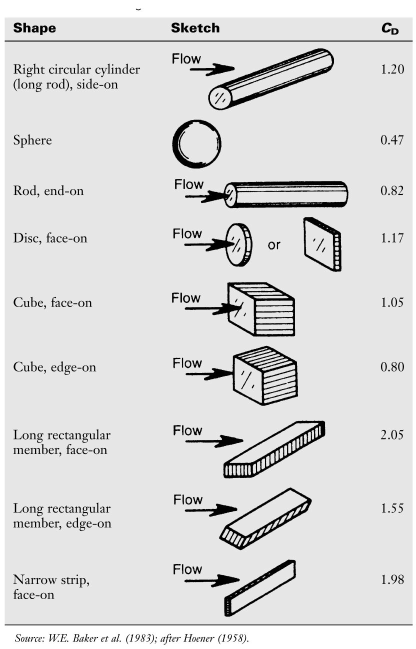
(a) Beam tip displacement

(b) Beam tip velocity

Figure 59: Some results of test DRAG11 compared with FLSR03 and POUT01.

7.2.2 Case DRAG12

This model is a repetition of case DRAG11 by using a more accurate value of the drag coefficient. The values of drag coefficients that can be found in the literature vary over a relatively wide range. As an example, from a table in reference [15] (after W.E. Baker, 1983, and Hoener, 1958) shown in Figure 60 we found that for a narrow strip, positioned face-on with respect to the flow, C_D may be as high as 1.98.



Shape	Sketch	C_D
Right circular cylinder (long rod), side-on	Flow	1.20
Sphere		0.47
Rod, end-on	Flow	0.82
Disc, face-on	Flow or	1.17
Cube, face-on	Flow	1.05
Cube, edge-on	Flow	0.80
Long rectangular member, face-on	Flow	2.05
Long rectangular member, edge-on	Flow	1.55
Narrow strip, face-on	Flow	1.98

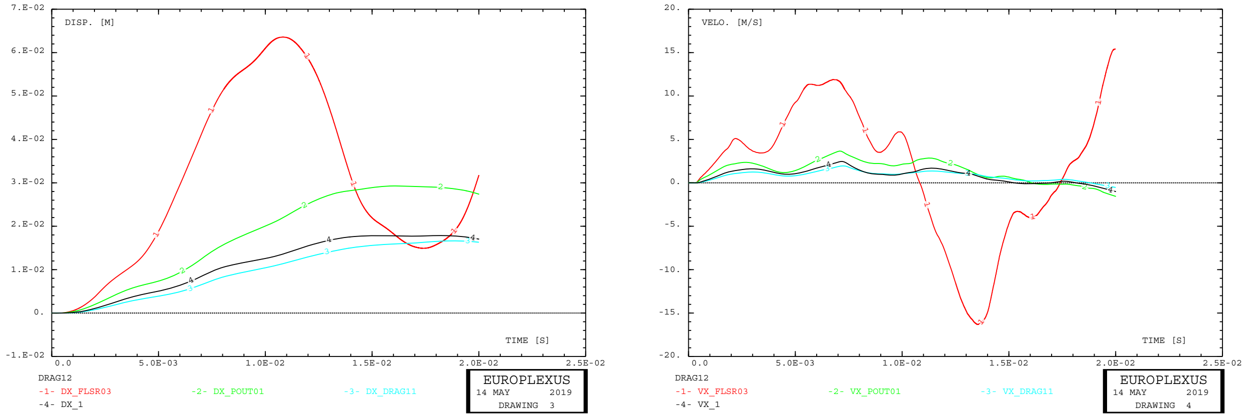
Source: W.E. Baker et al. (1983); after Hoener (1958).

Figure 60: Some drag coefficients from reference [15].

The result with this value of the coefficient is presented in Figure 61 and compared with the previous solutions. The present solution (black curve) is only slightly higher that solution DRAG11 (cyan curve), despite the use of an almost double value of the drag coefficient.

7.2.3 Case DRAG13

We want now to study what happens when the fluid mesh is refined. One possibility is to use mesh adaptivity. Note that automatic (FSI-driven) adaptivity is currently not available as part of the `DRAG` model (it is only available in conjunction with the more classical `FLSR` and `FLSW` FSI models).



(a) Beam tip displacement

(b) Beam tip velocity

Figure 61: Some results of test DRAG12 compared with FLSR03, POUT01 and DRAG11.

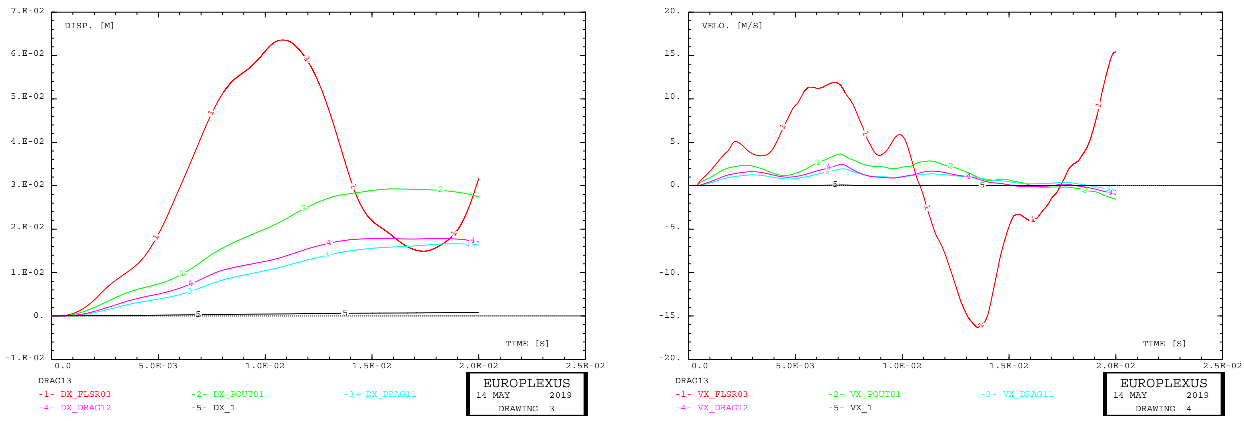
However, nothing prevents using a statically refined (constant) fluid mesh, by adapting the grid from the beginning of the calculation via the `INIT ADAP` directive, by choosing a suitable zone in the fluid mesh where the beam is expected to remain embedded during the whole transient calculation.

This solution is similar to case DRAG12 but uses a statically refined adaptive mesh near the beam:

```
 . . .
DIME ADAP NPOI 156299 FL38 165264 ENDA TERM
 . . .
COMP . . .
     GROU 3 . . .
            'refi' LECT flui TERM
                   COND CYLI X1 .5 Y1 0 Z1 0 X2 .5 Y2 0 Z2 0.9 R 0.08
 . . .
INIT ADAP SPLI LEVE 3 LECT refi TERM
 . . .
OPTI . . .
     ADAP RCON
 . . .
```

The `ADAP RCON` option is selected in order to have a smooth mesh transition near the refined region.

The result of this calculation is presented in Figure 62 and compared with the previous solutions. The present solution (black curve) is much lower than all other solutions (and almost invisible on the Figure).



(a) Beam tip displacement

(b) Beam tip velocity

Figure 62: Results for tests DRAG13 compared with FLSR03, POUT01, DRAG11 and DRAG12.

7.2.4 Case DRAG14

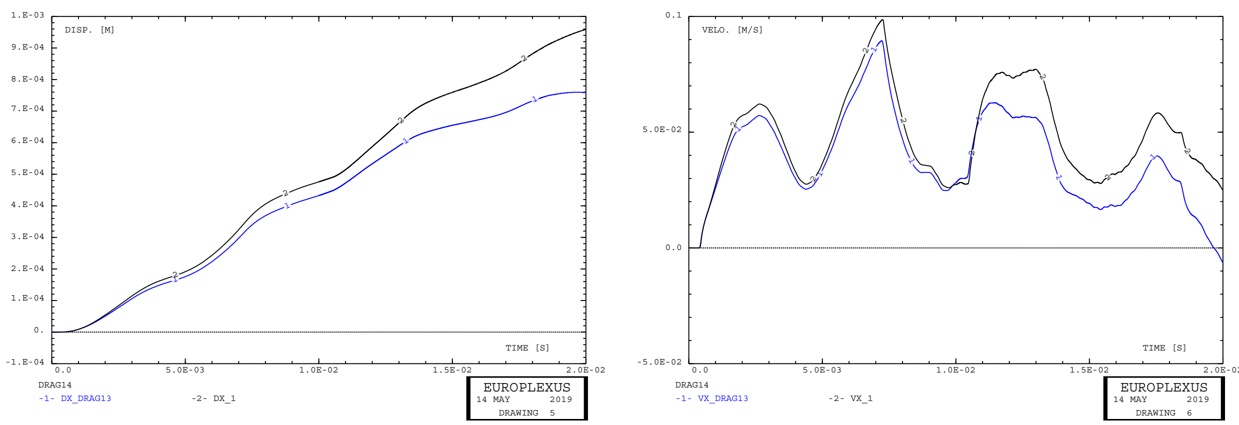
Another way of locally refining the fluid mesh, without resorting to mesh adaptivity, is to use a graded mesh. Again, this mesh will be static (constant during the calculation) so it should encompass at least the entire zone that is expected to be occupied by the beam during the whole transient.

To produce a graded mesh with Cast3m, use is made of the `pxracub8.proc` Gibiane procedure. This greatly simplifies the job, but making the mesh still remains quite laborious. See the Cast3m procedure and input files in the Appendix for full details.

Apart from the changes in the Cast3m mesh, the EPX input file is almost identical to that of case DRAG12. In the `DRAG` directive we choose the refined region only (instead of the whole fluid domain) as `FLUI` so as to speed up somewhat the fast search operations.

```
 . . .
COMP . . .
     GROU 3 . . .
            'fldr' LECT flui TERM COND XB GT 0.4
                                  COND XB LT 0.6
 . . .
LINK DECO
     DRAG STRU LECT stru TERM
          FLUI LECT fldr TERM
          CD 1.98 LECT stru TERM
!         DGRI
 . . .
```

The result of this calculation is compared in Figure 63 against the previous solution (the one with mesh adaptivity). The two solutions are in relatively good agreement, as it was expected since the size of the refined fluid mesh is the same (0.5 cm) in both cases. However this means also that, like the previous one, the present solution (black curve) is much lower than all other solutions as shown in Figure 64.



(a) Beam tip displacement

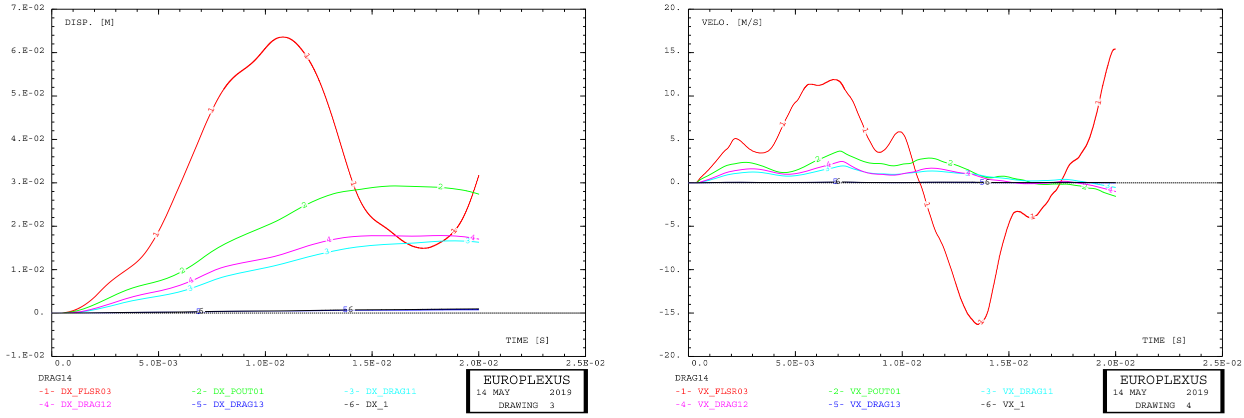
(b) Beam tip velocity

Figure 63: Results for tests DRAG14 compared with DRAG13.

7.2.5 Case DRAG15

To conclude the study of the effects of fluid mesh size, we perform a simulation with a twice *coarser* mesh than that of case DRAG12.

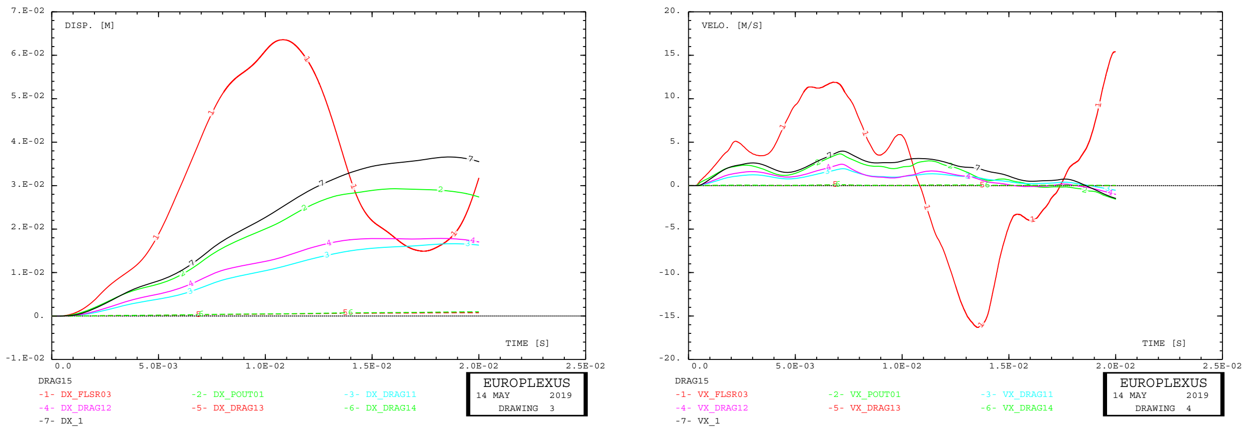
The result of this calculation (black solid curve) is compared in Figure 65 against all previous solutions (coloured curves). A bit surprisingly at first sight, this solution is in much better agreement with the solution POUT01 (green curve) than all other solutions with `DRAG` obtained so far (in particular, than solutions with finer fluid meshes).



(a) Beam tip displacement

(b) Beam tip velocity

Figure 64: Results for tests DRAG14 compared with FLSR03, POUT01 and DRAG11 to DRAG13.



(a) Beam tip displacement

(b) Beam tip velocity

Figure 65: Results for tests DRAG15 compared with FLSR03, POUT01 and DRAG11 to DRAG14.

7.2.6 Analysis of cases DRAG11 to DRAG15

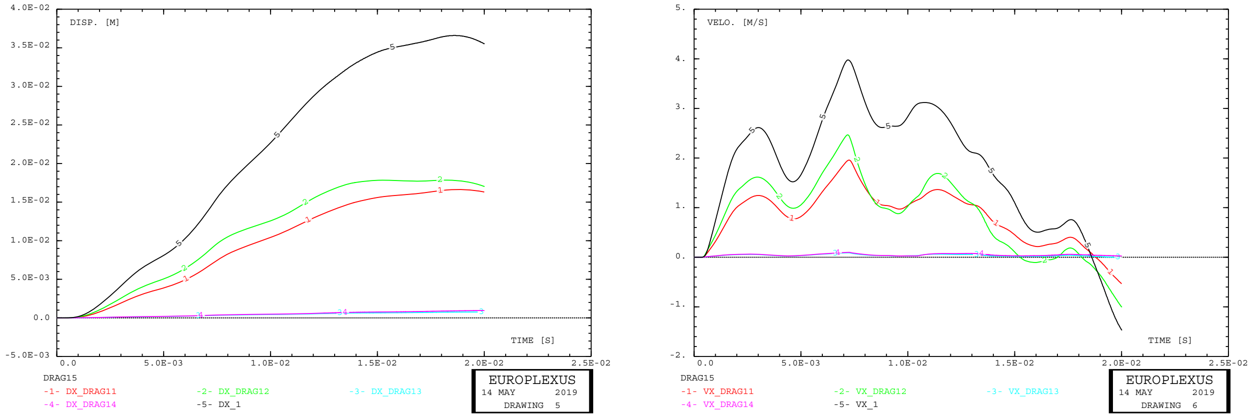
By comparing the results of the five calculations done so far with the `DRAG` model, cases DRAG11 to DRAG15, as shown in Figure 66, one may notice the following issues:

1. It is strange that by almost doubling the drag coefficient C_D the beam displacement increases by only 10% or so. Compare the case DRAG11 (red curve, $C_D = 1.0$) and the case DRAG12 (green curve, $C_D = 1.98$).
2. It is also strange that, by refining the fluid mesh, no convergence towards a unique solution seems to be reached. The more refined the fluid mesh, the lower is the drag effect on the beam, i.e. the lower is the beam displacement. Compare cases DRAG15 (black curve, $h_F = 4.0$ cm), DRAG12 (green curve, $h_F = 2.0$ cm) and DRAG13/DRAG14 (cyan/magenta curve, $h_F = 0.5$ cm), all using $C_D = 1.98$.

7.2.7 Critical analysis of the feed-back mechanism

By critically reviewing the drag model, attention is drawn upon the feed-back mechanism. The only quantity influencing the drag force that might vary significantly in the four simulations mentioned above at point 2 is the relative fluid velocity $v_R = v_F - v_S$, since all other parameters are geometrical ones and are about the same in all those simulations.

Assume that at a certain time a certain relative velocity occurs. This determines the value of the drag force exerted by the fluid on the structure. The structure exerts an equal and opposite force



(a) Beam tip displacement

(b) Beam tip velocity

Figure 66: Results for tests DRAG11 to DRAG15.

on the fluid. This *feed-back* force is then applied to the nodes of the fluid element that contains the structural point under consideration, thus slowing down the fluid and reducing the relative velocity (recall that the drag force depends quadratically on v_R).

However, in the discrete model the amount of slow-down will depend upon the mass of the fluid subjected to the feed-back force (mass of the concerned fluid nodes), which in turn depends upon the fluid mesh size h_F. The smaller h_F, the smaller is the fluid mass (with a cubic relationship) and therefore the stronger is the local deceleration of the fluid. As a consequence, the relative velocity tends to zero and so will do the drag force at the next time step.

The above qualitative reasoning gives a clue for the interpretation of the anomalies observed above. To verify this, the five calculations DRAG11 to DRAG15 will be repeated below by activating an optional keyword (`NOFB`) in the `DRAG` directive (see Section 6.2) that avoids applying the feed-back force to the fluid nodes.

Eliminating the feed-back may look counter-intuitive (besides being un-physical) at first sight. However, one should better consider the assumptions of the drag model. Drag is a local phenomenon that occurs in the vicinity of the structure, which is assumed to be very thin in the present work (the case of large flat structures, typically treated with the `FLSR` or `FLSW` algorithms would be different). The drag force is produced by a local perturbation of the fluid flow that causes a stagnation pressure (higher than the ambient pressure) on the exposed side of the obstacle, and an under-pressure on the other side, caused by a downstream wake in the fluid. For viscous fluids there is also a (usually smaller) frictional component due to the fluid sliding along the structure, but this is totally neglected in EPX.

The idea behind using a drag coefficient is that this coefficient, which is determined experimentally, already encompasses in itself all such phenomena and allows to compute the drag force only based upon the relative velocity between the fluid and the structure $v_R = v_F - v_S$. But in this expression v_f is the *undisturbed* velocity of the fluid at a certain distance from the structure, and not the one close to it, which varies from point to point due to the complex interaction pattern (for example, $v_F = v_S$ at the stagnation point, but not along the lateral walls of the obstacle).

In the drag model used so far, due to the feed-back effect, it is like if we would use the v_F at the stagnation point (or about so) in computing the drag force, and this explains the anomalies observed.

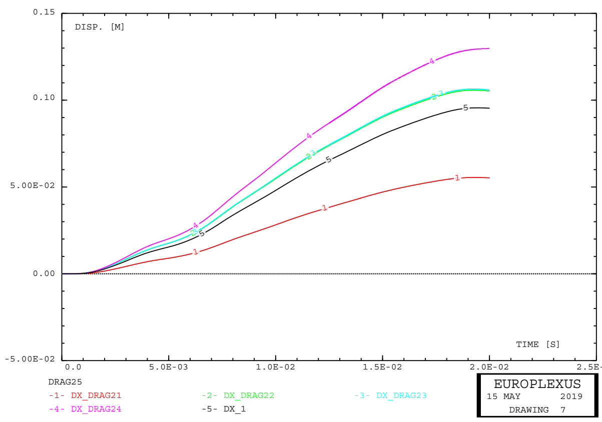
Computing the undisturbed fluid velocity in EPX would be quite cumbersome, Therefore, as a drastic but much simpler measure, we choose to completely neglect the feed-back effect when the `NOFB` keyword is activated. As a consequence, the fluid will flow undisturbed, like if the structure would not be there in the first place. This type of calculation might be classified as decoupled. We will not be able to see the fine-scale (local) effects of the presence of the structure on the fluid flow, since these are encompassed in the drag coefficient model. If such effects have to be included, one should use a full-fledged simulation with a very fine discretization in the fluid and a continuum model for the structure. But such a type of analysis is out of reach in large complex industrial applications.

Although it introduces some approximations, the drag model (without feed-back) can be very convenient from the computational viewpoint since it allows to perform FSI analyses with relatively coarse fluid meshes. This of course, provided we can prove that mesh-independency is substantially achieved by removing the feed-back effect, as it will be investigated in the following examples.

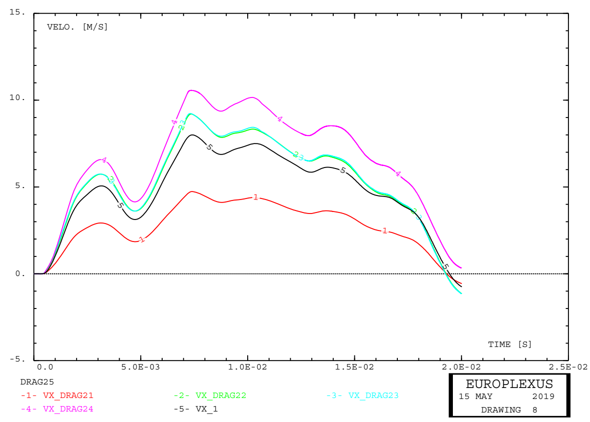
7.2.8 Cases DRAG21 to DRAG25

These tests are repetitions of cases DRAG11 to DRAG15, respectively, by simply adding the `NOFB` keyword in the `DRAG` directive in order to completely disable the feed-back effect.

Results are summarized and compared with one another in Figure 67. We can observe that the effect of varying C_D is now almost linear (red and green curves, corresponding to cases DRAG21 and DRAG22), which solves the first issue in Section 7.2.6. We also see that by varying the fluid mesh size some spread between the solutions (cases DRAG22 to DRAG25, green, cyan, magenta and black curves) persists but it is now much smaller than in the corresponding solutions with feed-back. Remarkably, the solutions with medium and fine adaptive fluid meshes (cases DRAG22 and DRAG23, green and cyan curves) are almost identical. The solution with coarse fluid mesh is a bit off, possibly due to excessive coarseness. The solution with fine graded mesh is also a bit off, possibly due to the use of irregular element shapes in the transition zones of the graded mesh, which might affect the regularity of the fluid flow.



(a) Beam tip displacement



(b) Beam tip velocity

Figure 67: Results for tests DRAG21 to DRAG25.

7.3 Cantilever beam under blast loading with VFCC fluid

We now do another series of calculations with the `DRAG` model applied to the problem of the cantilever beam under blast loading, where the fluid domain is discretized by VFCCs (type CUVF).

The performed simulations are summarized in Table 9 and are described in the following subsections. All calculations are performed with the `NOFB` optional keyword, i.e. the feed-back mechanism is disabled. Note that at the moment of this writing, the feed-back mechanism is not implemented for the VFCC type of fluid discretization, so the `NOFB` keyword could also be omitted (but it is included for clarity). And, due to the observations about the negative effects of the feed-back mechanism in Section 7.2.7, it is likely that this mechanism will never be implemented in the VFCC/FLSW model.

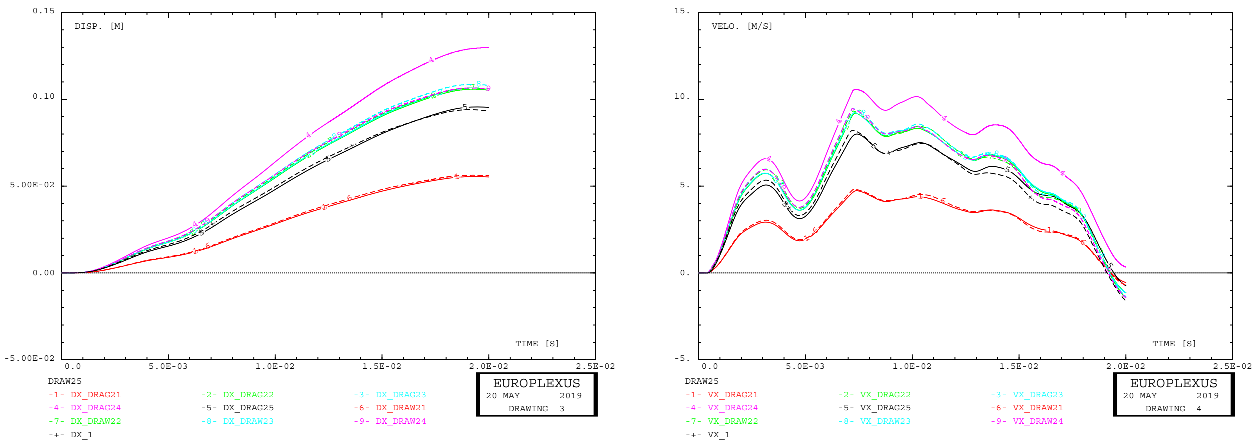
7.3.1 Cases DRAW21 to DRAW25

These models are similar to cases DRAG21 to DRAG25, respectively, but use VFCC instead of FE for the fluid domain.

Case	Mesh	Description	Steps	CPU [s]	Computer
DRAW21	125000 CUVF 10 POUT	`CD 1.00 NOFB`	1442	951	M6700
DRAW22	125000 CUVF 10 POUT	`CD 1.98 NOFB`	1442	971	M6700
DRAW23	290264 CUVF 10 POUT	Statically adapted fluid mesh `NOFB`	3398	5970	EVICOM
DRAW24	895000 CUVF 10 POUT	Statically graded fluid mesh `NOFB`, $C_S = 0.25$			EVICOM
DRAW25	16250 CUVF 10 POUT	Twice coarser fluid mesh `NOFB`	1021	84	M6700

Table 9: Cantilever beam under blast loading calculations with the **DRAG** model and VFCC fluid.

The results are summarized in Figure 68. The solid curves refer to cases DRAGxx while the dashed curves refer to cases DRAWxx. All solution pairs are very similar, with the only exception of case DRAG24 which is quite higher (as already noted in Section 7.2.8).



(a) Beam tip displacement

(b) Beam tip velocity

Figure 68: Results for tests DRAW21 to DRAW25 compared with DRAG21 to DRAG25.

8 Application example: a suspended bridge

To conclude, we consider a possible example of application of the models developed in this report. The goal is to study transient dynamic wind effects on a long cable-suspended bridge. The model considered is only conceptual and un-realistic as concerns the real geometry of such a bridge, the material properties, etc. However, it illustrates at least qualitatively the possibilities offered by the newly developed commands in EPX.

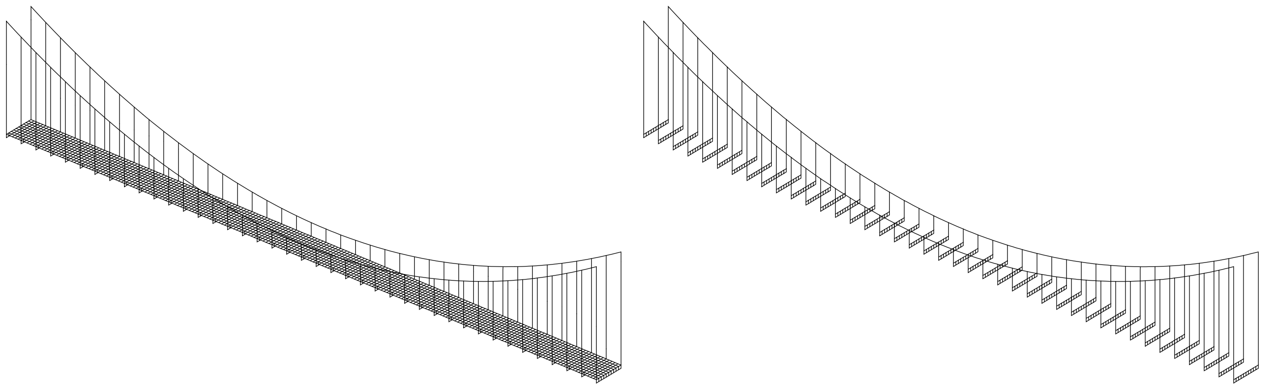
8.1 Simulations without fluid domain discretization

We start by setting up a much simplified geometrical model of the bridge, see Figure 69. The bridge deck, meshed by quadrangular shells, is 200 m long and 10 m wide. To reinforce the deck, a series of 1 m tall longitudinal ribs (also modelled by shells) is added, as shown in Figure 69(b) where the deck has been removed for clarity. The suspension cables have a parabolic shape. They are attached at a height of 34 m from the deck and reach 4 m above the deck at the lowest (central point). A total of 41 vertical cables on each side sustain the bridge. The two extremities of the deck are simply supported (blocked displacements but free rotations). The four extremities of the suspension cables are blocked in displacement. All cables are represented by POUT elements which offer also a certain resistance to bending and compression.

The bridge (structural) mesh is built by Cast3m as follows:

```
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'brid01.msh';
opti trac psc ftra 'brid01_mesh.ps';
p0 = 0 0 0;
p1 = 100 0 30;
p2 = 100 0 0;
pi = 50 0 0;
tol = 0.01;
par1 = para 100 p0 pi p1;
par1c = chan poi1 (para 20 p0 pi p1);
elim tol (par1 et par1c);
vzm = 0 0 -1;
dd = 1.0;
dens dd;
n = nbno par1c;
k = 0;
repe loop1 n;
  k = k + 1;
  nk = par1c poin k;
  x y z = coor nk;
  cabk = d (x y z) (x y -4);
  travk = (d (x y -4) (x (y+10) -4)) tran 1 vzm;
  si (ega k 1);
    cab0 = cabk;
    trav0 = travk;
    pp = (x y -4);
  sinon;
    impk = pp d (x y -4);
    pp = (x y -4);
    si (ega k 2);
      cab1 = cabk;
      trav1 = travk;
      imp1 = impk;
    sinon;
      cab1 = cab1 et cabk;
      trav1 = trav1 et travk;
      imp1 = imp1 et impk;
    finsi;
  finsi;
fin loop1;
bri1 = par1 et cab1 et imp1 et trav1;
elim tol bri1;
vy = 0 10 0;
vz = 0 0 10;
par2 = par1 plus vy;
cab2 = cab1 plus vy;
imp2 = imp1 plus vy;
cab02 = cab0 plus vy;
bri2 = par2 et cab2 et imp2;
elim tol (bri2 et cab02);
bas12 = imp1 tran vy;
elim tol (bas12 et imp2);
stru1 = bri1 et bri2 et bas12;
par3 = par1 syme plan p0 (p0 plus vy) (p0 plus vz);
cab3 = cab1 syme plan p0 (p0 plus vy) (p0 plus vz);
imp3 = imp1 syme plan p0 (p0 plus vy) (p0 plus vz);
trav3 = trav1 syme plan p0 (p0 plus vy) (p0 plus vz);
par4 = par2 syme plan p0 (p0 plus vy) (p0 plus vz);
cab4 = cab2 syme plan p0 (p0 plus vy) (p0 plus vz);
imp4 = imp2 syme plan p0 (p0 plus vy) (p0 plus vz);
bri3 = par3 et cab3 et imp3;
bri4 = par4 et cab4 et imp4;
trav = trav0 et trav1 et trav3;
bas34 = bas12 syme plan p0 (p0 plus vy) (p0 plus vz);
stru2 = bri3 et bri4 et bas34;
stru12 = stru1 et stru2;
elim tol stru12;
base = bas12 et bas34;
paras = par1 et par2 et par3 et par4;
cabls = cab1 et cab2 et cab3 et cab4 et cab0 et cab02;
mesh = base et paras et cabls et trav;
elim tol mesh;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
trac cach qual (paras et cabls et trav);
trac cach mesh;
trac cach (paras et cabls et trav);
fin;
```

The bridge is subjected to its own weight, represented by gravity (at least in some of the simulations), and/or to the effect of a lateral wind. All parts are assigned a linear elastic material with steel-like properties. This is unrealistic at least for the deck, but it is chosen to keep things simple.



(a) Whole mesh (b) Mesh without the deck

Figure 69: Mesh for the bridge problem.

A first set of simulations is performed without using a discretized fluid domain, for simplicity. Such simulations are inexpensive in terms of CPU and may be used to fine-tune the structural model. They are summarized in Table 10.

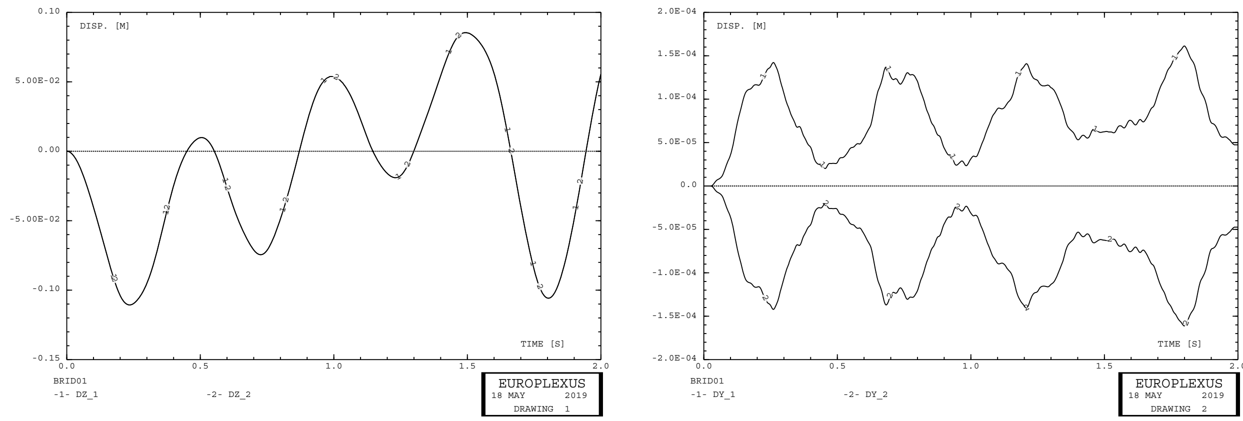
Case	Mesh	Description	Final time [s]	Steps	CPU [s]	Computer
BRID01	2410 Q4GS 1596 POUT	Gravity	2.0	21 662	258	M6700
BRID02	2410 Q4GS 1596 POUT	Gravity, damping	5.0	54 154	484	M6700
BRID03	2410 Q4GS 1596 POUT	Gravity, damping, drag	5.0	54 154	524	M6700
BRID04	2410 Q4GS 1596 POUT	Gravity, drag	5.0	54 155	587	M6700
BRID05	2410 Q4GS 1596 POUT	Drag	5.0	54 157	568	M6700

Table 10: Suspended bridge simulations without discretized fluid.

8.1.1 Case BRID01

In this first simulation, the bridge is subjected only to its own weight, in order to study the oscillations of the structure under the sudden appearance of gravity at $t = 0$. The calculation is performed until 2 s of physical time.

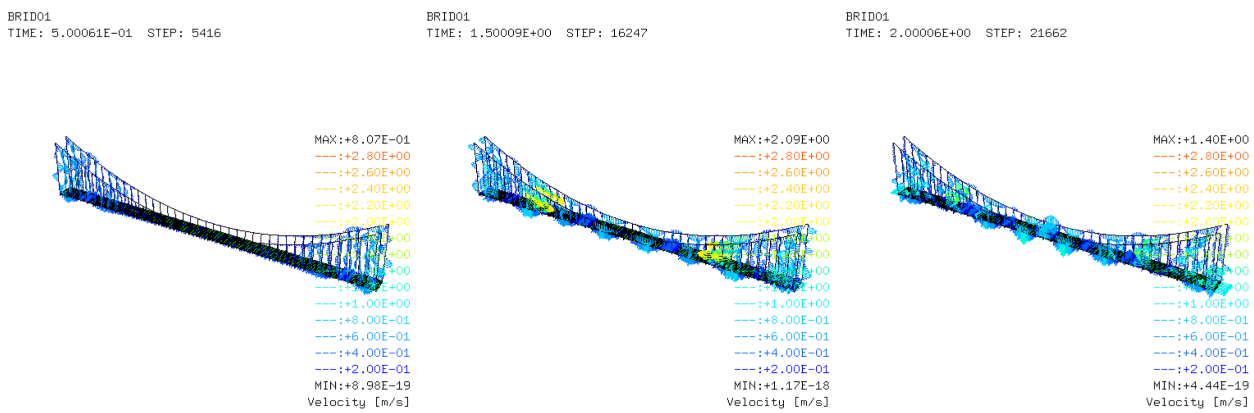
Figure 70(a) shows the vertical displacement of the bridge's central points on either side of the road, exhibiting elastic oscillations with a main frequency of about 2 Hz. The horizontal displacements of the same two points, shown in Figure 70(b), are due only to elasticity (no cross-wind effect in this test) and so they are negligible.



(a) Vertical displacement (b) Horizontal diaplacement

Figure 70: Displacements in test BRID01.

Figure 71 shows the deformed shape and velocity field of the bridge at some selected time instants. There are elastic oscillations which tend to persist because the numerical model does not include any damping effects (neither in the time integration algorithm nor in the material, which is taken as perfectly elastic).



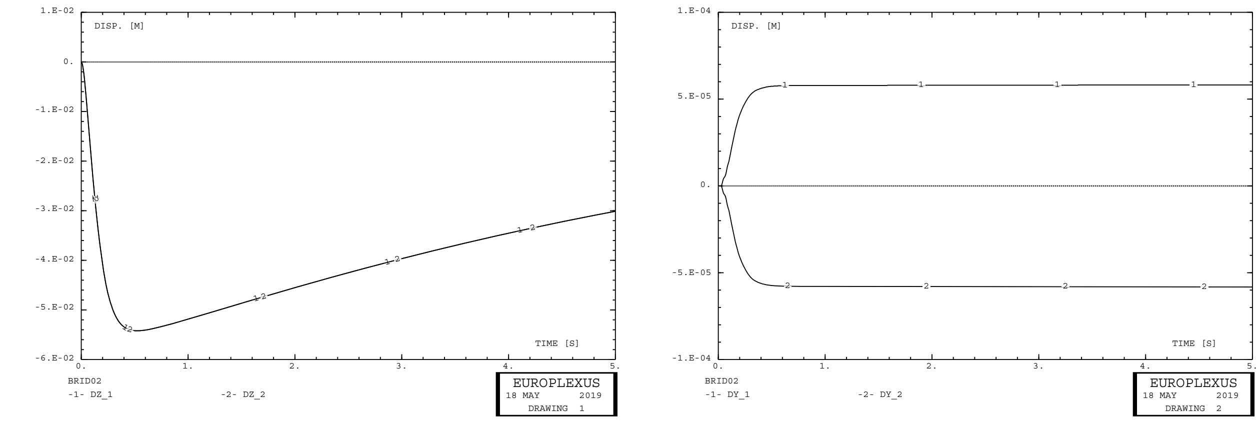
(a) $t = 0.5$ s (b) $t = 1.5$ s (c) $t = 2.0$ s

Figure 71: Bridge deformation and velocity fields for tests BRID01.

8.1.2 Case BRID02

We repeat the previous test by adding some numerical damping in order to obtain an approximation of the "static" deformation of the bridge under its own weight. The activated option is `OPTI QUAS STAT 2.0 1.0`, which adds quasi-static critical damping for a frequency of 2 Hz. The simulation is now carried out until a final time of 5.0 s.

Figure 72 shows the displacements of the bridge's central points on either side of the road. The elastic oscillations have disappeared, but at 5 s time the vertical position of the bridge central point is not yet completely stabilized.



(a) Vertical displacement

(b) Horizontal diaplacement

Figure 72: Displacements in test BRID02.

8.1.3 Case BRID03

We now add some wind drag forces to the previous model. The input file reads:

```
BRID03
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM Q4GS base trav POUT paras cabls TERM
COMP NGRO 7 'nb1' LECT base TERM COND X LT -99.9
            'nb2' LECT base TERM COND X GT  99.9
            'nb3' LECT cabls TERM COND X LT -99.9 COND Z GT 29.9
            'nb4' LECT cabls TERM COND X GT  99.9 COND Z GT 29.9
            'nblo' LECT nb1 nb2 nb3 nb4 TERM
            'ncen1' LECT base TERM COND NEAR POIN 0 0 -4
            'ncen2' LECT base TERM COND NEAR POIN 0 10 -4
     COUL VERT LECT base TERM
          ROUG LECT paras TERM
          GR50 LECT cabls TERM
     ORIE INVE LECT bas34 TERM
     EPAI 0.02 LECT base trav TERM
     GEOP RECT VX 0 VY 1 VZ 0 AY 0.20 AZ 0.20 LECT paras TERM
     GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04 LECT cabls TERM
MATE LINE RO 7800. YOUN 2.D11 NU 0.3
          LECT base paras cabls trav TERM
LINK DECO
     BLOQ 123 LECT nblo TERM
     DRAG ROF 1.0 VFX 0 VFY 100 VFZ 0
          STRU LECT paras cabls TERM
          CD 1.0 LECT paras cabls TERM
CHAR CONST GRAV 0 0 -9.81 LECT tous TERM
ECRI DEPL VITE TFRE 5.E-1
     NOEL POIN LECT ncen1 ncen2 TERM
     FICH SPLI ALIC TFRE 5.E-2
     FICH ALIC TEMP TFRE 5.E-3
          POIN LECT ncen1 ncen2 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     QUAS STAT 2.0 1.0
CALC TINI 0. TEND 5.E0
FIN
```

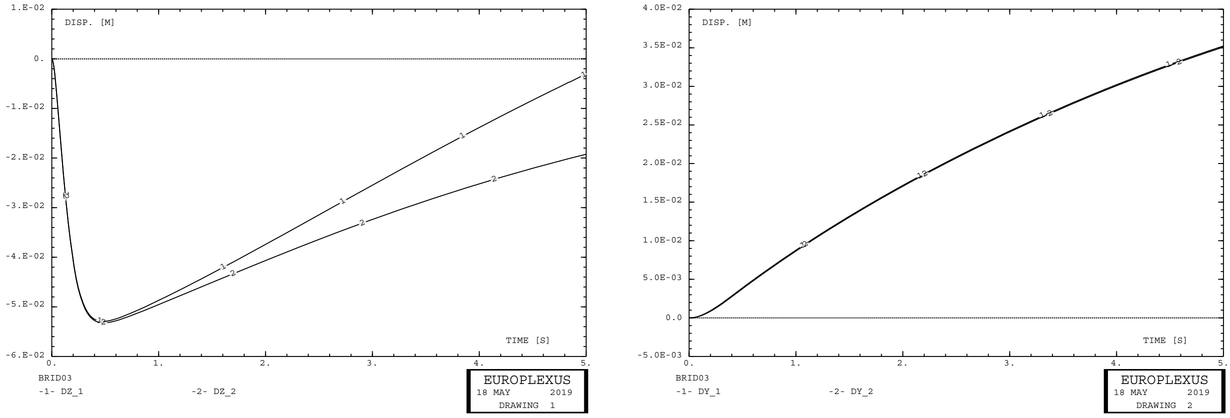
The far-field conditions for the drag calculations are set as follows. The air is supposed to have a density of 1.0 kg/m^3 and the wind has a speed of 100 m/s in the x-direction, that is, horizontally across the bridge. This velocity value is unrealistically high but it is used to generate relatively large motions in the bridge.

Drag effects are modelled by the `LINK DECO DRAG` directive and, as such, they can only act on the beam members of the structure (i.e. on the main suspension cables `paras` and on the vertical cables `cabls`). Drag forces on the deck are *not* simulated, which is of course highly unrealistic. Note also that, unlike in the previous two simulations, the decoupled version of blockages (`LINK DECO BLOQ`) has to be used instead of the coupled one, for the reasons already discussed in some of the first examples in this report.

Figure 73 shows the displacements of the bridge's central points on either side of the road. Some horizontal displacement takes place (not yet stabilized at 5 s) and this also leads to a small rotation (twisting) of the deck, as it appears from the fact that the vertical displacements on the two sides of the road are no longer the same.

8.1.4 Case BRID04

This test is similar to the previous one (with gravity and drag forces) but we remove the quasi-static damping (which might be excessive and mask out some physical oscillatory effects of the real bridge



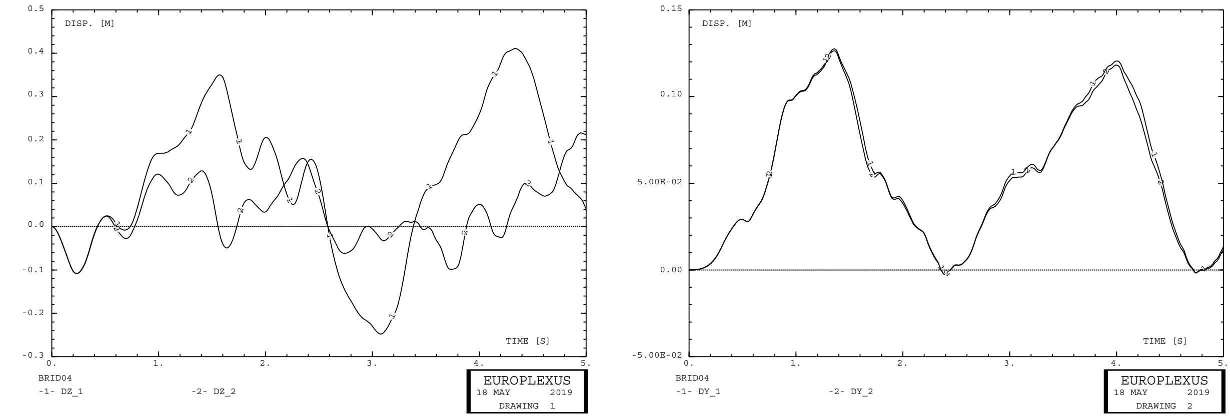
(a) Vertical displacement

(b) Horizontal diaplacement

Figure 73: Displacements in test BRID03.

behaviour).

Figure 74 shows the displacements of the bridge's central points on either side of the road. Elastic oscillations are back and it seems that also the horizontal movement has an oscillatory behaviour (with a period of about 2.5 s) under the wind effect.



(a) Vertical displacement

(b) Horizontal diaplacement

Figure 74: Displacements in test BRID04.

Figure 75 shows the deformed shape and velocity field of the bridge at some selected time instants.

8.1.5 Case BRID05

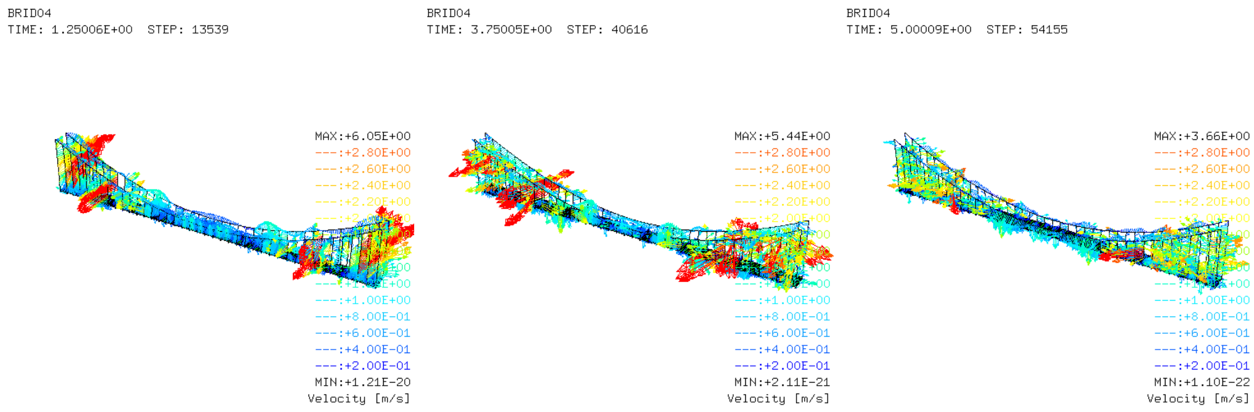
To conclude this preliminary series of tests without fluid, we perform a final calculation that includes only the effects of drag forces (on the beams) but no gravity and no damping.

Figure 76 shows the displacements of the bridge's central points on either side of the road.

Figure 77 shows the deformed shape and velocity field of the bridge at some selected time instants.

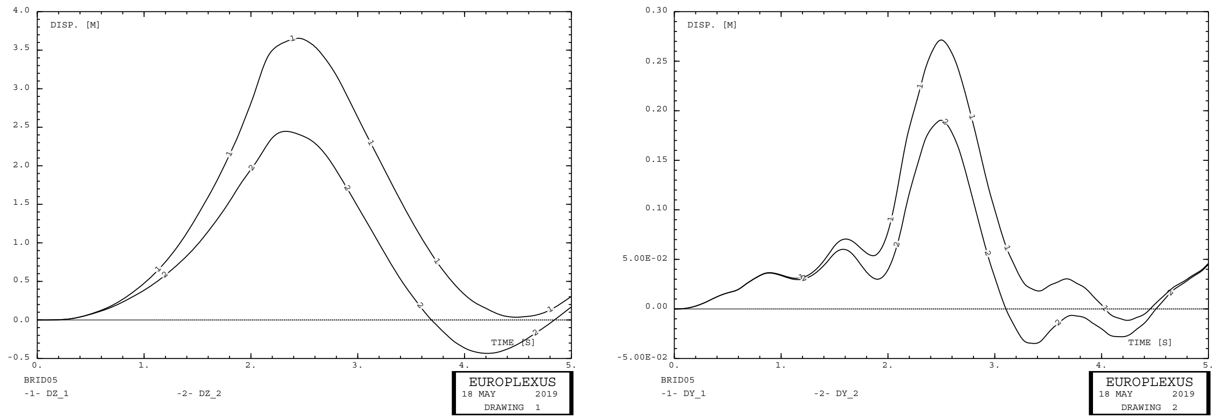
8.2 Simulations with fluid domain discretization

We now want to perform more complete simulations of the suspended bridge by including also the effect of the wind on the deck. To this end, the `DRAG` model cannot be used because the deck is modelled by 3D shell elements, not by 3D beams. Therefore, it is necessary to discretize a fluid domain encompassing (at least) the whole deck. We choose the Cell-Centred Finite Volume (VFCC) formulation for the fluid.



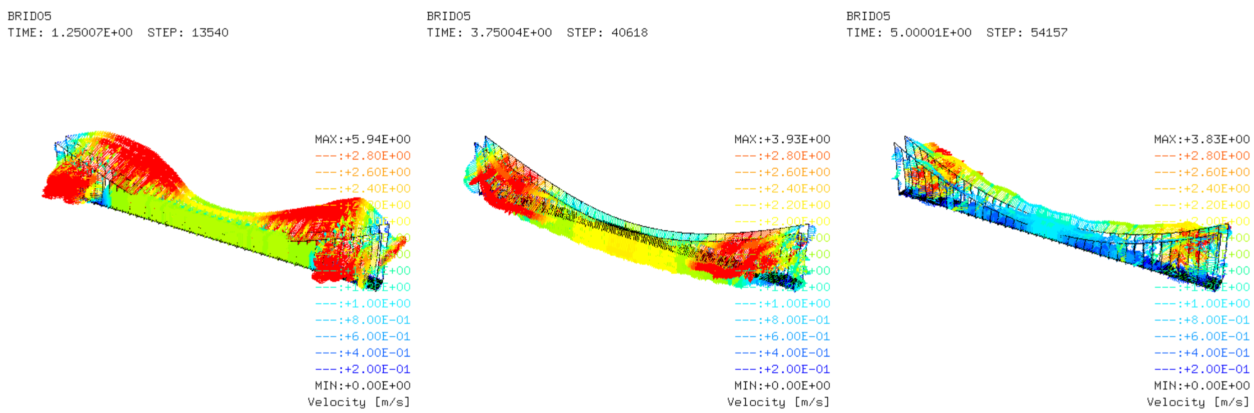
(a) $t = 1.25$ s (b) $t = 3.75$ s (c) $t = 5.00$ s

Figure 75: Bridge deformation and velocity fields for tests BRID04.



(a) Vertical displacement (b) Horizontal diaplacement

Figure 76: Displacements in test BRID05.



(a) $t = 1.25$ s (b) $t = 3.75$ s (c) $t = 5.00$ s

Figure 77: Bridge deformation and velocity fields for tests BRID05.

The bridge deck will be embedded in a parallelepiped (box) of fluid oriented along the global axes and representing the atmospheric air. To simulate a constant wind at 100 m/s in the x direction we need to prescribe suitable inlet and outlet boundary conditions at two of the box faces. The other four (lateral) faces of the box will be let without any specific boundary condition and will therefore represent a rigid inviscid wall (parallel to the undisturbed flow direction), according to the conventions of the VFCC model.

Before running the complete bridge test case (which is a long calculation) we want to check the fluid boundary conditions in a simpler geometry (a thin long tube). The outlet condition will be an absorbing one, represented by specialized boundary-condition elements (CLxx) with the `CLVF ABSO` material. For the inlet condition, an imposed mass flow rate will be used. If the initial and boundary conditions are correctly chosen, we expect the flow to remain stationary in the tube, with constant pressure and constant velocity everywhere.

The calculations performed are summarized in Table 11.

Case	Mesh	Description	Final time [s]	Steps	CPU [s]	Computer
DEBI01	80 CUVF 8 CL3D	With `CLVF DEBI`, options from [16]	5.0	4762	2.3	M6700
DEBI02	80 CUVF 8 CL3D	With `CLVF ESUB`, options from [16]	5.0	4819	2.5	M6700
DEBI03	80 CUVF 8 CL3D	With `CLVF ESUB`, simplified options	5.0	4742	1.4	M6700
DEBI04	80 CUVF 8 CL3D	Idem DEBI02 but `CSTA 0.25`	5.0	9484	4.6	M6700
DEBI05	80 CUVF 8 CL3D	Idem DEBI02 but `PIMP` instead of `ABSO`	5.0	4743	2.9	M6700
DEBI06	80 CUVF 8 CL3D	Idem DEBI05 but `FCON 6` instead of `4`	5.0	4742	2.6	M6700

Table 11: Calculations to check inlet and outlet boundary conditions.

8.2.1 Preliminary case DEBI01

The Cast3m mesh of this test includes only a (dummy) material point, just to give EPX something to read:

```
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'debi01.msh';
opti trac psc ftra 'debi01_mesh.ps';
p0 = 0 0 0;
pm = manu poi1 p0;
mesh = pm;
tass mesh noop;
sauv form mesh;
trac qual mesh;
fin;
```

The EPX input file is:

```
DEBI01
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME NALE 1 NBLE 1 TERM
GEOM PMAT pm TERM
COMP EPAI 1.0 LECT pm TERM
     STFL VFCC X0 -10 Y0 -1 Z0 -1 ! Automatically generate structured
               LX   20 LY   2 LZ   2 ! fluid mesh (box)
               NX   20 NY   2 NZ   2
               CLX1 CLX2
     GROU 5 'stru' LECT pm TERM
            'flui' STFL FLUI
            'boun' STFL CLXS
            'inlt' LECT boun TERM COND XB LT 0
            'outl' LECT boun TERM COND XB GT 0
     COUL GR50 LECT stru TERM
          TURQ LECT flui TERM
          ROUG LECT inlt TERM
          VERT LECT outl TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE MASS 1.0
          LECT stru TERM
     GAZP RO 1 GAMM 1.4 PINI 1.E5 PREF 1.E5
          LECT flui TERM
     CLVF DEBI RO 1 PRES 1.E5 GAMA 1.4 PREF 1.E5
          DEBX 100. DEBY 0. DEBZ 0.
          LECT inlt TERM
     CLVF ABSO RO 1
          LECT outl TERM
INIT VITC VITX 100 VITY 0 VITZ 0 LECT flui TERM
ECRI DEPL VITE TFRE 5.E-1
     NOEL POIN LECT stru TERM
     FICH ALIC TFRE 0.5
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 4
          ORDR 2
          OTPS 2
          RECO 1
          LMAS 3
          LQDM 3
          LENE 3
          KMAS 0.75
          KQDM 0.75
          KENE 0.75
          CENE
CALC TINI 0. TEND 5.E0
FIN
```

The fluid box, measuring $20 \times 2 \times 2$ m, is generated in EPX by the `STFL` command. The fluid elements have a size of 1 m. The CLxx elements are also generated automatically on the two faces of the box perpendicular to the x-axis (`CLX1`, `CLX2`). The `GROU` directive is used to name the fluid (`flui`), the CLxx boundary condition elements (`boun`) and to subdivide these into the inlet part (`inlt`) and the outlet part (`outl`).

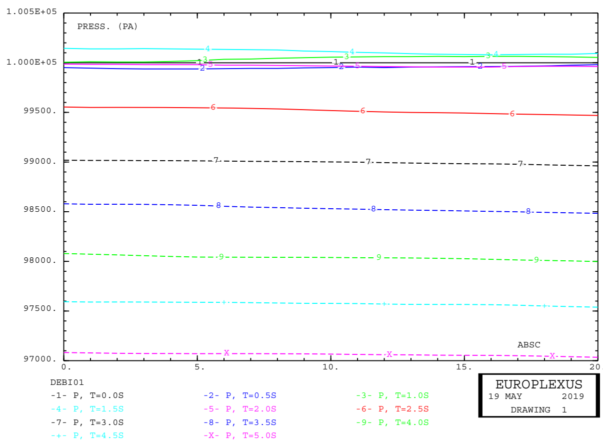
The inlet and outlet boundary conditions are set by assigning appropriate impedance materials to the CLxx elements. To this end, inspiration is taken from a model presented in reference [16]. The problem is known as the Woodward-Colella test or *la marche montante*.

For the outlet, the absorbing model `CLVF ABSO` requires only the far-field fluid density `RO`, here assumed to be $\rho = 1.0$ kg/m^3 like in the interior of the (undisturbed) fluid domain.

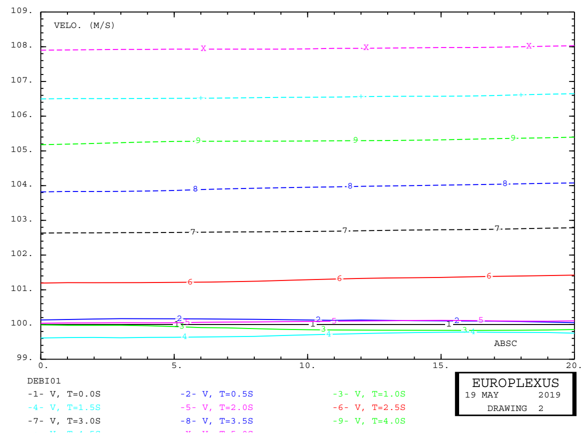
For the inlet, we tentatively use the `CLVF DEBI` model as in [16], which requires the density `RO` ($\rho = 1.0$ kg/m^3), the pressure `PRES` ($p = 1.0 \times 10^5$ Pa), the ratio of specific heats `GAMA` ($\gamma = 1.4$) and the reference pressure `PREF` ($p_{\text{ref}} = 1.0 \times 10^5$ Pa), which are set like in the interior of the fluid domain. In addition, one should give the components of the mass flow rate `DEBX`, `DEBY` and `DEBZ`. In our case we set $D_x = D_z = 0$ and $D_y = \rho v_y = 1.0 \times 100.0 = 100.0$ kg/(m^2·s). The `INIT VITC` directive is used to set the initial velocity $v_{y0} = 100.0$ m/s over the entire fluid domain.

Numerous options are set for the VFCC model, as shown in the input file listing above. These are taken from the Woodward-Colella problem in [16].

Figure 78 shows the distributions of pressure and of velocity along the tube at various selected time instants (at regular intervals of 0.5 s between $t = 0$ and $t = 5$ s). One can see that the flow remains almost stationary, but the values slowly deviate from the initial ones by about 3% and 8%, respectively, in 5 s, which seem unacceptable.



(a) Pressure distribution



(b) Velocity distribution

Figure 78: Results of test DEBI01.

8.2.2 Preliminary case DEBI02

The `CLVF DEBI` model is said to be valid for supersonic inlet flow (like in the Woodward-Colella test, where the Mach number at the inlet is $M = 3$). However, in the DEBI01 test the inlet flow is subsonic (100 m/s in air at atmospheric conditions). Therefore, we try replacing the inlet condition by `CLVF ESUB`, by leaving all the parameters unchanged. This model should be valid for subsonic inlet flow.

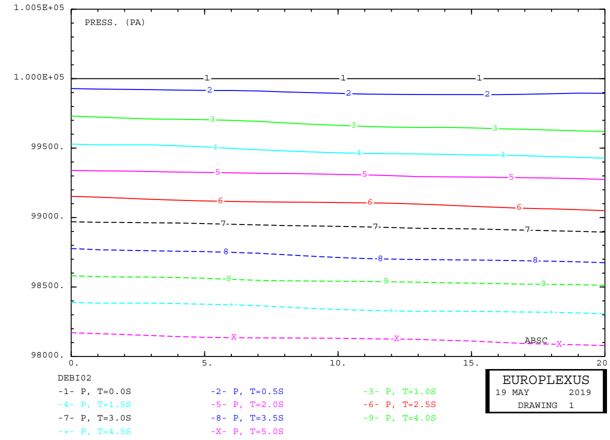
The results, shown in Figure 79, present similar problems to those encountered with the `CLVF DEBI` in case DEBI01.

8.2.3 Preliminary case DEBI03

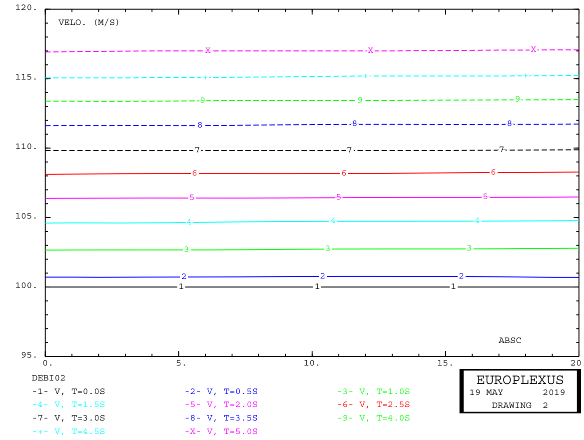
By inspecting the non-regression benchmark tests, we find a case BM_VFCC_CLVF_ESUB that uses the `CLVF ESUB` model. The VFCC options are different from (simpler than) those used in the Woodward-Colella test. By trying with these options:

```
 . . .
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 6
          ORDR 2
          OTPS 2
          RECO 0
 . . .
```

we finally obtain the correct solution, i.e. perfectly stationary flow, as shown in Figure 80.

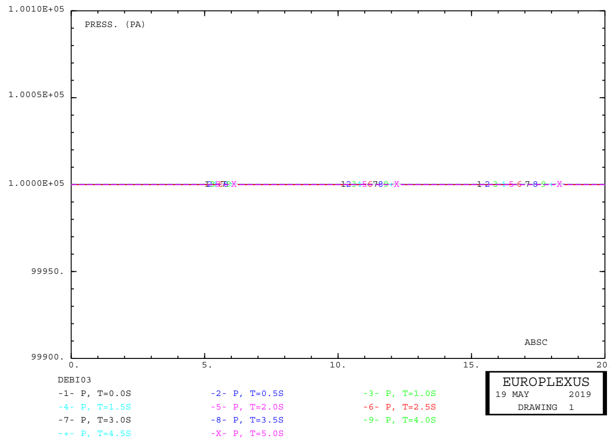


(a) Pressure distribution

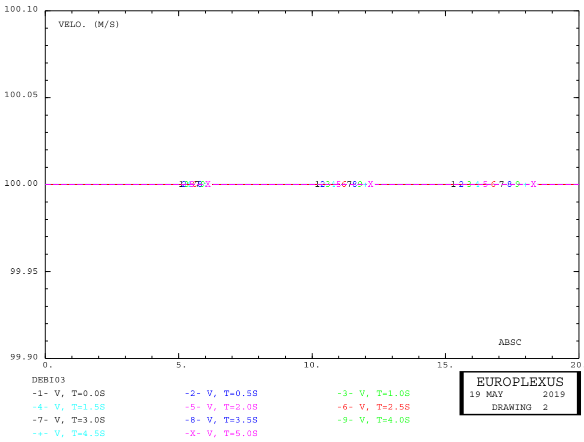


(b) Velocity distribution

Figure 79: Results of test DEBI02.



(a) Pressure distribution



(b) Velocity distribution

Figure 80: Results of test DEBI03.

8.2.4 Preliminary case DEBI04

Upon consultation, CEA colleagues A. Beccantini and P. Galon suggest using a smaller stability safety coefficient to regularize the solution with full second-order (`RECO 1`). Therefore, we repeat the test DEBI02 by setting `CSTA 0.25` instead of `CSTA 0.5`.

The correct solution, i.e. perfectly stationary flow, is obtained as shown in Figure 81.

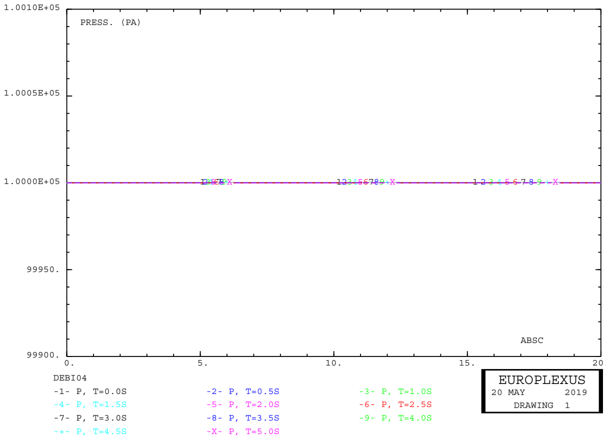
8.2.5 Preliminary case DEBI05

Another point raised by CEA colleagues is that at the flow outlet the absorbing condition is perhaps not fully adequate and could be rather replaced by a subsonic outlet condition. Thus we repeat case DEBI02 one more time by replacing:

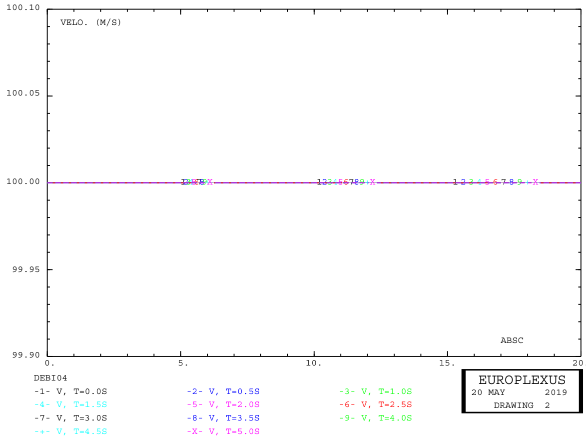
```
MATE ...
    CLVF ABSO RO 1
        LECT outl TERM
```

by:

```
MATE ...
    CLVF PIMP RO 1. PRES 1.E5 GAMA 1.4 PREF 1.E5 IMPO 6
        LECT outl TERM
```



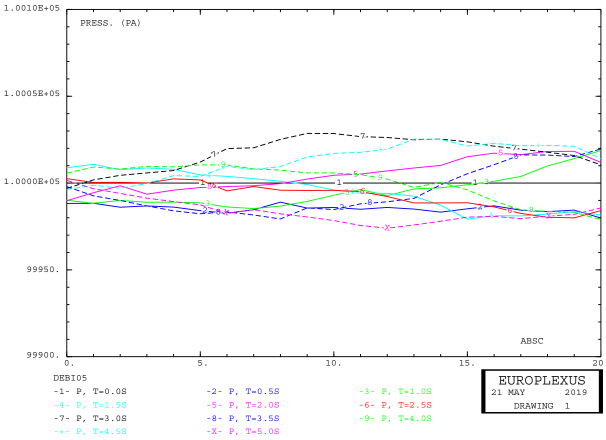
(a) Pressure distribution



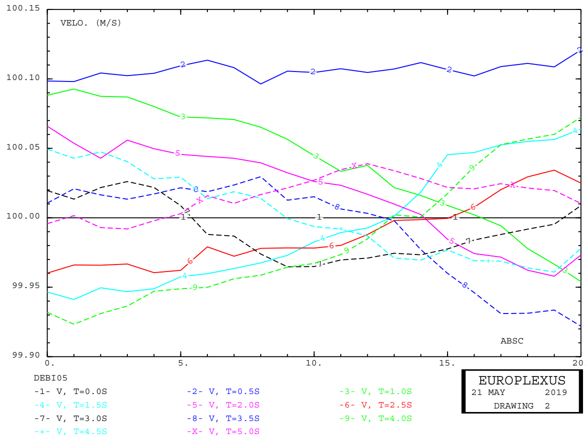
(b) Velocity distribution

Figure 81: Results of test DEBI04.

According to the Users' manual [1], the `IMPO 6` parameter enforces that the "ghost" state has the same density and velocity as the internal state. The solution, shown in Figure 82, exhibits some very small oscillations.



(a) Pressure distribution



(b) Velocity distribution

Figure 82: Results of test DEBI05.

8.2.6 Preliminary case DEBI06

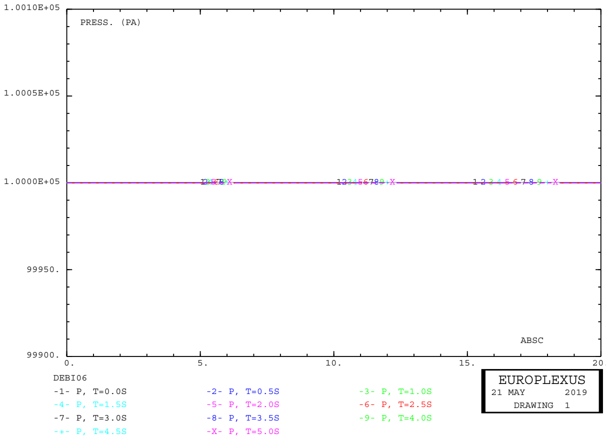
As a final test suggested by CEA colleagues, we repeat the previous calculation DEBI05 by replacing the exact Riemann (for perfect gas) flux solver (`FCON 4`) by the HLLC flux solver (which is the default, by the way).

The solution, shown in Figure 83, exhibits no oscillations.

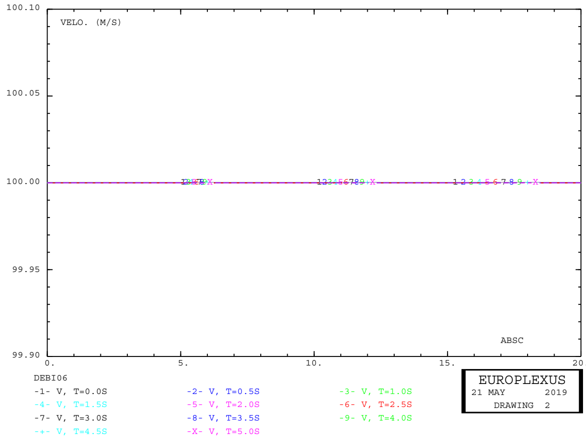
This terminates the preliminary tests. Next, we return to the suspended bridge problem by adding a discretized fluid domain. Simulations are summarized in Table 12.

Case	Mesh	Description	Final time [s]	Steps	CPU [s]	Computer
BRID06	195840 CUVF 2410 Q4GS 1596 POUT	Fluid via `STFL`	5.0	56 218	58 480	EVICOM

Table 12: Suspended bridge simulations with discretized fluid.



(a) Pressure distribution



(b) Velocity distribution

Figure 83: Results of test DEBI06.

8.2.7 Case BRID06

This test uses the same structural mesh as the previous bridge tests, but a discretized fluid domain is added by the STFL directive. The EPX input file is:

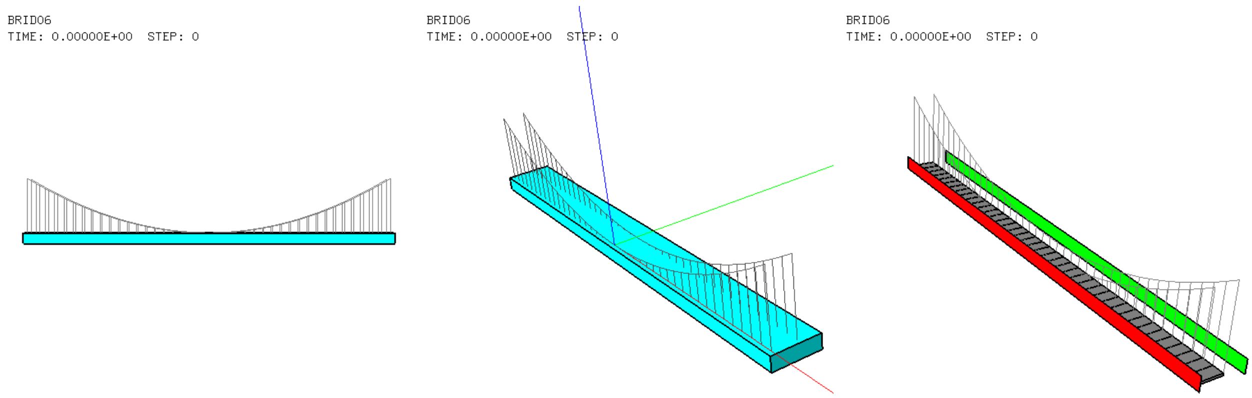
```
BRID06
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME ! ADAP NPOI 50000 CUVF 40000 NVFI 130000 ENDA
     NALE 1 NBLE 1 TERM
GEOM Q4GS base trav POUT paras cabls TERM
COMP EPAI 0.02 LECT base trav TERM
     GEOP RECT VX 0 VY 1 VZ 0 AY 0.20 AZ 0.20 LECT paras TERM
     GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04 LECT cabls TERM
     ORIE INVE LECT bas34 TERM
     STFL VFCC X0 -102 Y0 -2  Z0 -6  ! Automatically generate structured
               LX  204 LY  20 LZ  6  ! fluid mesh (box)
               NX  408 NY  40 NZ  12
               CLY1 CLY2
     GROU 5 'stru' LECT base trav paras cabls TERM
            'flui' STFL FLUI
            'boun' STFL CLXS
            'inlt' LECT boun TERM COND YB LT 0
            'outl' LECT boun TERM COND YB GT 0
     NGRO 7 'nb1' LECT base TERM COND X LT -99.9
            'nb2' LECT base TERM COND X GT  99.9
            'nb3' LECT cabls TERM COND X LT -99.9 COND Z GT 29.9
            'nb4' LECT cabls TERM COND X GT  99.9 COND Z GT 29.9
            'nblo' LECT nb1 nb2 nb3 nb4 TERM
            'ncen1' LECT base TERM COND NEAR POIN 0 0 -4
            'ncen2' LECT base TERM COND NEAR POIN 0 10 -4
     COUL GR50 LECT stru TERM
          TURQ LECT flui TERM
          ROUG LECT inlt TERM
          VERT LECT outl TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE LINE RO 7800. YOUN 2.D11 NU 0.3
          LECT stru TERM
     GAZP RO 1 GAMM 1.4 PINI 1.E5 PREF 1.E5
          LECT flui _cuvf TERM
     CLVF ESUB RO 1 PRES 1.E5 GAMA 1.4 PREF 1.E5
          DEBX 0. DEBY 100. DEBZ 0.
          LECT inlt TERM
     CLVF ABSO RO 1
          LECT outl TERM
LINK DECO
     BLOQ 123 LECT nblo TERM
     DRAG ROF 1.0 VFX 0 VFY 100 VFZ 0
          STRU LECT paras cabls TERM
          CD 1.0 LECT paras cabls TERM
     FLSW STRU LECT base trav TERM
          STFL
          R    0.440 ! Radius of influence fluid-structure
                     ! >= 0.87 * dens fluid (h_f = 0.5 m here)
          HGRI 1.100 ! Grid: slightly bigger than the biggest
                     ! structural element (h_s = 1 m here)
          DGRI
          FACE
          BFLU 2 FSCP 1
        ! ADAP LMAX 2
INIT VITC VITX 0 VITY 100 VITZ 0 LECT flui TERM
ECRI DEPL VITE TFRE 5.E-1
     NOEL POIN LECT ncen1 ncen2 TERM
     FICH SPLI ALIC TFRE 5.E-2
     FICH ALIC TEMP TFRE 5.E-3
          POIN LECT ncen1 ncen2 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 6
        !FCON 4
          ORDR 2
          OTPS 2
          RECO 0
        !RECO 1
        !LMAS 3
        !LQDM 3
        !LENE 3
        !KMAS 0.75
        !KQDM 0.75
        !KENE 0.75
        !CENE
CALC TINI 0. TEND 5.E0
FIN
```

The fluid box tightly encompasses only the deck of the bridge, as shown in Figure 84 where also the inlet and outlet faces are highlighted. As concerns the FSI conditions, the DRAG model is used to load the cables, like in the previous bridge simulations, while the (standard) FLSW model is used to couple the discretized fluid with the bridge deck. No interaction occurs between the discretized fluid domain and the beams, although they are partly superposed in the model.

This test was run on the EVICOM computer and took 56 218 steps and 58 480 s of CPU to reach the final time of 5 s.

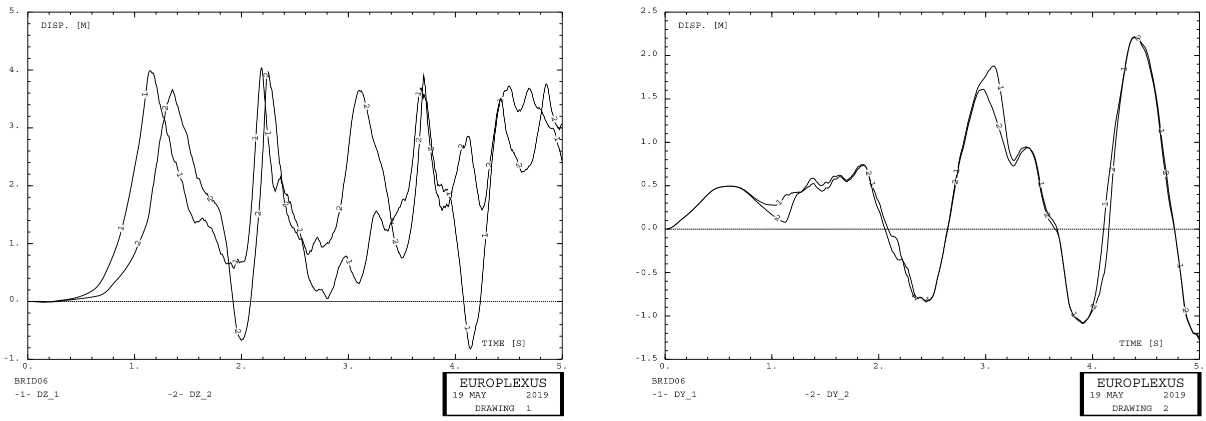
Figure 85 shows the displacements of the bridge's central points on either side of the road.

Figure 86 shows the deformed shape and velocity field of the bridge deck at some selected time instants, while Figure 87 shows the same results but for the whole structure, including both the deck



(a) Fluid domain (cyan) (b) Same viewed from another point (c) Inlet (red), outlet (green)

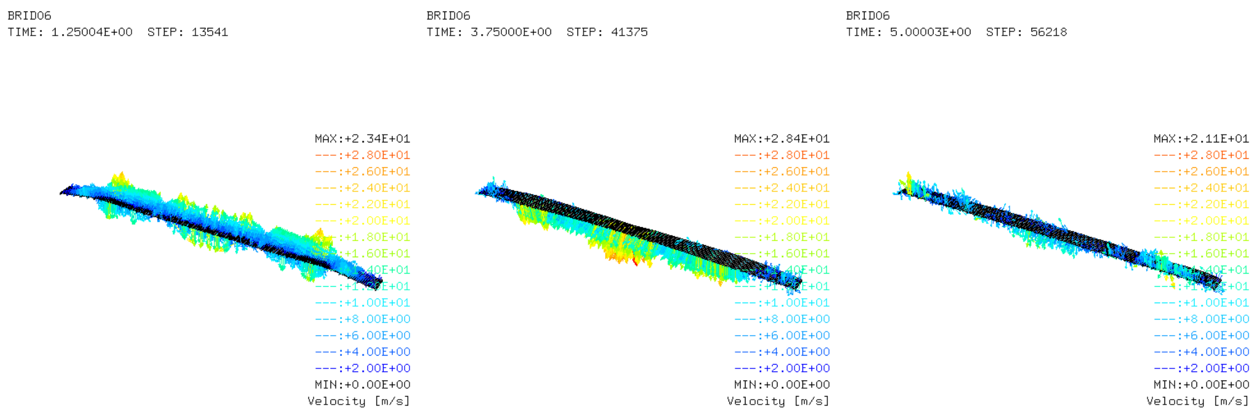
Figure 84: Some details of model BRID06.



(a) Vertical displacement (b) Horizontal diaplacement

Figure 85: Displacements in test BRID06.

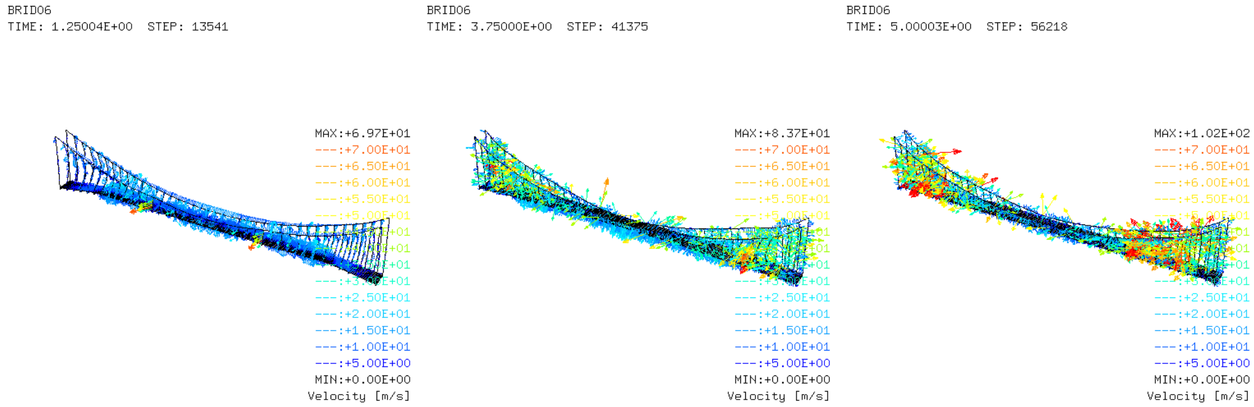
and the beams. Note that the velocity color scale in this second Figure is much higher (5 times) that of the first Figure in order to accommodate the velocities in the cables, which are much higher than in the deck.



(a) $t = 1.25$ s (b) $t = 3.75$ s (c) $t = 5.00$ s

Figure 86: Bridge deck deformation and velocity fields in test BRID06.

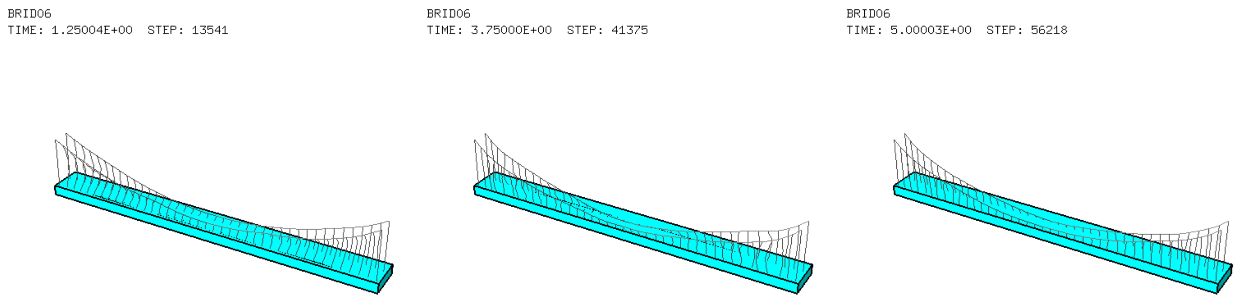
Finally, Figure 88 shows the deformed shape of the bridge in comparison with the (fixed) fluid domain at some selected time instants. From this it emerges that at some particular times the bridge



(a) $t = 1.25$ s (b) $t = 3.75$ s (c) $t = 5.00$ s

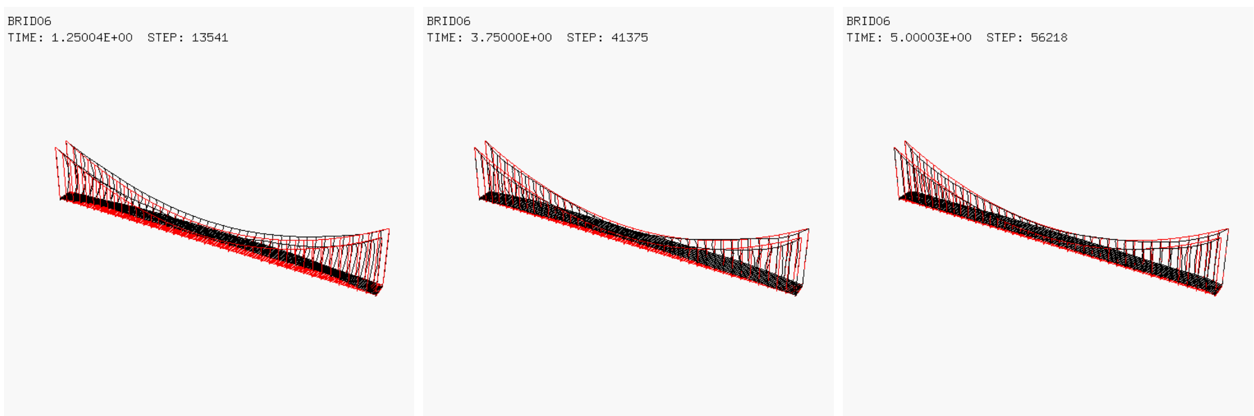
Figure 87: Bridge deck and cables deformation and velocity fields in test BRID06.

deck gets slightly out of the discretized fluid domain, due to the strong oscillations. The oscillations can be observed in Figure 89, where the initial configuration of the bridge is represented by red lines for comparison with the deformed configuration (in black). Therefore, it would be necessary to re-run the case with a larger discretized fluid region. However, this is out of scope here since the only purpose of this example is that of showing the capabilities of the new models in EPX.



(a) $t = 1.25$ s (b) $t = 3.75$ s (c) $t = 5.00$ s

Figure 88: Bridge deck and cables deformation and fluid domain in test BRID06.



(a) $t = 1.25$ s (b) $t = 3.75$ s (c) $t = 5.00$ s

Figure 89: Bridge deck and cables deformation with respect to initial configuration in test BRID06.

References

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

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

[3] ParaView Software: https://www.paraview.org/.

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[14] T.J.R. Hughes, W.K. Liu, I. Levit. Nonlinear dynamic finite element analysis of shells. In *Nonlinear Finite Elements Analysis in Structural Mechanics*, Eds. W. Wunderlich *et al.*, Springer, Berlin, 1981.

[15] S. Mannan (Editor). Lees' Loss Prevention in the Process Industries. 4th Edition. Chapter 17 - Explosions. Table 17.74. Elsevier, 2012.

[16] P. Galon, S. Nunziati. Méthode des volumes finis dans EUROPLEXUS — Extension du schéma à l'ordre deux en espace et en temps. CEA report D2MS/SEMT/DYN/RT/08-001/B (Revision 1), 2008.

Appendix I — Input files

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

brid01.dgibi

```
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'brid01.msh';
opti trac psc ftra 'brid01_mesh.ps';
p0 = 0 0 0;
p1 = 100 0 30;
p2 = 100 0 0;
pi = 50 0 0;
tol = 0.01;
par1 = para 100 p0 pi p1;
par1c = chan poi1 (para 20 p0 pi p1);
elim tol (par1 et par1c);
vzm = 0 0 -1;
dd = 1.0;
dens dd;
n = nbno par1c;
k = 0;
repe loop1 n;
  k = k + 1;
  nk = par1c poin k;
  x y z = coor nk;
  cabk = d (x y z) (x y -4);
  travk = (d (x y -4) (x (y+10) -4)) tran 1 vzm;
  si (ega k 1);
    cab0 = cabk;
    trav0 = travk;
    pp = (x y -4);
  sinon;
    impk = pp d (x y -4);
    pp = (x y -4);
    si (ega k 2);
      cab1 = cabk;
      trav1 = travk;
      imp1 = impk;
    sinon;
      cab1 = cab1 et cabk;
      trav1 = trav1 et travk;
      imp1 = imp1 et impk;
    finsi;
  finsi;
fin loop1;
bri1 = par1 et cab1 et imp1 et trav1;
elim tol bri1;
vy = 0 10 0;
vz = 0 0 10;
par2 = par1 plus vy;
cab2 = cab1 plus vy;
imp2 = imp1 plus vy;
cab02 = cab0 plus vy;
bri2 = par2 et cab2 et imp2;
elim tol (bri2 et cab02);
bas12 = imp1 tran vy;
elim tol (bas12 et imp2);
stru1 = bri1 et bri2 et bas12;
par3 = par1 syme plan p0 (p0 plus vy) (p0 plus vz);
cab3 = cab1 syme plan p0 (p0 plus vy) (p0 plus vz);
imp3 = imp1 syme plan p0 (p0 plus vy) (p0 plus vz);
trav3 = trav1 syme plan p0 (p0 plus vy) (p0 plus vz);
par4 = par2 syme plan p0 (p0 plus vy) (p0 plus vz);
cab4 = cab2 syme plan p0 (p0 plus vy) (p0 plus vz);
imp4 = imp2 syme plan p0 (p0 plus vy) (p0 plus vz);
bri3 = par3 et cab3 et imp3;
bri4 = par4 et cab4 et imp4;
trav = trav0 et trav1 et trav3;
bas34 = bas12 syme plan p0 (p0 plus vy) (p0 plus vz);
stru2 = bri3 et bri4 et bas34;
stru12 = stru1 et stru2;
elim tol stru12;
base = bas12 et bas34;
paras = par1 et par2 et par3 et par4;
cabls = cab1 et cab2 et cab3 et cab4 et cab0 et cab02;
mesh = base et paras et cabls et trav;
elim tol mesh;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
trac cach qual (paras et cabls et trav);
trac cach mesh;
trac cach (paras et cabls et trav);
fin;
```

brid01.epx

```
BRID01
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM Q4GS base trav POUT paras cabls TERM
COMP NGRO 7 'nb1' LECT base TERM COND X LT -99.9
            'nb2' LECT base TERM COND X GT  99.9
            'nb3' LECT cabls TERM COND X LT -99.9 COND Z GT 29.9
            'nb4' LECT cabls TERM COND X GT  99.9 COND Z GT 29.9
            'nblo' LECT nb1 nb2 nb3 nb4 TERM
            'ncen1' LECT base TERM COND NEAR POIN 0 0 -4
            'ncen2' LECT base TERM COND NEAR POIN 0 10 -4
     COUL VERT LECT base TERM
          ROUG LECT paras TERM
          GR50 LECT cabls TERM
     ORIE INVE LECT bas34 TERM
     EPAI 0.02 LECT base trav TERM
     GEOP RECT VX 0 VY 1 VZ 0 AY 0.20 AZ 0.20 LECT paras TERM
     GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04 LECT cabls TERM
MATE LINE RO 7800. YOUN 2.D11 NU 0.3
          LECT base paras cabls trav TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
CHAR CONST GRAV 0 0 -9.81 LECT tous TERM
ECRI DEPL VITE TFRE 2.E-1
     NOEL POIN LECT ncen1 ncen2 TERM
     FICH SPLI ALIC TFRE 2.E-2
     FICH ALIC TEMP TFRE 2.E-3
          POIN LECT ncen1 ncen2 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 2.E0
FIN
```

brid01f.epx

```
Post-treatment (animation from alice file)
ECHO
 CONV WIN
RESU SPLI ALIC 'brid01.ali' GARD PSCR
SORT VISU NSTO 1
*=====================================================================
PLAY
CAME   1 EYE   2.19879E+02 -3.75842E+02  2.66895E+02
!        Q    -8.36516E-01 -4.82963E-01 -1.29410E-01 -2.24144E-01
         VIEW -4.33013E-01  7.50000E-01 -5.00000E-01
         RIGH  8.66025E-01  5.00000E-01 -2.77556E-17
         UP   -2.50000E-01  4.33013E-01  8.66025E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  5.00000E+00  1.30000E+01
!RSPHERE:  1.01558E+02
!RADIUS :  5.07789E+02
!ASPECT :  1.00000E+00
!NEAR   :  3.96076E+02
!FAR    :  7.10905E+02
SCEN GEOM NAVI FREE
     VECT SCCO FIEL VITE SCAL USER PROG 0.2 PAS 0.2 2.8 TERM
SLER CAM1 1 NFRA 1
FREQ 25
GO
TRAC OFFS FICH BMP REND
GO
TRAC OFFS FICH BMP REND
GO
TRAC OFFS FICH BMP REND
GO
TRAC OFFS FICH BMP REND
ENDPLAY
*=====================================================================
FIN
```

brid01p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'brid01.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT ncen1 TERM
COUR 2 'dz_2' DEPL COMP 3 NOEU LECT ncen2 TERM
COUR 3 'dy_1' DEPL COMP 2 NOEU LECT ncen1 TERM
COUR 4 'dy_2' DEPL COMP 2 NOEU LECT ncen2 TERM
TRAC 1 2 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 AXES 1.0 'DISP. [M]' YZER
TRAC 3 4 AXES 1.0 'DISP. [M]' YZER
LIST 3 4 AXES 1.0 'DISP. [M]' YZER
FIN
```

brid01q.epx

```
Post-treatment (animation from alice file)
ECHO
 CONV WIN
RESU SPLI ALIC 'brid01.ali' GARD PSCR
SORT VISU NSTO 1
*=====================================================================
PLAY
CAME   1 EYE   2.19879E+02 -3.75842E+02  2.66895E+02
```

```
!        Q    -8.36516E-01 -4.82963E-01 -1.29410E-01 -2.24144E-01
         VIEW -4.33013E-01  7.50000E-01 -5.00000E-01
         RIGH  8.66025E-01  5.00000E-01 -2.77556E-17
         UP   -2.50000E-01  4.33013E-01  8.66025E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  5.00000E+00  1.30000E+01
!RSPHERE:  1.01558E+02
!RADIUS :  5.07789E+02
!ASPECT :  1.00000E+00
!NEAR   :  3.96076E+02
!FAR    :  7.10905E+02
SCEN GEOM NAVI FREE
     VECT SCCO FIEL VITE SCAL USER PROG 0.2 PAS 0.2 2.8 TERM
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*======================================================================
FIN
```

brid01z.epx

```
Post-treatment (animation from alice file)
ECHO
 CONV WIN
RESU SPLI ALIC 'brid01.ali' GARD PSCR
SORT VISU NSTO 101
FIN
```

brid02.dgibi

```
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'brid02.msh';
opti trac psc ftra 'brid02_mesh.ps';
p0 = 0 0 0;
p1 = 100 0 30;
p2 = 100 0 0;
pi = 50 0 0;
tol = 0.01;
par1 = para 100 p0 pi p1;
par1c = chan poi1 (para 20 p0 pi p1);
elim tol (par1 et par1c);
vzm = 0 0 -1;
dd = 1.0;
dens dd;
n = nbno par1c;
k = 0;
repe loop1 n;
  k = k + 1;
  nk = par1c poin k;
  x y z = coor nk;
  cabk = d (x y z) (x y -4);
  travk = (d (x y -4) (x (y+10) -4)) tran 1 vzm;
  si (ega k 1);
    cab0 = cabk;
    trav0 = travk;
    pp = (x y -4);
  sinon;
    impk = pp d (x y -4);
    pp = (x y -4);
    si (ega k 2);
      cab1 = cabk;
      trav1 = travk;
      imp1 = impk;
    sinon;
      cab1 = cab1 et cabk;
      trav1 = trav1 et travk;
      imp1 = imp1 et impk;
    finsi;
  finsi;
fin loop1;
bri1 = par1 et cab1 et imp1 et trav1;
elim tol bri1;
vy = 0 10 0;
vz = 0 0 10;
par2 = par1 plus vy;
cab2 = cab1 plus vy;
imp2 = imp1 plus vy;
cab02 = cab0 plus vy;
bri2 = par2 et cab2 et imp2;
elim tol (bri2 et cab02);
bas12 = imp1 tran vy;
elim tol (bas12 et imp2);
stru1 = bri1 et bri2 et bas12;
par3 = par1 syme plan p0 (p0 plus vy) (p0 plus vz);
cab3 = cab1 syme plan p0 (p0 plus vy) (p0 plus vz);
imp3 = imp1 syme plan p0 (p0 plus vy) (p0 plus vz);
trav3 = trav1 syme plan p0 (p0 plus vy) (p0 plus vz);
par4 = par2 syme plan p0 (p0 plus vy) (p0 plus vz);
cab4 = cab2 syme plan p0 (p0 plus vy) (p0 plus vz);
imp4 = imp2 syme plan p0 (p0 plus vy) (p0 plus vz);
bri3 = par3 et cab3 et imp3;
bri4 = par4 et cab4 et imp4;
trav = trav0 et trav1 et trav3;
bas34 = bas12 syme plan p0 (p0 plus vy) (p0 plus vz);
stru2 = bri3 et bri4 et bas34;
stru12 = stru1 et stru2;
elim tol stru12;
base = bas12 et bas34;
paras = par1 et par2 et par3 et par4;
cabls = cab1 et cab2 et cab3 et cab4 et cab0 et cab02;
mesh = base et paras et cabls et trav;
elim tol mesh;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
trac cach qual (paras et cabls et trav);
fin;
```

brid02.epx

```
BRID02
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM Q4GS base trav POUT paras cabls TERM
COMP NGRO 7 'nb1' LECT base TERM COND X LT -99.9
            'nb2' LECT base TERM COND X GT  99.9
            'nb3' LECT cabls TERM COND X LT -99.9 COND Z GT 29.9
            'nb4' LECT cabls TERM COND X GT  99.9 COND Z GT 29.9
            'nblo' LECT nb1 nb2 nb3 nb4 TERM
            'ncen1' LECT base TERM COND NEAR POIN 0 0 -4
            'ncen2' LECT base TERM COND NEAR POIN 0 10 -4
     COUL VERT LECT base TERM
          ROUG LECT paras TERM
          GR50 LECT cabls TERM
     ORIE INVE LECT bas34 TERM
     EPAI 0.02 LECT base trav TERM
     GEOP RECT VX 0 VY 1 VZ 0 AY 0.20 AZ 0.20 LECT paras TERM
     GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04 LECT cabls TERM
MATE LINE RO 7800. YOUN 2.D11 NU 0.3
          LECT base paras cabls trav TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
CHAR CONST GRAV 0 0 -9.81 LECT tous TERM
ECRI DEPL VITE TFRE 5.E-1
     NOEL POIN LECT ncen1 ncen2 TERM
     FICH SPLI ALIC TFRE 5.E-2
     FICH ALIC TEMP TFRE 5.E-3
          POIN LECT ncen1 ncen2 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     QUAS STAT 2.0 1.0
CALC TINI 0. TEND 5.E0
FIN
```

brid02p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'brid02.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT ncen1 TERM
COUR 2 'dz_2' DEPL COMP 3 NOEU LECT ncen2 TERM
COUR 3 'dy_1' DEPL COMP 2 NOEU LECT ncen1 TERM
COUR 4 'dy_2' DEPL COMP 2 NOEU LECT ncen2 TERM
TRAC 1 2 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 AXES 1.0 'DISP. [M]' YZER
TRAC 3 4 AXES 1.0 'DISP. [M]' YZER
LIST 3 4 AXES 1.0 'DISP. [M]' YZER
FIN
```

brid03.dgibi

```
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'brid03.msh';
opti trac psc ftra 'brid03_mesh.ps';
p0 = 0 0 0;
p1 = 100 0 30;
p2 = 100 0 0;
pi = 50 0 0;
tol = 0.01;
par1 = para 100 p0 pi p1;
par1c = chan poi1 (para 20 p0 pi p1);
elim tol (par1 et par1c);
vzm = 0 0 -1;
dd = 1.0;
dens dd;
n = nbno par1c;
k = 0;
repe loop1 n;
  k = k + 1;
  nk = par1c poin k;
  x y z = coor nk;
  cabk = d (x y z) (x y -4);
  travk = (d (x y -4) (x (y+10) -4)) tran 1 vzm;
  si (ega k 1);
    cab0 = cabk;
    trav0 = travk;
    pp = (x y -4);
  sinon;
    impk = pp d (x y -4);
    pp = (x y -4);
```

```
    si (ega k 2);
      cab1 = cabk;
      trav1 = travk;
      imp1 = impk;
    sinon;
      cab1 = cab1 et cabk;
      trav1 = trav1 et travk;
      imp1 = imp1 et impk;
    finsi;
  finsi;
fin loop1;
bri1 = par1 et cab1 et imp1 et trav1;
elim tol bri1;
vy = 0 10 0;
vz = 0 0 10;
par2 = par1 plus vy;
cab2 = cab1 plus vy;
imp2 = imp1 plus vy;
cab02 = cab0 plus vy;
bri2 = par2 et cab2 et imp2;
elim tol (bri2 et cab02);
bas12 = imp1 tran vy;
elim tol (bas12 et imp2);
stru1 = bri1 et bri2 et bas12;
par3 = par1 syme plan p0 (p0 plus vy) (p0 plus vz);
cab3 = cab1 syme plan p0 (p0 plus vy) (p0 plus vz);
imp3 = imp1 syme plan p0 (p0 plus vy) (p0 plus vz);
trav3 = trav1 syme plan p0 (p0 plus vy) (p0 plus vz);
par4 = par2 syme plan p0 (p0 plus vy) (p0 plus vz);
cab4 = cab2 syme plan p0 (p0 plus vy) (p0 plus vz);
imp4 = imp2 syme plan p0 (p0 plus vy) (p0 plus vz);
bri3 = par3 et cab3 et imp3;
bri4 = par4 et cab4 et imp4;
trav = trav0 et trav1 et trav3;
bas34 = bas12 syme plan p0 (p0 plus vy) (p0 plus vz);
stru2 = bri3 et bri4 et bas34;
stru12 = stru1 et stru2;
elim tol stru12;
base = bas12 et bas34;
paras = par1 et par2 et par3 et par4;
cabls = cab1 et cab2 et cab3 et cab4 et cab0 et cab02;
mesh = base et paras et cabls et trav;
elim tol mesh;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
trac cach qual (paras et cabls et trav);
fin;
```

brid03.epx

```
BRIDO3
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM Q4GS base trav POUT paras cabls TERM
COMP NGRO 7 'nb1' LECT base TERM COND X LT -99.9
            'nb2' LECT base TERM COND X GT  99.9
            'nb3' LECT cabls TERM COND X LT -99.9 COND Z GT 29.9
            'nb4' LECT cabls TERM COND X GT  99.9 COND Z GT 29.9
            'nblo' LECT nb1 nb2 nb3 nb4 TERM
            'ncen1' LECT base TERM COND NEAR POIN 0 0 -4
            'ncen2' LECT base TERM COND NEAR POIN 0 10 -4
     COUL VERT LECT base TERM
          ROUG LECT paras TERM
          GR50 LECT cabls TERM
     ORIE INVE LECT bas34 TERM
     EPAI 0.02 LECT base trav TERM
     GEOP RECT VX 0 VY 1 VZ 0 AY 0.20 AZ 0.20 LECT paras TERM
     GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04 LECT cabls TERM
MATE LINE RO 7800. YOUN 2.D11 NU 0.3
          LECT base paras cabls trav TERM
LINK DECO
     BLOQ 123 LECT nblo TERM
     DRAG ROF 1.0 VFX 0 VFY 100 VFZ 0
     STRU LECT paras cabls TERM
     CD 1.0 LECT paras cabls TERM
CHAR CONST GRAV 0 0 -9.81 LECT tous TERM
ECRI DEPL VITE TFRE 5.E-1
     NOEL POIN LECT ncen1 ncen2 TERM
     FICH SPLI ALIC TFRE 5.E-2
     FICH ALIC TEMP TFRE 5.E-3
          POIN LECT ncen1 ncen2 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     QUAS STAT 2.0 1.0
CALC TINI 0. TEND 5.E0
FIN
```

brid03p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'brid03.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT ncen1 TERM
COUR 2 'dz_2' DEPL COMP 3 NOEU LECT ncen2 TERM
COUR 3 'dy_1' DEPL COMP 2 NOEU LECT ncen1 TERM
COUR 4 'dy_2' DEPL COMP 2 NOEU LECT ncen2 TERM
TRAC 1 2 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 AXES 1.0 'DISP. [M]' YZER
TRAC 3 4 AXES 1.0 'DISP. [M]' YZER
LIST 3 4 AXES 1.0 'DISP. [M]' YZER
FIN
```

brid04.dgibi

```
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'brid04.msh';
opti trac psc ftra 'brid04_mesh.ps';
p0 = 0 0 0;
p1 = 100 0 30;
p2 = 100 0 0;
pi = 50 0 0;
tol = 0.01;
par1 = para 100 p0 pi p1;
par1c = chan poi1 (para 20 p0 pi p1);
elim tol (par1 et par1c);
vzm = 0 0 -1;
dd = 1.0;
dens dd;
n = nbno par1c;
k = 0;
repe loop1 n;
  k = k + 1;
  nk = par1c poin k;
  x y z = coor nk;
  cabk = d (x y z) (x y -4);
  travk = (d (x y -4) (x (y+10) -4)) tran 1 vzm;
  si (ega k 1);
    cab0 = cabk;
    trav0 = travk;
    pp = (x y -4);
  sinon;
    impk = pp d (x y -4);
    pp = (x y -4);
    si (ega k 2);
      cab1 = cabk;
      trav1 = travk;
      imp1 = impk;
    sinon;
      cab1 = cab1 et cabk;
      trav1 = trav1 et travk;
      imp1 = imp1 et impk;
    finsi;
  finsi;
fin loop1;
bri1 = par1 et cab1 et imp1 et trav1;
elim tol bri1;
vy = 0 10 0;
vz = 0 0 10;
par2 = par1 plus vy;
cab2 = cab1 plus vy;
imp2 = imp1 plus vy;
cab02 = cab0 plus vy;
bri2 = par2 et cab2 et imp2;
elim tol (bri2 et cab02);
bas12 = imp1 tran vy;
elim tol (bas12 et imp2);
stru1 = bri1 et bri2 et bas12;
par3 = par1 syme plan p0 (p0 plus vy) (p0 plus vz);
cab3 = cab1 syme plan p0 (p0 plus vy) (p0 plus vz);
imp3 = imp1 syme plan p0 (p0 plus vy) (p0 plus vz);
trav3 = trav1 syme plan p0 (p0 plus vy) (p0 plus vz);
par4 = par2 syme plan p0 (p0 plus vy) (p0 plus vz);
cab4 = cab2 syme plan p0 (p0 plus vy) (p0 plus vz);
imp4 = imp2 syme plan p0 (p0 plus vy) (p0 plus vz);
bri3 = par3 et cab3 et imp3;
bri4 = par4 et cab4 et imp4;
trav = trav0 et trav1 et trav3;
bas34 = bas12 syme plan p0 (p0 plus vy) (p0 plus vz);
stru2 = bri3 et bri4 et bas34;
stru12 = stru1 et stru2;
elim tol stru12;
base = bas12 et bas34;
paras = par1 et par2 et par3 et par4;
cabls = cab1 et cab2 et cab3 et cab4 et cab0 et cab02;
mesh = base et paras et cabls et trav;
elim tol mesh;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
trac cach qual (paras et cabls et trav);
fin;
```

brid04.epx

```
BRIDO4
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM Q4GS base trav POUT paras cabls TERM
COMP NGRO 7 'nb1' LECT base TERM COND X LT -99.9
            'nb2' LECT base TERM COND X GT  99.9
            'nb3' LECT cabls TERM COND X LT -99.9 COND Z GT 29.9
            'nb4' LECT cabls TERM COND X GT  99.9 COND Z GT 29.9
            'nblo' LECT nb1 nb2 nb3 nb4 TERM
            'ncen1' LECT base TERM COND NEAR POIN 0 0 -4
```

```
           'ncen2' LECT base TERM COND NEAR POIN 0 10 -4
     COUL VERT LECT base TERM
          ROUG LECT paras TERM
          GR50 LECT cabls TERM
     ORIE INVE LECT bas34 TERM
     EPAI 0.02 LECT base trav TERM
     GEOP RECT VX 0 VY 1 VZ 0 AY 0.20 AZ 0.20 LECT paras TERM
     GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04 LECT cabls TERM
MATE LINE RO 7800. YOUN 2.D11 NU 0.3
          LECT base paras cabls trav TERM
LINK DECO
     BLOQ 123 LECT nblo TERM
     DRAG ROF 1.0 VFX 0 VFY 100 VFZ 0
     STRU LECT paras cabls TERM
     CD 1.0 LECT paras cabls TERM
CHAR CONST GRAV 0 0 -9.81 LECT tous TERM
ECRI DEPL VITE TFRE 5.E-1
     NOEL POIN LECT ncen1 ncen2 TERM
     FICH SPLI ALIC TFRE 5.E-2
     FICH ALIC TEMP TFRE 5.E-3
          POIN LECT ncen1 ncen2 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 5.E0
FIN
```

brid04p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'brid04.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT ncen1 TERM
COUR 2 'dz_2' DEPL COMP 3 NOEU LECT ncen2 TERM
COUR 3 'dy_1' DEPL COMP 2 NOEU LECT ncen1 TERM
COUR 4 'dy_2' DEPL COMP 2 NOEU LECT ncen2 TERM
TRAC 1 2 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 AXES 1.0 'DISP. [M]' YZER
TRAC 3 4 AXES 1.0 'DISP. [M]' YZER
LIST 3 4 AXES 1.0 'DISP. [M]' YZER
FIN
```

brid05.dgibi

```
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'brid05.msh';
opti trac psc ftra 'brid05_mesh.ps';
p0 = 0 0 0;
p1 = 100 0 30;
p2 = 100 0 0;
pi = 50 0 0;
tol = 0.01;
par1 = para 100 p0 pi p1;
par1c = chan poi1 (para 20 p0 pi p1);
elim tol (par1 et par1c);
vzm = 0 0 -1;
dd = 1.0;
dens dd;
n = nbno par1c;
k = 0;
repe loop1 n;
  k = k + 1;
  nk = par1c poin k;
  x y z = coor nk;
  cabk = d (x y z) (x y -4);
  travk = (d (x y -4) (x (y+10) -4)) tran 1 vzm;
  si (ega k 1);
    cab0 = cabk;
    trav0 = travk;
    pp = (x y -4);
  sinon;
    impk = pp d (x y -4);
    pp = (x y -4);
    si (ega k 2);
      cab1 = cabk;
      trav1 = travk;
      imp1 = impk;
    sinon;
      cab1 = cab1 et cabk;
      trav1 = trav1 et travk;
      imp1 = imp1 et impk;
    finsi;
  finsi;
fin loop1;
bri1 = par1 et cab1 et imp1 et trav1;
elim tol bri1;
vy = 0 10 0;
vz = 0 0 10;
par2 = par1 plus vy;
cab2 = cab1 plus vy;
imp2 = imp1 plus vy;
cab02 = cab0 plus vy;
bri2 = par2 et cab2 et imp2;
elim tol (bri2 et cab02);
bas12 = imp1 tran vy;
elim tol (bas12 et imp2);
stru1 = bri1 et bri2 et bas12;
par3 = par1 syme plan p0 (p0 plus vy) (p0 plus vz);
cab3 = cab1 syme plan p0 (p0 plus vy) (p0 plus vz);
imp3 = imp1 syme plan p0 (p0 plus vy) (p0 plus vz);
trav3 = trav1 syme plan p0 (p0 plus vy) (p0 plus vz);
par4 = par2 syme plan p0 (p0 plus vy) (p0 plus vz);
cab4 = cab2 syme plan p0 (p0 plus vy) (p0 plus vz);
imp4 = imp2 syme plan p0 (p0 plus vy) (p0 plus vz);
bri3 = par3 et cab3 et imp3;
bri4 = par4 et cab4 et imp4;
trav = trav0 et trav1 et trav3;
bas34 = bas12 syme plan p0 (p0 plus vy) (p0 plus vz);
stru2 = bri3 et bri4 et bas34;
stru12 = stru1 et stru2;
elim tol stru12;
base = bas12 et bas34;
paras = par1 et par2 et par3 et par4;
cabls = cab1 et cab2 et cab3 et cab4 et cab0 et cab02;
mesh = base et paras et cabls et trav;
elim tol mesh;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
trac cach qual (paras et cabls et trav);
fin;
```

brid05.epx

```
BRID05
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM Q4GS base trav POUT paras cabls TERM
COMP NGRO 7 'nb1' LECT base TERM COND X LT -99.9
            'nb2' LECT base TERM COND X GT  99.9
            'nb3' LECT cabls TERM COND X LT -99.9 COND Z GT 29.9
            'nb4' LECT cabls TERM COND X GT  99.9 COND Z GT 29.9
            'nblo' LECT nb1 nb2 nb3 nb4 TERM
            'ncen1' LECT base TERM COND NEAR POIN 0 0 -4
            'ncen2' LECT base TERM COND NEAR POIN 0 10 -4
     COUL VERT LECT base TERM
          ROUG LECT paras TERM
          GR50 LECT cabls TERM
     ORIE INVE LECT bas34 TERM
     EPAI 0.02 LECT base trav TERM
     GEOP RECT VX 0 VY 1 VZ 0 AY 0.20 AZ 0.20 LECT paras TERM
     GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04 LECT cabls TERM
MATE LINE RO 7800. YOUN 2.D11 NU 0.3
          LECT base paras cabls trav TERM
LINK DECO
     BLOQ 123 LECT nblo TERM
     DRAG ROF 1.0 VFX 0 VFY 100 VFZ 0
     STRU LECT paras cabls TERM
     CD 1.0 LECT paras cabls TERM
ECRI DEPL VITE TFRE 5.E-1
     NOEL POIN LECT ncen1 ncen2 TERM
     FICH SPLI ALIC TFRE 5.E-2
     FICH ALIC TEMP TFRE 5.E-3
          POIN LECT ncen1 ncen2 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 5.E0
FIN
```

brid05p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'brid05.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT ncen1 TERM
COUR 2 'dz_2' DEPL COMP 3 NOEU LECT ncen2 TERM
COUR 3 'dy_1' DEPL COMP 2 NOEU LECT ncen1 TERM
COUR 4 'dy_2' DEPL COMP 2 NOEU LECT ncen2 TERM
TRAC 1 2 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 AXES 1.0 'DISP. [M]' YZER
TRAC 3 4 AXES 1.0 'DISP. [M]' YZER
LIST 3 4 AXES 1.0 'DISP. [M]' YZER
FIN
```

brid05r.epx

```
Post-treatment (animation from alice file)
ECHO
 CONV WIN
RESU SPLI ALIC 'brid05.ali' GARD PSCR
SORT VISU NSTO 1
*=================================================================
PLAY
CAME   1 EYE   2.19879E+02 -3.75842E+02  2.66895E+02
!        Q    -8.36516E-01 -4.82963E-01 -1.29410E-01 -2.24144E-01
         VIEW -4.33013E-01  7.50000E-01 -5.00000E-01
         RIGH  8.66025E-01  5.00000E-01 -2.77556E-17
         UP   -2.50000E-01  4.33013E-01  8.66025E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  5.00000E+00  1.30000E+01
!RSPHERE:  1.01558E+02
!RADIUS :  5.07789E+02
!ASPECT :  1.00000E+00
!NEAR   :  3.96076E+02
```

```
!FAR    :  7.10905E+02
SCEN GEOM NAVI FREE
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=======================================================================
FIN
```

brid06.dgibi

```
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'brid06.msh';
opti trac psc ftra 'brid06_mesh.ps';
p0 = 0 0 0;
p1 = 100 0 30;
p2 = 100 0 0;
pi = 50 0 0;
tol = 0.01;
par1 = para 100 p0 pi p1;
par1c = chan poi1 (para 20 p0 pi p1);
elim tol (par1 et par1c);
vzm = 0 0 -1;
dd = 1.0;
dens dd;
n = nbno par1c;
k = 0;
repe loop1 n;
  k = k + 1;
  nk = par1c poin k;
  x y z = coor nk;
  cabk = d (x y z) (x y -4);
  travk = (d (x y -4) (x (y+10) -4)) tran 1 vzm;
  si (ega k 1);
    cab0 = cabk;
    trav0 = travk;
    pp = (x y -4);
  sinon;
    impk = pp d (x y -4);
    pp = (x y -4);
    si (ega k 2);
      cab1 = cabk;
      trav1 = travk;
      imp1 = impk;
    sinon;
      cab1 = cab1 et cabk;
      trav1 = trav1 et travk;
      imp1 = imp1 et impk;
    finsi;
  finsi;
fin loop1;
bri1 = par1 et cab1 et imp1 et trav1;
elim tol bri1;
vy = 0 10 0;
vz = 0 0 10;
par2 = par1 plus vy;
cab2 = cab1 plus vy;
imp2 = imp1 plus vy;
cab02 = cab0 plus vy;
bri2 = par2 et cab2 et imp2;
elim tol (bri2 et cab02);
bas12 = imp1 tran vy;
elim tol (bas12 et imp2);
stru1 = bri1 et bri2 et bas12;
par3 = par1 syme plan p0 (p0 plus vy) (p0 plus vz);
cab3 = cab1 syme plan p0 (p0 plus vy) (p0 plus vz);
imp3 = imp1 syme plan p0 (p0 plus vy) (p0 plus vz);
trav3 = trav1 syme plan p0 (p0 plus vy) (p0 plus vz);
par4 = par2 syme plan p0 (p0 plus vy) (p0 plus vz);
cab4 = cab2 syme plan p0 (p0 plus vy) (p0 plus vz);
imp4 = imp2 syme plan p0 (p0 plus vy) (p0 plus vz);
bri3 = par3 et cab3 et imp3;
bri4 = par4 et cab4 et imp4;
trav = trav0 et trav1 et trav3;
bas34 = bas12 syme plan p0 (p0 plus vy) (p0 plus vz);
stru2 = bri3 et bri4 et bas34;
stru12 = stru1 et stru2;
elim tol stru12;
base = bas12 et bas34;
paras = par1 et par2 et par3 et par4;
cabls = cab1 et cab2 et cab3 et cab4 et cab0 et cab02;
mesh = base et paras et cabls et trav;
elim tol mesh;
tass mesh noop;
sauv form mesh;
trac cach qual mesh;
trac cach qual (paras et cabls et trav);
fin;
```

brid06.epx

```
BRID06
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME ! ADAP NPOI 50000 CUVF 40000 NVFI 130000 ENDA
     NALE 1 NBLE 1 TERM
GEOM Q4GS base trav POUT paras cabls TERM
COMP EPAI 0.02 LECT base trav TERM
     GEOP RECT VX 0 VY 1 VZ 0 AY 0.20 AZ 0.20 LECT paras TERM
     GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04 LECT cabls TERM
     ORIE INVE LECT bas34 TERM
     STFL VFCC X0 -102 Y0 -2  Z0 -6  ! Automatically generate structured
              LX  204 LY  20 LZ  6  ! fluid mesh (box)
              NX  408 NY  40 NZ  12
              CLY1 CLY2
     GROU 5 'stru' LECT base trav paras cabls TERM
            'flui' STFL FLUI
            'boun' STFL CLXS
            'inlt' LECT boun TERM COND YB LT 0
            'outl' LECT boun TERM COND YB GT 0
     NGRO 7 'nb1' LECT base TERM COND X LT -99.9
            'nb2' LECT base TERM COND X GT  99.9
            'nb3' LECT cabls TERM COND X LT -99.9 COND Z GT 29.9
            'nb4' LECT cabls TERM COND X GT  99.9 COND Z GT 29.9
            'nblo' LECT nb1 nb2 nb3 nb4 TERM
            'ncen1' LECT base TERM COND NEAR POIN 0 0 -4
            'ncen2' LECT base TERM COND NEAR POIN 0 10 -4
     COUL GR50 LECT stru TERM
          TURQ LECT flui TERM
          ROUG LECT inlt TERM
          VERT LECT outl TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE LINE RO 7800. YOUN 2.D11 NU 0.3
          LECT stru TERM
     GAZP RO 1 GAMM 1.4 PINI 1.E5 PREF 1.E5
          LECT flui _cuvf TERM
     CLVF ESUB RO 1 PRES 1.E5 GAMA 1.4 PREF 1.E5
          DEBX 0. DEBY 100. DEBZ 0.
          LECT inlt TERM
     CLVF ABSO RO 1
          LECT outl TERM
LINK DECO
     BLOQ 123 LECT nblo TERM
     DRAG ROF 1.0 VFX 0 VFY 100 VFZ 0
          STRU LECT paras cabls TERM
          CD 1.0 LECT paras cabls TERM
     FLSW STRU LECT base trav TERM
          STFL
          R    0.440 ! Radius of influence fluid-structure
                     ! >= 0.87 * dens fluid (h_f = 0.5 m here)
          HGRI 1.100 ! Grid: slightly bigger than the biggest
                     ! structural element (h_s = 1 m here)
          DGRI
          FACE
          BFLU 2 FSCP 1
        ! ADAP LMAX 2
INIT VITC VITX 0 VITY 100 VITZ 0 LECT flui TERM
ECRI DEPL VITE TFRE 5.E-1
     NOEL POIN LECT ncen1 ncen2 TERM
     FICH SPLI ALIC TFRE 5.E-2
     FICH ALIC TEMP TFRE 5.E-3
          POIN LECT ncen1 ncen2 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 6
         !FCON 4
          ORDR 2
          OTPS 2
          RECO 0
         !RECO 1
         !LMAS 3
         !LQDM 3
         !LENE 3
         !KMAS 0.75
         !KQDM 0.75
         !KENE 0.75
         !CENE
CALC TINI 0. TEND 5.E0
FIN
```

brid06f.epx

```
Post-treatment (animation from alice file)
ECHO
 CONV WIN
RESU SPLI ALIC 'brid06.ali' GARD PSCR
SORT VISU NSTO 1
*=======================================================================
PLAY
CAME   1 EYE   2.19879E+02 -3.75842E+02  2.66895E+02
!        Q    -8.36516E-01 -4.82963E-01 -1.29410E-01 -2.24144E-01
         VIEW -4.33013E-01  7.50000E-01 -5.00000E-01
         RIGH  8.66025E-01  5.00000E-01 -2.77556E-17
         UP   -2.50000E-01  4.33013E-01  8.66025E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  5.00000E+00  1.30000E+01
!RSPHERE:  1.01558E+02
!RADIUS :  5.07789E+02
!ASPECT :  1.00000E+00
!NEAR   :  3.96076E+02
!FAR    :  7.10905E+02
SCEN GEOM NAVI FREE
     VECT SCCO FIEL VITE SCAL USER PROG 2 PAS 2 28 TERM
          SUPP LECT base trav TERM
```

```
SLER CAM1 1 NFRA 1
FREQ 25
GO
TRAC OFFS FICH BMP
     OBJE LECT base trav TERM REND
GO
TRAC OFFS FICH BMP
     OBJE LECT base trav TERM REND
GO
TRAC OFFS FICH BMP
     OBJE LECT base trav TERM REND
GO
TRAC OFFS FICH BMP
     OBJE LECT base trav TERM REND
ENDPLAY
*======================================================================
     VISU NSTO 1
*======================================================================
PLAY
CAME   1 EYE   2.19879E+02 -3.75842E+02  2.66895E+02
!        Q    -8.36516E-01 -4.82963E-01 -1.29410E-01 -2.24144E-01
         VIEW -4.33013E-01  7.50000E-01 -5.00000E-01
         RIGH  8.66025E-01  5.00000E-01 -2.77556E-17
         UP   -2.50000E-01  4.33013E-01  8.66025E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  5.00000E+00  1.30000E+01
!RSPHERE:  1.01558E+02
!RADIUS :  5.07789E+02
!ASPECT :  1.00000E+00
!NEAR   :  3.96076E+02
!FAR    :  7.10905E+02
SCEN GEOM NAVI FREE
     VECT SCCO FIEL VITE SCAL USER PROG 5 PAS 5 70 TERM
          SUPP LECT stru TERM
SLER CAM1 1 NFRA 1
FREQ 25
GO
TRAC OFFS FICH BMP
     OBJE LECT stru TERM REND
GO
TRAC OFFS FICH BMP
     OBJE LECT stru TERM REND
GO
TRAC OFFS FICH BMP
     OBJE LECT stru TERM REND
GO
TRAC OFFS FICH BMP
     OBJE LECT stru TERM REND
ENDPLAY
*======================================================================
FIN
```

brid06p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'brid06.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_1' DEPL COMP 3 NOEU LECT ncen1 TERM
COUR 2 'dz_2' DEPL COMP 3 NOEU LECT ncen2 TERM
COUR 3 'dy_1' DEPL COMP 2 NOEU LECT ncen1 TERM
COUR 4 'dy_2' DEPL COMP 2 NOEU LECT ncen2 TERM
TRAC 1 2 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 AXES 1.0 'DISP. [M]' YZER
TRAC 3 4 AXES 1.0 'DISP. [M]' YZER
LIST 3 4 AXES 1.0 'DISP. [M]' YZER
FIN
```

brid06q.epx

```
Post-treatment (animation from alice file)
ECHO
 CONV WIN
RESU SPLI ALIC 'brid06.ali' GARD PSCR
SORT VISU NSTO 1
*======================================================================
PLAY
CAME   1 EYE   2.19879E+02 -3.75842E+02  2.66895E+02
!        Q    -8.36516E-01 -4.82963E-01 -1.29410E-01 -2.24144E-01
         VIEW -4.33013E-01  7.50000E-01 -5.00000E-01
         RIGH  8.66025E-01  5.00000E-01 -2.77556E-17
         UP   -2.50000E-01  4.33013E-01  8.66025E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  5.00000E+00  1.30000E+01
!RSPHERE:  1.01558E+02
!RADIUS :  5.07789E+02
!ASPECT :  1.00000E+00
!NEAR   :  3.96076E+02
!FAR    :  7.10905E+02
SCEN GEOM NAVI FREE
     VECT SCCO FIEL VITE SCAL USER PROG 2 PAS 2 28 TERM
          SUPP LECT base trav TERM
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1
     OBJE LECT base trav TERM REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL
     OBJE LECT base trav TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT base trav TERM REND
ENDPLAY
*======================================================================
     VISU NSTO 1
*======================================================================
PLAY
CAME   1 EYE   2.19879E+02 -3.75842E+02  2.66895E+02
!        Q    -8.36516E-01 -4.82963E-01 -1.29410E-01 -2.24144E-01
         VIEW -4.33013E-01  7.50000E-01 -5.00000E-01
         RIGH  8.66025E-01  5.00000E-01 -2.77556E-17
         UP   -2.50000E-01  4.33013E-01  8.66025E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  5.00000E+00  1.30000E+01
!RSPHERE:  1.01558E+02
!RADIUS :  5.07789E+02
!ASPECT :  1.00000E+00
!NEAR   :  3.96076E+02
!FAR    :  7.10905E+02
SCEN GEOM NAVI FREE
     VECT SCCO FIEL VITE SCAL USER PROG 5 PAS 5 70 TERM
          SUPP LECT stru TERM
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1
     OBJE LECT stru TERM REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL
     OBJE LECT stru TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT stru TERM REND
ENDPLAY
*======================================================================
FIN
```

brid06r.epx

```
Post-treatment (animation from alice file)
ECHO
 CONV WIN
RESU SPLI ALIC 'brid06.ali' GARD PSCR
SORT VISU NSTO 1
*======================================================================
PLAY
CAME   1 EYE   2.19879E+02 -3.75842E+02  2.66895E+02
!        Q    -8.36516E-01 -4.82963E-01 -1.29410E-01 -2.24144E-01
         VIEW -4.33013E-01  7.50000E-01 -5.00000E-01
         RIGH  8.66025E-01  5.00000E-01 -2.77556E-17
         UP   -2.50000E-01  4.33013E-01  8.66025E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  5.00000E+00  1.30000E+01
!RSPHERE:  1.01558E+02
!RADIUS :  5.07789E+02
!ASPECT :  1.00000E+00
!NEAR   :  3.96076E+02
!FAR    :  7.10905E+02
SCEN GEOM NAVI FREE
          LINE HEOU SSHA SFRE
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1
     OBJE LECT tous DIFF boun TERM REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL
     OBJE LECT tous DIFF boun TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT tous DIFF boun TERM REND
ENDPLAY
*======================================================================
FIN
```

brid06s.epx

```
Post-treatment (animation from alice file)
ECHO
 CONV WIN
RESU SPLI ALIC 'brid06.ali' GARD PSCR
SORT VISU NSTO 1
*======================================================================
PLAY
CAME   1 EYE   2.19879E+02 -3.75842E+02  2.66895E+02
!        Q    -8.36516E-01 -4.82963E-01 -1.29410E-01 -2.24144E-01
         VIEW -4.33013E-01  7.50000E-01 -5.00000E-01
         RIGH  8.66025E-01  5.00000E-01 -2.77556E-17
         UP   -2.50000E-01  4.33013E-01  8.66025E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  5.00000E+00  1.30000E+01
!RSPHERE:  1.01558E+02
!RADIUS :  5.07789E+02
!ASPECT :  1.00000E+00
!NEAR   :  3.96076E+02
!FAR    :  7.10905E+02
SCEN GEOM NAVI FREE
          LINE HEOU SSHA SFRE
     LIMA ON
SLER CAM1 1 NFRA 1
FREQ 25
TRAC OFFS FICH BMP
```

```
     OBJE LECT tous DIFF boun TERM REND
GO
TRAC OFFS FICH BMP
     OBJE LECT tous DIFF boun TERM REND
GO
TRAC OFFS FICH BMP
     OBJE LECT tous DIFF boun TERM REND
GO
TRAC OFFS FICH BMP
     OBJE LECT tous DIFF boun TERM REND
GO
TRAC OFFS FICH BMP
     OBJE LECT tous DIFF boun TERM REND
ENDPLAY
*=====================================================================
FIN
```

brid06t.epx

```
Post-treatment (animation from alice file)
ECHO
 CONV WIN
RESU SPLI ALIC 'brid06.ali' GARD PSCR
SORT VISU NSTO 1
*=====================================================================
PLAY
CAME   1 EYE   2.19879E+02 -3.75842E+02  2.66895E+02
!        Q    -8.36516E-01 -4.82963E-01 -1.29410E-01 -2.24144E-01
         VIEW -4.33013E-01  7.50000E-01 -5.00000E-01
         RIGH  8.66025E-01  5.00000E-01 -2.77556E-17
         UP   -2.50000E-01  4.33013E-01  8.66025E-01
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  0.00000E+00  5.00000E+00  1.30000E+01
!RSPHERE:  1.01558E+02
!RADIUS :  5.07789E+02
!ASPECT :  1.00000E+00
!NEAR   :  3.96076E+02
!FAR    :  7.10905E+02
SCEN GEOM NAVI FREE
         INIT WIRE
     COLO SELE RED APPL INWI
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1
     OBJE LECT stru TERM DEFO REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL
     OBJE LECT stru TERM DEFO REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT stru TERM DEFO REND
ENDPLAY
*=====================================================================
FIN
```

brid06z.epx

```
Post-treatment (animation from alice file)
ECHO
 CONV WIN
RESU SPLI ALIC 'brid06.ali' GARD PSCR
SORT VISU NSTO 2
FIN
```

debi01.dgibi

```
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'debi01.msh';
opti trac psc ftra 'debi01_mesh.ps';
p0 = 0 0 0;
pm = manu poi1 p0;
mesh = pm;
tass mesh noop;
sauv form mesh;
trac qual mesh;
fin;
```

debi01.epx

```
DEBI01
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME NALE 1 NBLE 1 TERM
GEOM PMAT pm TERM
COMP EPAI 1.0 LECT pm TERM
     STFL VFCC X0 -10 Y0 -1 Z0 -1 ! Automatically generate structured
              LX  20 LY  2 LZ  2 ! fluid mesh (box)
              NX  20 NY  2 NZ  2
              CLX1 CLX2
     GROU 5 'stru' LECT pm TERM
            'flui' STFL FLUI
            'boun' STFL CLXS
            'inlt' LECT boun TERM COND XB LT 0
            'outl' LECT boun TERM COND XB GT 0
     COUL GR50 LECT stru TERM
          TURQ LECT flui TERM
          ROUG LECT inlt TERM
          VERT LECT outl TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE MASS 1.0
          LECT stru TERM
     GAZP RO 1 GAMM 1.4 PINI 1.E5 PREF 1.E5
          LECT flui TERM
     CLVF DEBI RO 1 PRES 1.E5 GAMA 1.4 PREF 1.E5
          DEBX 100. DEBY 0. DEBZ 0.
          LECT inlt TERM
     CLVF ABSO RO 1
          LECT outl TERM
INIT VITC VITX 100 VITY 0 VITZ 0 LECT flui TERM
ECRI DEPL VITE TFRE 5.E-1
     NOEL POIN LECT stru TERM
     FICH ALIC TFRE 0.5
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 4
          ORDR 2
          OTPS 2
          RECO 1
          LMAS 3
          LQDM 3
          LENE 3
          KMAS 0.75
          KQDM 0.75
          KENE 0.75
          CENE
CALC TINI 0. TEND 5.E0
FIN
```

debi01x.epx

```
DEBI01X
ECHO
OPTI PRIN
RESU ALIC 'debi01.ali' GARD PSCR
COMP NGRO 1 'xaxo' LECT tous TERM
               COND LINE X1 -10 Y1 1 Z1 1 X2 10 Y2 1 Z2 1 TOL 1.E-2
SORT GRAP
SCOU 100 'P, t=0.0s' ECRO COMP 1 NSTO 1 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 101 'P, t=0.5s' ECRO COMP 1 NSTO 2 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 102 'P, t=1.0s' ECRO COMP 1 NSTO 3 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 103 'P, t=1.5s' ECRO COMP 1 NSTO 4 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 104 'P, t=2.0s' ECRO COMP 1 NSTO 5 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 105 'P, t=2.5s' ECRO COMP 1 NSTO 6 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 106 'P, t=3.0s' ECRO COMP 1 NSTO 7 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 107 'P, t=3.5s' ECRO COMP 1 NSTO 8 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 108 'P, t=4.0s' ECRO COMP 1 NSTO 9 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 109 'P, t=4.5s' ECRO COMP 1 NSTO 10 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 110 'P, t=5.0s' ECRO COMP 1 NSTO 11 SAXE 1.0 'ABSC' LECT xaxo TERM
TRAC 100 101 102 103 104 105 106 107 108 109 110 AXES 1.0 'Press. (Pa)'
COLO NOIR BLEU VERT TURQ ROSE ROUG NOIR BLEU VERT TURQ ROSE
DASH 0    0    0    0    0    0    2    2    2    2    2
SCOU 200 'V, t=0.0s' VCVI COMP 1 NSTO 1 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 201 'V, t=0.5s' VCVI COMP 1 NSTO 2 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 202 'V, t=1.0s' VCVI COMP 1 NSTO 3 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 203 'V, t=1.5s' VCVI COMP 1 NSTO 4 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 204 'V, t=2.0s' VCVI COMP 1 NSTO 5 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 205 'V, t=2.5s' VCVI COMP 1 NSTO 6 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 206 'V, t=3.0s' VCVI COMP 1 NSTO 7 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 207 'V, t=3.5s' VCVI COMP 1 NSTO 8 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 208 'V, t=4.0s' VCVI COMP 1 NSTO 9 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 209 'V, t=4.5s' VCVI COMP 1 NSTO 10 SAXE 1.0 'ABSC' LECT xaxo TERM
SCOU 210 'V, t=5.0s' VCVI COMP 1 NSTO 11 SAXE 1.0 'ABSC' LECT xaxo TERM
TRAC 200 201 202 203 204 205 206 207 208 209 210 AXES 1.0 'Velo. (m/s)'
COLO NOIR BLEU VERT TURQ ROSE ROUG NOIR BLEU VERT TURQ ROSE
DASH 0    0    0    0    0    0    2    2    2    2    2
FIN
```

debi02.dgibi

```
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'debi02.msh';
opti trac psc ftra 'debi02_mesh.ps';
p0 = 0 0 0;
pm = manu poi1 p0;
mesh = pm;
tass mesh noop;
sauv form mesh;
trac qual mesh;
fin;
```

debi02.epx

```
DEBI02
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME NALE 1 NBLE 1 TERM
GEOM PMAT pm TERM
COMP EPAI 1.0 LECT pm TERM
     STFL VFCC X0 -10 Y0 -1 Z0 -1 ! Automatically generate structured
```

```
               LX  20 LY  2 LZ  2 ! fluid mesh (box)
               NX  20 NY  2 NZ  2
               CLX1 CLX2
     GROU 5 'stru' LECT pm TERM
            'flui' STFL FLUI
            'boun' STFL CLXS
            'inlt' LECT boun TERM COND XB LT 0
            'outl' LECT boun TERM COND XB GT 0
     COUL GR50 LECT stru TERM
          TURQ LECT flui TERM
          ROUG LECT inlt TERM
          VERT LECT outl TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE MASS 1.0
          LECT stru TERM
     GAZP RO 1 GAMM 1.4 PINI 1.E5 PREF 1.E5
          LECT flui TERM
     CLVF ESUB RO 1 PRES 1.E5 GAMA 1.4 PREF 1.E5
          DEBX 100. DEBY 0. DEBZ 0.
          LECT inlt TERM
     CLVF ABSO RO 1
          LECT outl TERM
INIT VITC VITX 100 VITY 0 VITZ 0 LECT flui TERM
ECRI DEPL VITE TFRE 5.E-1
     NOEL POIN LECT stru TERM
     FICH ALIC TFRE 0.5
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 4
          ORDR 2
          OTPS 2
          RECO 1
          LMAS 3
          LQDM 3
          LENE 3
          KMAS 0.75
          KQDM 0.75
          KENE 0.75
          CENE
CALC TINI 0. TEND 5.E0
FIN
```

debi03.dgibi

```
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'debi03.msh';
opti trac psc ftra 'debi03_mesh.ps';
p0 = 0 0 0;
pm = manu poi1 p0;
mesh = pm;
tass mesh noop;
sauv form mesh;
trac qual mesh;
fin;
```

debi03.epx

```
DEBI03
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME NALE 1 NBLE 1 TERM
GEOM PMAT pm TERM
COMP EPAI 1.0 LECT pm TERM
     STFL VFCC X0 -10 Y0 -1 Z0 -1 ! Automatically generate structured
               LX  20 LY  2 LZ  2 ! fluid mesh (box)
               NX  20 NY  2 NZ  2
               CLX1 CLX2
     GROU 5 'stru' LECT pm TERM
            'flui' STFL FLUI
            'boun' STFL CLXS
            'inlt' LECT boun TERM COND XB LT 0
            'outl' LECT boun TERM COND XB GT 0
     COUL GR50 LECT stru TERM
          TURQ LECT flui TERM
          ROUG LECT inlt TERM
          VERT LECT outl TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE MASS 1.0
          LECT stru TERM
     GAZP RO 1 GAMM 1.4 PINI 1.E5 PREF 1.E5
          LECT flui TERM
     CLVF ESUB RO 1 PRES 1.E5 GAMA 1.4 PREF 1.E5
          DEBX 100. DEBY 0. DEBZ 0.
          LECT inlt TERM
     CLVF ABSO RO 1
          LECT outl TERM
INIT VITC VITX 100 VITY 0 VITZ 0 LECT flui TERM
ECRI DEPL VITE TFRE 5.E-1
     NOEL POIN LECT stru TERM
     FICH ALIC TFRE 0.5
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 6
          ORDR 2
          OTPS 2
          RECO 0
CALC TINI 0. TEND 5.E0
FIN
```

debi04.dgibi

```
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'debi04.msh';
opti trac psc ftra 'debi04_mesh.ps';
p0 = 0 0 0;
pm = manu poi1 p0;
mesh = pm;
tass mesh noop;
sauv form mesh;
trac qual mesh;
fin;
```

debi04.epx

```
DEBI04
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME NALE 1 NBLE 1 TERM
GEOM PMAT pm TERM
COMP EPAI 1.0 LECT pm TERM
     STFL VFCC X0 -10 Y0 -1 Z0 -1 ! Automatically generate structured
               LX  20 LY  2 LZ  2 ! fluid mesh (box)
               NX  20 NY  2 NZ  2
               CLX1 CLX2
     GROU 5 'stru' LECT pm TERM
            'flui' STFL FLUI
            'boun' STFL CLXS
            'inlt' LECT boun TERM COND XB LT 0
            'outl' LECT boun TERM COND XB GT 0
     COUL GR50 LECT stru TERM
          TURQ LECT flui TERM
          ROUG LECT inlt TERM
          VERT LECT outl TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE MASS 1.0
          LECT stru TERM
     GAZP RO 1 GAMM 1.4 PINI 1.E5 PREF 1.E5
          LECT flui TERM
     CLVF ESUB RO 1 PRES 1.E5 GAMA 1.4 PREF 1.E5
          DEBX 100. DEBY 0. DEBZ 0.
          LECT inlt TERM
     CLVF ABSO RO 1
          LECT outl TERM
INIT VITC VITX 100 VITY 0 VITZ 0 LECT flui TERM
ECRI DEPL VITE TFRE 5.E-1
     NOEL POIN LECT stru TERM
     FICH ALIC TFRE 0.5
OPTI PAS AUTO NOTE CSTA 0.25 LOG 1
     VFCC FCON 4
          ORDR 2
          OTPS 2
          RECO 1
          LMAS 3
          LQDM 3
          LENE 3
          KMAS 0.75
          KQDM 0.75
          KENE 0.75
          CENE
CALC TINI 0. TEND 5.E0
FIN
```

debi05.dgibi

```
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'debi05.msh';
opti trac psc ftra 'debi05_mesh.ps';
p0 = 0 0 0;
pm = manu poi1 p0;
mesh = pm;
tass mesh noop;
sauv form mesh;
trac qual mesh;
fin;
```

debi05.epx

```
DEBI05
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME NALE 1 NBLE 1 TERM
GEOM PMAT pm TERM
COMP EPAI 1.0 LECT pm TERM
     STFL VFCC X0 -10 Y0 -1 Z0 -1 ! Automatically generate structured
               LX  20 LY  2 LZ  2 ! fluid mesh (box)
               NX  20 NY  2 NZ  2
               CLX1 CLX2
```

```
     GROU 5 'stru' LECT pm TERM
            'flui' STFL FLUI
            'boun' STFL CLXS
            'inlt' LECT boun TERM COND XB LT 0
            'outl' LECT boun TERM COND XB GT 0
     COUL GR50 LECT stru TERM
          TURQ LECT flui TERM
          ROUG LECT inlt TERM
          VERT LECT outl TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE MASS 1.0
          LECT stru TERM
     GAZP RO 1 GAMM 1.4 PINI 1.E5 PREF 1.E5
          LECT flui TERM
     CLVF ESUB RO 1 PRES 1.E5 GAMA 1.4 PREF 1.E5
          DEBX 100. DEBY 0. DEBZ 0.
          LECT inlt TERM
     CLVF PIMP RO 1. PRES 1.E5 GAMA 1.4 PREF 1.E5 IMPO 6
          LECT outl TERM
INIT VITC VITX 100 VITY 0 VITZ 0 LECT flui TERM
ECRI DEPL VITE TFRE 5.E-1
     NOEL POIN LECT stru TERM
     FICH ALIC TFRE 0.5
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 4
          ORDR 2
          OTPS 2
          RECO 1
          LMAS 3
          LQDM 3
          LENE 3
          KMAS 0.75
          KQDM 0.75
          KENE 0.75
          CENE
CALC TINI 0. TEND 5.E0
FIN
```

debi06.dgibi

```
opti echo 1;
opti dime 3 elem cub8;
opti sauv form 'debi06.msh';
opti trac psc ftra 'debi06_mesh.ps';
p0 = 0 0 0;
pm = manu poi1 p0;
mesh = pm;
tass mesh noop;
sauv form mesh;
trac qual mesh;
fin;
```

debi06.epx

```
DEBI06
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME NALE 1 NBLE 1 TERM
GEOM PMAT pm TERM
COMP EPAI 1.0 LECT pm TERM
     STFL VFCC X0 -10 Y0 -1 Z0 -1 ! Automatically generate structured
               LX  20 LY  2 LZ  2 ! fluid mesh (box)
               NX  20 NY  2 NZ  2
               CLX1 CLX2
     GROU 5 'stru' LECT pm TERM
            'flui' STFL FLUI
            'boun' STFL CLXS
            'inlt' LECT boun TERM COND XB LT 0
            'outl' LECT boun TERM COND XB GT 0
     COUL GR50 LECT stru TERM
          TURQ LECT flui TERM
          ROUG LECT inlt TERM
          VERT LECT outl TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE MASS 1.0
          LECT stru TERM
     GAZP RO 1 GAMM 1.4 PINI 1.E5 PREF 1.E5
          LECT flui TERM
     CLVF ESUB RO 1 PRES 1.E5 GAMA 1.4 PREF 1.E5
          DEBX 100. DEBY 0. DEBZ 0.
          LECT inlt TERM
     CLVF PIMP RO 1. PRES 1.E5 GAMA 1.4 PREF 1.E5 IMPO 6
          LECT outl TERM
INIT VITC VITX 100 VITY 0 VITZ 0 LECT flui TERM
ECRI DEPL VITE TFRE 5.E-1
     NOEL POIN LECT stru TERM
     FICH ALIC TFRE 0.5
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 6
          ORDR 2
          OTPS 2
          RECO 1
          LMAS 3
          LQDM 3
          LENE 3
          KMAS 0.75
          KQDM 0.75
          KENE 0.75
          CENE
CALC TINI 0. TEND 5.E0
FIN
```

drag03.dgibi

```
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'drag03_mesh.ps';
opti sauv form 'drag03.msh';
dds = 1.0;
dens dds;
xs0 = 5.0;
ys0 = 0.5;
zs0 = 0.5;
p0 = xs0 ys0 zs0;
xs1 = 5.0;
ys1 = 0.5;
zs1 = 3.5;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = stru;
tass mesh noop;
sauv form mesh;
trac cach mesh;
fin;
```

drag03.epx

```
DRAG03
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     COUL VERT LECT stru TERM
MATE LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK DECO
     BLOQ 123456 LECT p0 TERM
     DRAG ROF 1.0 VFX 20.0
          STRU LECT stru TERM
          CD 1.0 LECT stru TERM
ECRI DEPL VITE TFRE 2.E-1
     NOEL POIN LECT p0 p1 TERM
     FICH ALIC TFRE 4.E-2
     FICH ALIC TEMP FREQ 1
          POIN LECT p0 p1 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 4.0
FIN
```

drag03b.epx

```
DRAG03B
ECHO
RESU ALIC 'drag03.ali' GARD PSCR
SORT VISU NSTO 1
*=======================================================================
PLAY
CAME   1 EYE   5.00000E+00 -9.25000E+00  2.00000E+00
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E+00  5.00000E-01  2.00000E+00
!RSPHERE:  1.50000E+00
!RADIUS :  9.75000E+00
!ASPECT :  1.00000E+00
!NEAR   :  8.25000E+00
!FAR    :  1.27500E+01
SCEN GEOM NAVI FREE
     VECT SCCO FIEL VITE SCAL USER PROG 0.05 PAS 0.05 0.70 TERM
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 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
```

drag03p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'drag03.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_p0' DEPL COMP 1 NOEU LECT p0 TERM
COUR 2 'dx_p1' DEPL COMP 1 NOEU LECT p1 TERM
TRAC 1 2 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_p0' VITE COMP 1 NOEU LECT p0 TERM
COUR 12 'vx_p1' VITE COMP 1 NOEU LECT p1 TERM
TRAC 11 12 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 12 AXES 1.0 'VELO. [M/S]' YZER
FIN
```

drag04.dgibi

```
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'drag04_mesh.ps';
opti sauv form 'drag04.msh';
dds = 1.0;
dens dds;
xs0 = 5.0;
ys0 = 0.5;
zs0 = 0.5;
p0 = xs0 ys0 zs0;
xs1 = 5.0;
ys1 = 0.5;
zs1 = 3.5;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = stru;
tass mesh noop;
sauv form mesh;
trac cach mesh;
fin;
```

drag04.epx

```
DRAG04
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     COUL VERT LECT stru TERM
MATE LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK DECO
     BLOQ 123456 LECT p0 p1 TERM
     DRAG ROF 1.0 VFX 20.0
          STRU LECT stru TERM
          CD 1.0 LECT stru TERM
ECRI DEPL VITE TFRE 2.E-1
     NOEL POIN LECT p0 p1 TERM
     FICH ALIC TFRE 4.E-2
     FICH ALIC TEMP FREQ 1
          POIN LECT p0 p1 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 4.0
FIN
```

drag04b.epx

```
DRAG04B
ECHO
RESU ALIC 'drag04.ali' GARD PSCR
SORT VISU NSTO 1
*=======================================================================
PLAY
CAME   1 EYE    5.00000E+00 -9.25000E+00  2.00000E+00
!         Q      7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
          VIEW  0.00000E+00  1.00000E+00  2.05103E-10
          RIGH  1.00000E+00  0.00000E+00  0.00000E+00
          UP    0.00000E+00 -2.05103E-10  1.00000E+00
          FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E+00  5.00000E-01  2.00000E+00
!RSPHERE:  1.50000E+00
!RADIUS :  9.75000E+00
!ASPECT :  1.00000E+00
!NEAR   :  8.25000E+00
!FAR    :  1.27500E+01
SCEN GEOM NAVI FREE
     VECT SCCO FIEL VITE SCAL USER PROG 0.005 PAS 0.005 0.070 TERM
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 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
```

drag04p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'drag04.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_p0' DEPL COMP 1 NOEU LECT p0 TERM
COUR 2 'dx_p1' DEPL COMP 1 NOEU LECT p1 TERM
TRAC 1 2 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_p0' VITE COMP 1 NOEU LECT p0 TERM
COUR 12 'vx_p1' VITE COMP 1 NOEU LECT p1 TERM
TRAC 11 12 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 12 AXES 1.0 'VELO. [M/S]' YZER
COUR 3 'fex_p0' FEXT COMP 1 NOEU LECT p0 TERM
COUR 4 'fex_p1' FEXT COMP 1 NOEU LECT p1 TERM
TRAC 3 4 AXES 1.0 'FEXT [N]' YZER
LIST 3 4 AXES 1.0 'FEXT [N]' YZER
COUR 5 'fdec_p0' FDEC COMP 1 NOEU LECT p0 TERM
COUR 6 'fdec_p1' FDEC COMP 1 NOEU LECT p1 TERM
TRAC 5 6 AXES 1.0 'FDEC [N]' YZER
LIST 5 6 AXES 1.0 'FDEC [N]' YZER
FIN
```

drag05.dgibi

```
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'drag05_mesh.ps';
opti sauv form 'drag05.msh';
dds = 1.0;
dens dds;
xs0 = 5.0;
ys0 = 0.5;
zs0 = 0.5;
p0 = xs0 ys0 zs0;
xs1 = 5.0;
ys1 = 0.5;
zs1 = 3.5;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = stru;
tass mesh noop;
sauv form mesh;
trac cach mesh;
fin;
```

drag05.epx

```
DRAG05
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     COUL VERT LECT stru TERM
MATE LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK DECO
     BLOQ 123456 LECT p0 p1 TERM
     DRAG ROF 1.0 VFZ 20.0
          STRU LECT stru TERM
          CD 1.0 LECT stru TERM
ECRI DEPL VITE TFRE 2.E-1
     NOEL POIN LECT p0 p1 TERM
     FICH ALIC TFRE 4.E-2
     FICH ALIC TEMP FREQ 1
          POIN LECT p0 p1 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 4.0
FIN
```

drag05b.epx

```
DRAG05B
ECHO
RESU ALIC 'drag05.ali' GARD PSCR
SORT VISU NSTO 1
*=======================================================================
PLAY
CAME   1 EYE    5.00000E+00 -9.25000E+00  2.00000E+00
!         Q      7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
          VIEW  0.00000E+00  1.00000E+00  2.05103E-10
          RIGH  1.00000E+00  0.00000E+00  0.00000E+00
          UP    0.00000E+00 -2.05103E-10  1.00000E+00
          FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E+00  5.00000E-01  2.00000E+00
!RSPHERE:  1.50000E+00
!RADIUS :  9.75000E+00
!ASPECT :  1.00000E+00
!NEAR   :  8.25000E+00
!FAR    :  1.27500E+01
SCEN GEOM NAVI FREE
```

```
     VECT SCCO FIEL VITE SCAL USER PROG 0.005 PAS 0.005 0.070 TERM
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 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
```

drag05p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'drag05.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dz_p0' DEPL COMP 3 NOEU LECT p0 TERM
COUR 2 'dz_p1' DEPL COMP 3 NOEU LECT p1 TERM
TRAC 1 2 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vz_p0' VITE COMP 3 NOEU LECT p0 TERM
COUR 12 'vz_p1' VITE COMP 3 NOEU LECT p1 TERM
TRAC 11 12 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 12 AXES 1.0 'VELO. [M/S]' YZER
COUR 3 'fex_p0' FEXT COMP 3 NOEU LECT p0 TERM
COUR 4 'fex_p1' FEXT COMP 3 NOEU LECT p1 TERM
TRAC 3 4 AXES 1.0 'FEXT [N]' YZER
LIST 3 4 AXES 1.0 'FEXT [N]' YZER
COUR 5 'fdec_p0' FDEC COMP 3 NOEU LECT p0 TERM
COUR 6 'fdec_p1' FDEC COMP 3 NOEU LECT p1 TERM
TRAC 5 6 AXES 1.0 'FDEC [N]' YZER
LIST 5 6 AXES 1.0 'FDEC [N]' YZER
FIN
```

drag08.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'drag08_mesh.ps';
opti sauv form 'drag08.msh';
lx = 8.0;
ly = 1.0;
lz = 4.0;
x0 = 0.0;
y0 = 0.0;
z0 = 0.0;
dd = 0.2;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 1.0;
dens dds;
xs0 = 5.0;
ys0 = 0.5;
zs0 = 0.5;
p0 = xs0 ys0 zs0;
xs1 = 5.0;
ys1 = 0.5;
zs1 = 3.5;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
fsrn = chan poi1 (enve flui);
mesh = flui et stru et fsrn;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

drag08.epx

```
DRAG08
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     COUL TURQ LECT flui TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT flui TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     FSR  LECT fsrn TERM
LINK DECO
     DRAG ROF 1.0
          STRU LECT stru TERM
          FLUI LECT flui TERM
          CD 50.0 LECT stru TERM
          DGRI
INIT VITE 1 100.0 LECT stru TERM
ECRI DEPL VITE TFRE 10.E-3
     NOEL POIN LECT p0 p1 TERM
     FICH SPLI ALIC TFRE 0.8E-3
     FICH ALIC TEMP FREQ 1
          POIN LECT p0 p1 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 80.E-3
FIN
```

drag08b.epx

```
DRAG08B
ECHO
RESU SPLI ALIC 'drag08.ali' GARD PSCR
SORT VISU NSTO 1
*=====================================================================
PLAY
CAME   1 EYE   5.03798E+00 -2.67173E+01  2.00000E+00 ! Side view
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.03798E+00  5.00000E-01  2.00000E+00
!RSPHERE:  5.44346E+00
!RADIUS :  2.72173E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.12295E+01
!FAR    :  3.81042E+01
CAME   2 EYE   5.03798E+00  5.00000E-01  2.92173E+01 ! Top view
!        Q     1.00000E+00  5.55112E-17  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.11022E-16 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  1.11022E-16
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.03798E+00  5.00000E-01  2.00000E+00
!RSPHERE:  5.44346E+00
!RADIUS :  2.72173E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.12295E+01
!FAR    :  3.81042E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LINE SSHA !HEOU
     VECT SCCO FIEL VITE SCAL USER PROG 7 PAS 7 98 TERM
          SUPP LECT stru TERM
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=====================================================================
FIN
```

drag08c.epx

```
DRAG08C
ECHO
RESU SPLI ALIC 'drag08.ali' GARD PSCR
SORT VISU NSTO 1
*=====================================================================
PLAY
CAME   1 EYE   5.03798E+00 -2.67173E+01  2.00000E+00 ! Side view
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.03798E+00  5.00000E-01  2.00000E+00
!RSPHERE:  5.44346E+00
!RADIUS :  2.72173E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.12295E+01
!FAR    :  3.81042E+01
CAME   2 EYE   5.03798E+00  5.00000E-01  2.92173E+01 ! Top view
!        Q     1.00000E+00  5.55112E-17  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.11022E-16 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  1.11022E-16
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.03798E+00  5.00000E-01  2.00000E+00
!RSPHERE:  5.44346E+00
!RADIUS :  2.72173E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.12295E+01
!FAR    :  3.81042E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LINE SSHA HEOU
     VECT SCCO FIEL VITE SCAL USER PROG 7 PAS 7 98 TERM
          SIVE
          SUPP LECT flui TERM
```

```
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=======================================================================
     VISU NSTO 1
*=======================================================================
PLAY
CAME   1 EYE   5.03798E+00 -2.67173E+01  2.00000E+00 ! Side view
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.03798E+00  5.00000E-01  2.00000E+00
!RSPHERE:  5.44346E+00
!RADIUS :  2.72173E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.12295E+01
!FAR    :  3.81042E+01
CAME   2 EYE   5.03798E+00  5.00000E-01  2.92173E+01 ! Top view
!        Q     1.00000E+00  5.55112E-17  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.11022E-16 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  1.11022E-16
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.03798E+00  5.00000E-01  2.00000E+00
!RSPHERE:  5.44346E+00
!RADIUS :  2.72173E+01
!ASPECT :  1.00000E+00
!NEAR   :  2.12295E+01
!FAR    :  3.81042E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          LINE SSHA HEOU
     VECT SCCO FIEL VITE SCAL USER PROG 7 PAS 7 98 TERM
          SIVE
          SUPP LECT flui TERM
SLER CAM1 2 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL REND
GO
TRAC OFFS FICH AVI CONT REND
ENDPLAY
*=======================================================================

FIN
```

drag08p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'drag08.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_p0' DEPL COMP 1 NOEU LECT p0 TERM
COUR 2 'dx_p1' DEPL COMP 1 NOEU LECT p1 TERM
TRAC 1 2 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_p0' VITE COMP 1 NOEU LECT p0 TERM
COUR 12 'vx_p1' VITE COMP 1 NOEU LECT p1 TERM
TRAC 11 12 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 12 AXES 1.0 'VELO. [M/S]' YZER
FIN
```

drag11.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'drag11_mesh.ps';
opti sauv form 'drag11.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

drag11.epx

```
DRAG11
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
LINK DECO
     DRAG STRU LECT stru TERM
          FLUI LECT flui TERM
          CD 1.0 LECT stru TERM
          DGRI
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

drag11p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'drag11.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout01p.pun' RENA 'dx_POUT01'
RCOU 211 'vx_1' FICH 'pout01p.pun' RENA 'vx_POUT01'
TRAC 101 201 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT NOIR
TRAC 111 211 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT NOIR
FIN
```

drag12.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'drag12_mesh.ps';
opti sauv form 'drag12.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
```

```
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

drag12.epx

```
DRAG12
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
LINK DECO
     DRAG STRU LECT stru TERM
          FLUI LECT flui TERM
          CD 1.98 LECT stru TERM
          DGRI
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

drag12p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'drag12.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout01p.pun' RENA 'dx_POUT01'
RCOU 211 'vx_1' FICH 'pout01p.pun' RENA 'vx_POUT01'
RCOU 301 'dx_1' FICH 'drag11p.pun' RENA 'dx_DRAG11'
RCOU 311 'vx_1' FICH 'drag11p.pun' RENA 'vx_DRAG11'
TRAC 101 201 301 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ NOIR
TRAC 111 211 311 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ NOIR
FIN
```

drag13.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'drag13_mesh.ps';
opti sauv form 'drag13.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

drag13.epx

```
DRAG13
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME ADAP NPOI 156299 FL38 165264 ENDA TERM
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 3 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
            'refi' LECT flui TERM
                   COND CYLI X1 .5 Y1 0 Z1 0 X2 .5 Y2 0 Z2 0.9 R 0.08
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air _fl38 TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
LINK DECO
     DRAG STRU LECT stru TERM
          FLUI LECT flui TERM
          CD 1.98 LECT stru TERM
          DGRI
INIT ADAP SPLI LEVE 3 LECT refi TERM
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     ADAP RCON
CALC TINI 0. TEND 20.E-3
FIN
```

drag13p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'drag13.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout01p.pun' RENA 'dx_POUT01'
RCOU 211 'vx_1' FICH 'pout01p.pun' RENA 'vx_POUT01'
RCOU 301 'dx_1' FICH 'drag11p.pun' RENA 'dx_DRAG11'
RCOU 311 'vx_1' FICH 'drag11p.pun' RENA 'vx_DRAG11'
RCOU 401 'dx_1' FICH 'drag12p.pun' RENA 'dx_DRAG12'
RCOU 411 'vx_1' FICH 'drag12p.pun' RENA 'vx_DRAG12'
TRAC 101 201 301 401 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ ROSE NOIR
TRAC 111 211 311 411 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ ROSE NOIR
FIN
```

drag14.dgibi

```
opti echo 0;
*opti donn 'pxbox3d.proc';
opti donn 'pxracub8.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'drag14_mesh.ps';
opti sauv form 'drag14.msh';
*lx = 2.0;
ly = 0.5;
*lz = 1.0;
*x0 = 0.0;
*y0 = 0.0 - (0.5*ly);
*z0 = 0.0;
*dd = 0.02;
*flui = pxbox3d x0 y0 z0 lx ly lz dd;
pf1 = 0 (0-(0.5*ly)) 0;
pf2 = 0 (0.5*ly)  0;
pf3 = 0 (0.5*ly)  1;
pf4 = 0 (-0.5*ly) 1;
n1 = 25;
n2 = 50;
c1 = pf1 d n1 pf2;
c2 = pf2 d n2 pf3;
c3 = pf3 d n1 pf4;
c4 = pf4 d n2 pf1;
s1 = dall c1 c2 c3 c4 plan;
vx = 0.34 0 0;
v1 = s1 volu tran 17 vx;
*
dist = 0.04;
tol = 0.0001;
vrac = pxracub8 (pf1 PLUS vx) (pf2 PLUS vx) (pf3 PLUS vx) (pf4 PLUS vx)
                n1 n2 dist tol;
*
vd = dist 0 0;
ppf1 = (pf1 PLUS vx) PLUS vd;
ppf2 = (pf2 PLUS vx) PLUS vd;
ppf3 = (pf3 PLUS vx) PLUS vd;
ppf4 = (pf4 PLUS vx) PLUS vd;
n12 = n1 + n1;
n22 = n2 + n2;
cc1 = ppf1 d n12 ppf2;
cc2 = ppf2 d n22 ppf3;
cc3 = ppf3 d n12 ppf4;
cc4 = ppf4 d n22 ppf1;
s2 = dall cc1 cc2 cc3 cc4 plan;
v2 = s2 volu tran 4 vd;
*
vxb = (vx PLUS vd) PLUS vd;
distb = 0.5*dist;
vracb = pxracub8 (pf1 PLUS vxb) (pf2 PLUS vxb) (pf3 PLUS vxb)
                 (pf4 PLUS vxb)
                  n12 n22 distb tol;
*
vdb = distb 0 0;
pppf1 = (ppf1 PLUS vd) PLUS vdb;
pppf2 = (ppf2 PLUS vd) PLUS vdb;
pppf3 = (ppf3 PLUS vd) PLUS vdb;
pppf4 = (ppf4 PLUS vd) PLUS vdb;
n13 = n12 + n12;
n23 = n22 + n22;
cc1b = pppf1 d n13 pppf2;
cc2b = pppf2 d n23 pppf3;
cc3b = pppf3 d n13 pppf4;
cc4b = pppf4 d n23 pppf1;
s3 = dall cc1b cc2b cc3b cc4b plan;
v3 = s3 volu tran (4*4) ((4*distb) 0 0);
*
ps1 = pppf1 PLUS ((4*distb) 0 0);
ps2 = pppf2 PLUS ((4*distb) 0 0);
ps3 = pppf3 PLUS ((4*distb) 0 0);
*
vr1 = vrac et v2 et vracb et v3;
elim tol vr1;
vr2 = vr1 SYME PLAN ps1 ps2 ps3;
*
s1c = s1 plus (0.70 0 0);
vxc = 1.30 0 0;
v3 = s1c volu tran 65 vxc;
*
flui = v1 et vr1 et vr2 et v3;
ELIM tol flui;
*
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach qual flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

drag14.epx

```
DRAG14
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 3 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
            'fldr' LECT flui TERM COND XB GT 0.4
                                  COND XB LT 0.6
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
LINK DECO
     DRAG STRU LECT stru TERM
          FLUI LECT fldr TERM
          CD 1.98 LECT stru TERM
!         DGRI
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

drag14p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'drag14.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout01p.pun' RENA 'dx_POUT01'
RCOU 211 'vx_1' FICH 'pout01p.pun' RENA 'vx_POUT01'
RCOU 301 'dx_1' FICH 'drag11p.pun' RENA 'dx_DRAG11'
RCOU 311 'vx_1' FICH 'drag11p.pun' RENA 'vx_DRAG11'
RCOU 401 'dx_1' FICH 'drag12p.pun' RENA 'dx_DRAG12'
RCOU 411 'vx_1' FICH 'drag12p.pun' RENA 'vx_DRAG12'
RCOU 501 'dx_1' FICH 'drag13p.pun' RENA 'dx_DRAG13'
RCOU 511 'vx_1' FICH 'drag13p.pun' RENA 'vx_DRAG13'
TRAC 101 201 301 401 501 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ ROSE BLEU NOIR
TRAC 111 211 311 411 511 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ ROSE BLEU NOIR
TRAC 501 1 AXES 1.0 'DISP. [M]' YZER
COLO BLEU NOIR
TRAC 511 11 AXES 1.0 'VELO. [M/S]' YZER
COLO BLEU NOIR
FIN
```

drag15.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'drag15_mesh.ps';
opti sauv form 'drag15.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.04;
```

```
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

drag15.epx

```
DRAG15
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
LINK DECO
     DRAG STRU LECT stru TERM
          FLUI LECT flui TERM
          CD 1.98 LECT stru TERM
          DGRI
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

drag15p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'drag15.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout01p.pun' RENA 'dx_POUT01'
RCOU 211 'vx_1' FICH 'pout01p.pun' RENA 'vx_POUT01'
RCOU 301 'dx_1' FICH 'drag11p.pun' RENA 'dx_DRAG11'
RCOU 311 'vx_1' FICH 'drag11p.pun' RENA 'vx_DRAG11'
RCOU 401 'dx_1' FICH 'drag12p.pun' RENA 'dx_DRAG12'
RCOU 411 'vx_1' FICH 'drag12p.pun' RENA 'vx_DRAG12'
RCOU 501 'dx_1' FICH 'drag13p.pun' RENA 'dx_DRAG13'
RCOU 511 'vx_1' FICH 'drag13p.pun' RENA 'vx_DRAG13'
RCOU 601 'dx_1' FICH 'drag14p.pun' RENA 'dx_DRAG14'
RCOU 611 'vx_1' FICH 'drag14p.pun' RENA 'vx_DRAG14'
TRAC 101 201 301 401 501 601 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ ROSE ROUG VERT NOIR
DASH 0    0    0    0    2    2    0
TRAC 111 211 311 411 511 611 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ ROSE ROUG VERT NOIR
DASH 0    0    0    0    2    2    0
TRAC 301 401 501 601 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ ROSE NOIR
TRAC 311 411 511 611 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ ROSE NOIR
FIN
```

drag21.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'drag21_mesh.ps';
opti sauv form 'drag21.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

drag21.epx

```
DRAG21
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
LINK DECO
     DRAG STRU LECT stru TERM
          FLUI LECT flui TERM
          CD 1.0 LECT stru TERM
          DGRI NOFB
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

drag21p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'drag21.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
```

```
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout01p.pun' RENA 'dx_POUT01'
RCOU 211 'vx_1' FICH 'pout01p.pun' RENA 'vx_POUT01'
RCOU 301 'dx_1' FICH 'drag11p.pun' RENA 'dx_DRAG11'
RCOU 311 'vx_1' FICH 'drag11p.pun' RENA 'vx_DRAG11'
TRAC 101 201 301 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT NOIR NOIR
DASH 0    0    2    0
TRAC 111 211 311 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT NOIR NOIR
DASH 0    0    2    0
FIN
```

drag22.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'drag22_mesh.ps';
opti sauv form 'drag22.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

drag22.epx

```
DRAG22
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
LINK DECO
     DRAG STRU LECT stru TERM
          FLUI LECT flui TERM
          CD 1.98 LECT stru TERM
          DGRI NOFB
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

drag22p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'drag22.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout01p.pun' RENA 'dx_POUT01'
RCOU 211 'vx_1' FICH 'pout01p.pun' RENA 'vx_POUT01'
RCOU 301 'dx_1' FICH 'drag11p.pun' RENA 'dx_DRAG11'
RCOU 311 'vx_1' FICH 'drag11p.pun' RENA 'vx_DRAG11'
RCOU 401 'dx_1' FICH 'drag12p.pun' RENA 'dx_DRAG12'
RCOU 411 'vx_1' FICH 'drag12p.pun' RENA 'vx_DRAG12'
RCOU 501 'dx_1' FICH 'drag21p.pun' RENA 'dx_DRAG21'
RCOU 511 'vx_1' FICH 'drag21p.pun' RENA 'vx_DRAG21'
TRAC 101 201 301 401 501 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ VERT TURQ NOIR
DASH 0    0    0    2    2    0
TRAC 111 211 311 411 511 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ VERT TURQ NOIR
DASH 0    0    0    2    2    0
FIN
```

drag23.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'drag23_mesh.ps';
opti sauv form 'drag23.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

drag23.epx

```
DRAG23
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME ADAP NPOI 156299 FL38 165264 ENDA TERM
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 3 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
            'refi' LECT flui TERM
                   COND CYLI X1 .5 Y1 0 Z1 0 X2 .5 Y2 0 Z2 0.9 R 0.08
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air _fl38 TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
```

```
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
LINK DECO
     DRAG STRU LECT stru TERM
          FLUI LECT flui TERM
          CD 1.98 LECT stru TERM
          DGRI NOFB
INIT ADAP SPLI LEVE 3 LECT refi TERM
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     ADAP RCON
CALC TINI 0. TEND 20.E-3
FIN
```

drag23p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'drag23.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout01p.pun' RENA 'dx_POUT01'
RCOU 211 'vx_1' FICH 'pout01p.pun' RENA 'vx_POUT01'
RCOU 301 'dx_1' FICH 'drag11p.pun' RENA 'dx_DRAG11'
RCOU 311 'vx_1' FICH 'drag11p.pun' RENA 'vx_DRAG11'
RCOU 401 'dx_1' FICH 'drag12p.pun' RENA 'dx_DRAG12'
RCOU 411 'vx_1' FICH 'drag12p.pun' RENA 'vx_DRAG12'
RCOU 501 'dx_1' FICH 'drag13p.pun' RENA 'dx_DRAG13'
RCOU 511 'vx_1' FICH 'drag13p.pun' RENA 'vx_DRAG13'
RCOU 601 'dx_1' FICH 'drag14p.pun' RENA 'dx_DRAG14'
RCOU 611 'vx_1' FICH 'drag14p.pun' RENA 'vx_DRAG14'
RCOU 701 'dx_1' FICH 'drag15p.pun' RENA 'dx_DRAG15'
RCOU 711 'vx_1' FICH 'drag15p.pun' RENA 'vx_DRAG15'
TRAC 101 201 301 401 501 601 701 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ ROSE BLEU ROUGE VERT NOIR
DASH 0    0    0    0    0    2    2    0
TRAC 111 211 311 411 511 611 711 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ ROSE BLEU ROUG VERT NOIR
DASH 0    0    0    0    0    2    2    0
FIN
```

drag24.dgibi

```
opti echo 0;
*opti donn 'pxbox3d.proc';
opti donn 'pxracub8.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'drag24_mesh.ps';
opti sauv form 'drag24.msh';
*lx = 2.0;
ly = 0.5;
*lz = 1.0;
*x0 = 0.0;
*y0 = 0.0 - (0.5*ly);
*z0 = 0.0;
*dd = 0.02;
*flui = pxbox3d x0 y0 z0 lx ly lz dd;
pf1 = 0 (0-(0.5*ly)) 0;
pf2 = 0 (0.5*ly)  0;
pf3 = 0 (0.5*ly)  1;
pf4 = 0 (-0.5*ly) 1;
n1 = 25;
n2 = 50;
c1 = pf1 d n1 pf2;
c2 = pf2 d n2 pf3;
c3 = pf3 d n1 pf4;
c4 = pf4 d n2 pf1;
s1 = dall c1 c2 c3 c4 plan;
vx = 0.34 0 0;
v1 = s1 volu tran 17 vx;
*
dist = 0.04;
tol = 0.0001;
vrac = pxracub8 (pf1 PLUS vx) (pf2 PLUS vx) (pf3 PLUS vx) (pf4 PLUS vx)
                n1 n2 dist tol;
*
vd = dist 0 0;
ppf1 = (pf1 PLUS vx) PLUS vd;
ppf2 = (pf2 PLUS vx) PLUS vd;
ppf3 = (pf3 PLUS vx) PLUS vd;
ppf4 = (pf4 PLUS vx) PLUS vd;
n12 = n1 + n1;
n22 = n2 + n2;
cc1 = ppf1 d n12 ppf2;
cc2 = ppf2 d n22 ppf3;
cc3 = ppf3 d n12 ppf4;
cc4 = ppf4 d n22 ppf1;
s2 = dall cc1 cc2 cc3 cc4 plan;
v2 = s2 volu tran 4 vd;
*
vxb = (vx PLUS vd) PLUS vd;
distb = 0.5*dist;
vracb = pxracub8 (pf1 PLUS vxb) (pf2 PLUS vxb) (pf3 PLUS vxb)
                 (pf4 PLUS vxb)
                  n12 n22 distb tol;
*
vdb = distb 0 0;
pppf1 = (ppf1 PLUS vd) PLUS vdb;
pppf2 = (ppf2 PLUS vd) PLUS vdb;
pppf3 = (ppf3 PLUS vd) PLUS vdb;
pppf4 = (ppf4 PLUS vd) PLUS vdb;
n13 = n12 + n12;
n23 = n22 + n22;
cc1b = pppf1 d n13 pppf2;
cc2b = pppf2 d n23 pppf3;
cc3b = pppf3 d n13 pppf4;
cc4b = pppf4 d n23 pppf1;
s3 = dall cc1b cc2b cc3b cc4b plan;
v3 = s3 volu tran (4*4) ((4*distb) 0 0);
*
ps1 = pppf1 PLUS ((4*distb) 0 0);
ps2 = pppf2 PLUS ((4*distb) 0 0);
ps3 = pppf3 PLUS ((4*distb) 0 0);
*
vr1 = vrac et v2 et vracb et v3;
elim tol vr1;
vr2 = vr1 SYME PLAN ps1 ps2 ps3;
*
s1c = s1 plus (0.70 0 0);
vxc = 1.30 0 0;
v3 = s1c volu tran 65 vxc;
*
flui = v1 et vr1 et vr2 et v3;
ELIM tol flui;
*
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach qual flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

drag24.epx

```
DRAG24
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 3 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
            'fldr' LECT flui TERM COND XB GT 0.4
                                  COND XB LT 0.6
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
LINK DECO
     DRAG STRU LECT stru TERM
          FLUI LECT fldr TERM
          CD 1.98 LECT stru TERM
          NOFB
!         DGRI
```

```
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

drag24p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'drag24.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout01p.pun' RENA 'dx_POUT01'
RCOU 211 'vx_1' FICH 'pout01p.pun' RENA 'vx_POUT01'
RCOU 301 'dx_1' FICH 'drag11p.pun' RENA 'dx_DRAG11'
RCOU 311 'vx_1' FICH 'drag11p.pun' RENA 'vx_DRAG11'
RCOU 401 'dx_1' FICH 'drag12p.pun' RENA 'dx_DRAG12'
RCOU 411 'vx_1' FICH 'drag12p.pun' RENA 'vx_DRAG12'
RCOU 501 'dx_1' FICH 'drag13p.pun' RENA 'dx_DRAG13'
RCOU 511 'vx_1' FICH 'drag13p.pun' RENA 'vx_DRAG13'
RCOU 601 'dx_1' FICH 'drag14p.pun' RENA 'dx_DRAG14'
RCOU 611 'vx_1' FICH 'drag14p.pun' RENA 'vx_DRAG14'
RCOU 701 'dx_1' FICH 'drag15p.pun' RENA 'dx_DRAG15'
RCOU 711 'vx_1' FICH 'drag15p.pun' RENA 'vx_DRAG15'
TRAC 101 201 301 401 501 601 701 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ ROSE BLEU ROUG VERT NOIR
DASH 0    0    0    0    0    2    2    0
TRAC 111 211 311 411 511 611 711 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ ROSE BLEU ROUG VERT NOIR
DASH 0    0    0    0    0    2    2    0
TRAC 601 1 AXES 1.0 'DISP. [M]' YZER
COLO BLEU NOIR
TRAC 611 11 AXES 1.0 'VELO. [M/S]' YZER
COLO BLEU NOIR
FIN
```

drag25.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'drag25_mesh.ps';
opti sauv form 'drag25.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.04;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

drag25.epx

```
DRAG25
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
LINK DECO
     DRAG STRU LECT stru TERM
          FLUI LECT flui TERM
          CD 1.98 LECT stru TERM
          DGRI NOFB
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

drag25p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'drag25.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout01p.pun' RENA 'dx_POUT01'
RCOU 211 'vx_1' FICH 'pout01p.pun' RENA 'vx_POUT01'
RCOU 301 'dx_1' FICH 'drag11p.pun' RENA 'dx_DRAG11'
RCOU 311 'vx_1' FICH 'drag11p.pun' RENA 'vx_DRAG11'
RCOU 401 'dx_1' FICH 'drag12p.pun' RENA 'dx_DRAG12'
RCOU 411 'vx_1' FICH 'drag12p.pun' RENA 'vx_DRAG12'
RCOU 501 'dx_1' FICH 'drag13p.pun' RENA 'dx_DRAG13'
RCOU 511 'vx_1' FICH 'drag13p.pun' RENA 'vx_DRAG13'
RCOU 601 'dx_1' FICH 'drag14p.pun' RENA 'dx_DRAG14'
RCOU 611 'vx_1' FICH 'drag14p.pun' RENA 'vx_DRAG14'
RCOU 701 'dx_1' FICH 'drag15p.pun' RENA 'dx_DRAG15'
RCOU 711 'vx_1' FICH 'drag15p.pun' RENA 'vx_DRAG15'
RCOU 801 'dx_1' FICH 'drag21p.pun' RENA 'dx_DRAG21'
RCOU 811 'vx_1' FICH 'drag21p.pun' RENA 'vx_DRAG21'
RCOU 901 'dx_1' FICH 'drag22p.pun' RENA 'dx_DRAG22'
RCOU 911 'vx_1' FICH 'drag22p.pun' RENA 'vx_DRAG22'
RCOU 1001 'dx_1' FICH 'drag23p.pun' RENA 'dx_DRAG23'
RCOU 1011 'vx_1' FICH 'drag23p.pun' RENA 'vx_DRAG23'
RCOU 1101 'dx_1' FICH 'drag24p.pun' RENA 'dx_DRAG24'
RCOU 1111 'vx_1' FICH 'drag24p.pun' RENA 'vx_DRAG24'
TRAC 101 201 301 401 501 601 701 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ ROSE ROUG VERT TURQ NOIR
DASH 0    0    0    0    2    2    2    0
TRAC 111 211 311 411 511 611 711 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ ROSE ROUG VERT TURQ NOIR
DASH 0    0    0    0    2    2    2    0
TRAC 101 201 801 901 1001 1101 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ ROSE ROUG VERT NOIR
DASH 0    0    0    0    2    2    0
TRAC 111 211 811 911 1011 1111 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ ROSE ROUG VERT NOIR
DASH 0    0    0    0    2    2    0
TRAC 801 901 1001 1101 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ ROSE NOIR
TRAC 811 911 1011 1111 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ ROSE NOIR
FIN
```

draw21.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'draw21_mesh.ps';
opti sauv form 'draw21.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
```

```
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

draw21.epx

```
DRAW21
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM CUVF flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 2 'nblo' LECT p0 TERM
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE GAZP RO 10.0 PINI 8.0E5 GAMM 1.4 PREF 0.8E5
          LECT expl TERM
     GAZP RO 1.0 PINI 0.8E5 GAMM 1.4 PREF 0.8E5
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
LINK DECO
     DRAG STRU LECT stru TERM
          FLUI LECT flui TERM
          CD 1.0 LECT stru TERM
          DGRI NOFB
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 6
          ORDR 2
          OTPS 2
          RECO 1
          NTIL
CALC TINI 0. TEND 20.E-3
FIN
```

draw21p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'draw21.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout01p.pun' RENA 'dx_POUT01'
RCOU 211 'vx_1' FICH 'pout01p.pun' RENA 'vx_POUT01'
RCOU 301 'dx_1' FICH 'drag11p.pun' RENA 'dx_DRAG11'
RCOU 311 'vx_1' FICH 'drag11p.pun' RENA 'vx_DRAG11'
RCOU 401 'dx_1' FICH 'drag21p.pun' RENA 'dx_DRAG21'
RCOU 411 'vx_1' FICH 'drag21p.pun' RENA 'vx_DRAG21'
TRAC 101 201 301 401 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ ROSE NOIR
TRAC 111 211 311 411 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ ROSE NOIR
FIN
```

draw22.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'draw22_mesh.ps';
opti sauv form 'draw22.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

draw22.epx

```
DRAW22
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM CUVF flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 2 'nblo' LECT p0 TERM
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE GAZP RO 10.0 PINI 8.0E5 GAMM 1.4 PREF 0.8E5
          LECT expl TERM
     GAZP RO 1.0 PINI 0.8E5 GAMM 1.4 PREF 0.8E5
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
LINK DECO
     DRAG STRU LECT stru TERM
          FLUI LECT flui TERM
          CD 1.98 LECT stru TERM
          DGRI NOFB
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 6
          ORDR 2
          OTPS 2
          RECO 1
          NTIL
CALC TINI 0. TEND 20.E-3
FIN
```

draw22p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'draw22.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout01p.pun' RENA 'dx_POUT01'
RCOU 211 'vx_1' FICH 'pout01p.pun' RENA 'vx_POUT01'
RCOU 301 'dx_1' FICH 'drag11p.pun' RENA 'dx_DRAG11'
RCOU 311 'vx_1' FICH 'drag11p.pun' RENA 'vx_DRAG11'
RCOU 401 'dx_1' FICH 'drag12p.pun' RENA 'dx_DRAG12'
```

```
RCOU 411 'vx_1' FICH 'drag12p.pun' RENA 'vx_DRAG12'
RCOU 501 'dx_1' FICH 'drag21p.pun' RENA 'dx_DRAG21'
RCOU 511 'vx_1' FICH 'drag21p.pun' RENA 'vx_DRAG21'
RCOU 601 'dx_1' FICH 'drag22p.pun' RENA 'dx_DRAG22'
RCOU 611 'vx_1' FICH 'drag22p.pun' RENA 'vx_DRAG22'
TRAC 601 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG NOIR
TRAC 611 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG NOIR
*TRAC 101 201 301 401 501 1 AXES 1.0 'DISP. [M]' YZER
*COLO ROUG VERT TURQ VERT TURQ NOIR
*DASH 0    0    0    2    2    0
*TRAC 111 211 311 411 511 11 AXES 1.0 'VELO. [M/S]' YZER
*COLO ROUG VERT TURQ VERT TURQ NOIR
*DASH 0    0    0    2    2    0
FIN
```

draw23.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'draw23_mesh.ps';
opti sauv form 'draw23.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

draw23.epx

```
DRAW23
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME ADAP NPOI 156299 CUVF 165264 NVFI 511136 ENDA TERM
GEOM CUVF flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 3 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
            'refi' LECT flui TERM
                   COND CYLI X1 .5 Y1 0 Z1 0 X2 .5 Y2 0 Z2 0.9 R 0.08
     NGRO 2 'nblo' LECT p0 TERM
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE GAZP RO 10.0 PINI 8.0E5 GAMM 1.4 PREF 0.8E5
          LECT expl TERM
     GAZP RO 1.0 PINI 0.8E5 GAMM 1.4 PREF 0.8E5
          LECT air _cuvf TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
LINK DECO
     DRAG STRU LECT stru TERM
          FLUI LECT flui TERM
          CD 1.98 LECT stru TERM
          DGRI NOFB
INIT ADAP SPLI LEVE 3 LECT refi TERM
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     ADAP RCON
     VFCC FCON 6
          ORDR 2
          OTPS 2
          RECO 1
          NTIL
CALC TINI 0. TEND 20.E-3
FIN
```

draw23p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'draw23.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout01p.pun' RENA 'dx_POUT01'
RCOU 211 'vx_1' FICH 'pout01p.pun' RENA 'vx_POUT01'
RCOU 301 'dx_1' FICH 'drag11p.pun' RENA 'dx_DRAG11'
RCOU 311 'vx_1' FICH 'drag11p.pun' RENA 'vx_DRAG11'
RCOU 401 'dx_1' FICH 'drag12p.pun' RENA 'dx_DRAG12'
RCOU 411 'vx_1' FICH 'drag12p.pun' RENA 'vx_DRAG12'
RCOU 501 'dx_1' FICH 'drag13p.pun' RENA 'dx_DRAG13'
RCOU 511 'vx_1' FICH 'drag13p.pun' RENA 'vx_DRAG13'
RCOU 601 'dx_1' FICH 'drag14p.pun' RENA 'dx_DRAG14'
RCOU 611 'vx_1' FICH 'drag14p.pun' RENA 'vx_DRAG14'
RCOU 701 'dx_1' FICH 'drag15p.pun' RENA 'dx_DRAG15'
RCOU 711 'vx_1' FICH 'drag15p.pun' RENA 'vx_DRAG15'
TRAC 101 201 301 401 501 601 701 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ ROSE BLEU ROUGE VERT NOIR
DASH 0    0    0    0    0    2    2    0
TRAC 111 211 311 411 511 611 711 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ ROSE BLEU ROUG VERT NOIR
DASH 0    0    0    0    0    2    2    0
FIN
```

draw24.dgibi

```
opti echo 0;
*opti donn 'pxbox3d.proc';
opti donn 'pxracub8.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'draw24_mesh.ps';
opti sauv form 'draw24.msh';
*lx = 2.0;
ly = 0.5;
*lz = 1.0;
*x0 = 0.0;
*y0 = 0.0 - (0.5*ly);
*z0 = 0.0;
*dd = 0.02;
*flui = pxbox3d x0 y0 z0 lx ly lz dd;
pf1 = 0 (0-(0.5*ly)) 0;
pf2 = 0 (0.5*ly)  0;
pf3 = 0 (0.5*ly)  1;
pf4 = 0 (-0.5*ly) 1;
n1 = 25;
n2 = 50;
c1 = pf1 d n1 pf2;
c2 = pf2 d n2 pf3;
c3 = pf3 d n1 pf4;
c4 = pf4 d n2 pf1;
s1 = dall c1 c2 c3 c4 plan;
vx = 0.34 0 0;
v1 = s1 volu tran 17 vx;
*
dist = 0.04;
tol = 0.0001;
vrac = pxracub8 (pf1 PLUS vx) (pf2 PLUS vx) (pf3 PLUS vx) (pf4 PLUS vx)
               n1 n2 dist tol;
*
vd = dist 0 0;
ppf1 = (pf1 PLUS vx) PLUS vd;
ppf2 = (pf2 PLUS vx) PLUS vd;
ppf3 = (pf3 PLUS vx) PLUS vd;
ppf4 = (pf4 PLUS vx) PLUS vd;
n12 = n1 + n1;
n22 = n2 + n2;
cc1 = ppf1 d n12 ppf2;
cc2 = ppf2 d n22 ppf3;
cc3 = ppf3 d n12 ppf4;
cc4 = ppf4 d n22 ppf1;
s2 = dall cc1 cc2 cc3 cc4 plan;
v2 = s2 volu tran 4 vd;
*
vxb = (vx PLUS vd) PLUS vd;
distb = 0.5*dist;
vracb = pxracub8 (pf1 PLUS vxb) (pf2 PLUS vxb) (pf3 PLUS vxb)
                 (pf4 PLUS vxb)
                  n12 n22 distb tol;
*
vdb = distb 0 0;
pppf1 = (ppf1 PLUS vd) PLUS vdb;
pppf2 = (ppf2 PLUS vd) PLUS vdb;
pppf3 = (ppf3 PLUS vd) PLUS vdb;
pppf4 = (ppf4 PLUS vd) PLUS vdb;
n13 = n12 + n12;
n23 = n22 + n22;
```

```
cc1b = pppf1 d n13 pppf2;
cc2b = pppf2 d n23 pppf3;
cc3b = pppf3 d n13 pppf4;
cc4b = pppf4 d n23 pppf1;
s3 = dall cc1b cc2b cc3b cc4b plan;
v3 = s3 volu tran (4*4) ((4*distb) 0 0);
*
ps1 = pppf1 PLUS ((4*distb) 0 0);
ps2 = pppf2 PLUS ((4*distb) 0 0);
ps3 = pppf3 PLUS ((4*distb) 0 0);
*
vr1 = vrac et v2 et vracb et v3;
elim tol vr1;
vr2 = vr1 SYME PLAN ps1 ps2 ps3;
*
s1c = s1 plus (0.70 0 0);
vxc = 1.30 0 0;
v3 = s1c volu tran 65 vxc;
*
flui = v1 et vr1 et vr2 et v3;
ELIM tol flui;
*
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach qual flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

draw24.epx

```
DRAW24
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM CUVF flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 3 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
            'fldr' LECT flui TERM COND XB GT 0.4
                                  COND XB LT 0.6
     NGRO 2 'nblo' LECT p0 TERM
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE GAZP RO 10.0 PINI 8.0E5 GAMM 1.4 PREF 0.8E5
          LECT expl TERM
     GAZP RO 1.0 PINI 0.8E5 GAMM 1.4 PREF 0.8E5
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
LINK DECO
     DRAG STRU LECT stru TERM
          FLUI LECT fldr TERM
          CD 1.98 LECT stru TERM
          NOFB
!         DGRI
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.25 LOG 1
     ADAP RCON
     VFCC FCON 6
          ORDR 2
          OTPS 2
          RECO 1
          NTIL
CALC TINI 0. TEND 20.E-3
FIN
```

draw24p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'draw24.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout01p.pun' RENA 'dx_POUT01'
RCOU 211 'vx_1' FICH 'pout01p.pun' RENA 'vx_POUT01'
RCOU 301 'dx_1' FICH 'drag11p.pun' RENA 'dx_DRAG11'
RCOU 311 'vx_1' FICH 'drag11p.pun' RENA 'vx_DRAG11'
RCOU 401 'dx_1' FICH 'drag12p.pun' RENA 'dx_DRAG12'
RCOU 411 'vx_1' FICH 'drag12p.pun' RENA 'vx_DRAG12'
RCOU 501 'dx_1' FICH 'drag13p.pun' RENA 'dx_DRAG13'
RCOU 511 'vx_1' FICH 'drag13p.pun' RENA 'vx_DRAG13'
RCOU 601 'dx_1' FICH 'drag14p.pun' RENA 'dx_DRAG14'
RCOU 611 'vx_1' FICH 'drag14p.pun' RENA 'vx_DRAG14'
RCOU 701 'dx_1' FICH 'drag15p.pun' RENA 'dx_DRAG15'
RCOU 711 'vx_1' FICH 'drag15p.pun' RENA 'vx_DRAG15'
TRAC 101 201 301 401 501 601 701 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ ROSE BLEU ROUG VERT NOIR
DASH 0    0    0    0    0    2    2    0
TRAC 111 211 311 411 511 611 711 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ ROSE BLEU ROUG VERT NOIR
DASH 0    0    0    0    0    2    2    0
TRAC 601 1 AXES 1.0 'DISP. [M]' YZER
COLO BLEU NOIR
TRAC 611 11 AXES 1.0 'VELO. [M/S]' YZER
COLO BLEU NOIR
FIN
```

draw24q2.epx

```
Post-treatment (animation from alice file)
ECHO
!CONV WIN
RESU SPLI ALIC 'draw24.ali' GARD PSCR
SORT VISU NSTO 1
*=====================================================================
PLAY
CAME   1 EYE   1.00000E+00 -5.74734E+00  4.91300E-01 ! Global view
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.00000E+00  0.00000E+00  4.91300E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
CAME   2 EYE   5.00000E-01 -5.74734E+00  4.00000E-01 ! Focus on structure
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   9.21120E+00
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  0.00000E+00  4.00000E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
SCEN GEOM NAVI FREE
SLER CAM1 2 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 31 FPS 5 KFRE 5 COMP -1
     OBJE LECT stru TERM REND
GOTR LOOP 29 OFFS FICH AVI CONT NOCL
     OBJE LECT stru TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT stru TERM REND
ENDPLAY
*=====================================================================
FIN
```

draw25.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'draw25_mesh.ps';
opti sauv form 'draw25.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.04;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
```

```
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

draw25.epx

```
DRAW25
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM CUVF flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 2 'nblo' LECT p0 TERM
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE GAZP RO 10.0 PINI 8.0E5 GAMM 1.4 PREF 0.8E5
          LECT expl TERM
     GAZP RO 1.0 PINI 0.8E5 GAMM 1.4 PREF 0.8E5
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
LINK DECO
     DRAG STRU LECT stru TERM
          FLUI LECT flui TERM
          CD 1.98 LECT stru TERM
          DGRI NOFB
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 6
          ORDR 2
          OTPS 2
          RECO 1
          NTIL
CALC TINI 0. TEND 20.E-3
FIN
```

draw25p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'draw25.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout01p.pun' RENA 'dx_POUT01'
RCOU 211 'vx_1' FICH 'pout01p.pun' RENA 'vx_POUT01'
RCOU 301 'dx_1' FICH 'drag11p.pun' RENA 'dx_DRAG11'
RCOU 311 'vx_1' FICH 'drag11p.pun' RENA 'vx_DRAG11'
RCOU 401 'dx_1' FICH 'drag12p.pun' RENA 'dx_DRAG12'
RCOU 411 'vx_1' FICH 'drag12p.pun' RENA 'vx_DRAG12'
RCOU 501 'dx_1' FICH 'drag13p.pun' RENA 'dx_DRAG13'
RCOU 511 'vx_1' FICH 'drag13p.pun' RENA 'vx_DRAG13'
RCOU 601 'dx_1' FICH 'drag14p.pun' RENA 'dx_DRAG14'
RCOU 611 'vx_1' FICH 'drag14p.pun' RENA 'vx_DRAG14'
RCOU 701 'dx_1' FICH 'drag15p.pun' RENA 'dx_DRAG15'
RCOU 711 'vx_1' FICH 'drag15p.pun' RENA 'vx_DRAG15'
RCOU 801 'dx_1' FICH 'drag21p.pun' RENA 'dx_DRAG21'
RCOU 811 'vx_1' FICH 'drag21p.pun' RENA 'vx_DRAG21'
RCOU 901 'dx_1' FICH 'drag22p.pun' RENA 'dx_DRAG22'
RCOU 911 'vx_1' FICH 'drag22p.pun' RENA 'vx_DRAG22'
RCOU 1001 'dx_1' FICH 'drag23p.pun' RENA 'dx_DRAG23'
RCOU 1011 'vx_1' FICH 'drag23p.pun' RENA 'vx_DRAG23'
RCOU 1101 'dx_1' FICH 'drag24p.pun' RENA 'dx_DRAG24'
RCOU 1111 'vx_1' FICH 'drag24p.pun' RENA 'vx_DRAG24'
RCOU 1201 'dx_1' FICH 'drag25p.pun' RENA 'dx_DRAG25'
RCOU 1211 'vx_1' FICH 'drag25p.pun' RENA 'vx_DRAG25'
TRAC 1201 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG NOIR
TRAC 1211 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG NOIR
*TRAC 101 201 301 401 501 601 701 1 AXES 1.0 'DISP. [M]' YZER
*COLO ROUG VERT TURQ ROSE ROUG VERT TURQ NOIR
*DASH 0    0    0    0    2    2    2    0
*TRAC 111 211 311 411 511 611 711 11 AXES 1.0 'VELO. [M/S]' YZER
*COLO ROUG VERT TURQ ROSE ROUG VERT TURQ NOIR
*DASH 0    0    0    0    2    2    2    0
*TRAC 101 201 801 901 1001 1101 1 AXES 1.0 'DISP. [M]' YZER
*COLO ROUG VERT TURQ ROSE ROUG VERT NOIR
*DASH 0    0    0    0    2    2    0
*TRAC 111 211 811 911 1011 1111 11 AXES 1.0 'VELO. [M/S]' YZER
*COLO ROUG VERT TURQ ROSE ROUG VERT NOIR
*DASH 0    0    0    0    2    2    0
*TRAC 801 901 1001 1101 1 AXES 1.0 'DISP. [M]' YZER
*COLO ROUG VERT TURQ ROSE NOIR
*TRAC 811 911 1011 1111 11 AXES 1.0 'VELO. [M/S]' YZER
*COLO ROUG VERT TURQ ROSE NOIR
FIN
```

draw25p2.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'draw25.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU  101 'dx_1' FICH 'drag21p.pun' RENA 'dx_DRAG21'
RCOU  111 'vx_1' FICH 'drag21p.pun' RENA 'vx_DRAG21'
RCOU  201 'dx_1' FICH 'drag22p.pun' RENA 'dx_DRAG22'
RCOU  211 'vx_1' FICH 'drag22p.pun' RENA 'vx_DRAG22'
RCOU  301 'dx_1' FICH 'drag23p.pun' RENA 'dx_DRAG23'
RCOU  311 'vx_1' FICH 'drag23p.pun' RENA 'vx_DRAG23'
RCOU  401 'dx_1' FICH 'drag24p.pun' RENA 'dx_DRAG24'
RCOU  411 'vx_1' FICH 'drag24p.pun' RENA 'vx_DRAG24'
RCOU  501 'dx_1' FICH 'drag25p.pun' RENA 'dx_DRAG25'
RCOU  511 'vx_1' FICH 'drag25p.pun' RENA 'vx_DRAG25'
RCOU 1101 'dx_1' FICH 'draw21p.pun' RENA 'dx_DRAW21'
RCOU 1111 'vx_1' FICH 'draw21p.pun' RENA 'vx_DRAW21'
RCOU 1201 'dx_1' FICH 'draw22p.pun' RENA 'dx_DRAW22'
RCOU 1211 'vx_1' FICH 'draw22p.pun' RENA 'vx_DRAW22'
RCOU 1301 'dx_1' FICH 'draw23p.pun' RENA 'dx_DRAW23'
RCOU 1311 'vx_1' FICH 'draw23p.pun' RENA 'vx_DRAW23'
RCOU 1401 'dx_1' FICH 'draw24p.pun' RENA 'dx_DRAW24'
RCOU 1411 'vx_1' FICH 'draw24p.pun' RENA 'vx_DRAW24'
TRAC 101 201 301 401 501 1101 1201 1301 1401 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ ROSE NOIR ROUG VERT TURQ ROSE NOIR
DASH 0    0    0    0    0    2    2    2    2    2
TRAC 111 211 311 411 511 1111 1211 1311 1411 11
     AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ ROSE NOIR ROUG VERT TURQ ROSE NOIR
DASH 0    0    0    0    0    2    2    2    2    2
FIN
```

flsr01.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'flsr01_mesh.ps';
opti sauv form 'flsr01.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
lsx = 0.04;
lsy = 0.04;
lsz = 0.80;
xs0 = 0.5 - (0.5*lsx);
ys0 = 0.0 - (0.5*lsy);
zs0 = 0.0;
dds = 0.04;
stru = pxbox3d xs0 ys0 zs0 lsx lsy lsz dds;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

flsr01.epx

```
FLSR01
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui CUB8 stru TERM
COMP GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
```

```
     NGRO 3 'nblo' LECT stru TERM COND Z LT 0.001
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT stru TERM COND Z GT 0.799
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          HGRI 0.041 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

flsr01p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'flsr01.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT 134007 TERM
COUR 2 'dx_2' DEPL COMP 1 NOEU LECT 134008 TERM
COUR 3 'dx_3' DEPL COMP 1 NOEU LECT 134009 TERM
COUR 4 'dx_4' DEPL COMP 1 NOEU LECT 134010 TERM
COUR 10 'dx_mean' MEAN 4 1 2 3 4
TRAC 1 2 3 4 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 3 4 AXES 1.0 'DISP. [M]' YZER
TRAC 10 AXES 1.0 'DISP. [M]' YZER
LIST 10 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT 134007 TERM
COUR 12 'vx_2' VITE COMP 1 NOEU LECT 134008 TERM
COUR 13 'vx_3' VITE COMP 1 NOEU LECT 134009 TERM
COUR 14 'vx_4' VITE COMP 1 NOEU LECT 134010 TERM
COUR 20 'vx_mean' MEAN 4 11 12 13 14
TRAC 11 12 13 14 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 12 13 14 AXES 1.0 'VELO. [M/S]' YZER
TRAC 20 AXES 1.0 'VELO. [M/S]' YZER
LIST 20 AXES 1.0 'VELO. [M/S]' YZER
TRAC 1 2 3 4 10 AXES 1.0 'DISP. [M]' YZER
COLO NOIR NOIR NOIR NOIR ROUG
TRAC 11 12 13 14 20 AXES 1.0 'VELO. [M/S]' YZER
COLO NOIR NOIR NOIR NOIR ROUG
FIN
```

flsr01q.epx

```
Post-treatment (animation from alice file)
ECHO
!CONV WIN
RESU SPLI ALIC 'flsr01.ali' GARD PSCR
SORT VISU NSTO 1
*======================================================================
PLAY
CAME   1 EYE   1.00000E+00 -5.74734E+00  4.91300E-01 ! Global view
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.00000E+00  0.00000E+00  4.91300E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
CAME   2 EYE   5.00000E-01 -5.74734E+00  4.00000E-01 ! Focus on structure
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   9.21120E+00
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  0.00000E+00  4.00000E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
SCEN GEOM NAVI FREE
SLER CAM1 2 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 5 KFRE 5 COMP -1
     OBJE LECT stru TERM REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL
     OBJE LECT stru TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT stru TERM REND
ENDPLAY
*======================================================================
FIN
```

flsr01r.epx

```
Post-treatment (animation from alice file)
ECHO
!CONV WIN
RESU SPLI ALIC 'flsr01.ali' GARD PSCR
SORT VISU NSTO 1
*======================================================================
PLAY
CAME   1 EYE   1.00000E+00 -5.74734E+00  4.91300E-01 ! Global view
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.00000E+00  0.00000E+00  4.91300E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
CAME   2 EYE   5.00000E-01 -5.74734E+00  4.00000E-01 ! Focus on structure
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   9.21120E+00
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  0.00000E+00  4.00000E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
SCEN GEOM NAVI FREE
          LINE HEOU SSHA
     ISO  SURF FIEL VITE SCAL USER PROG 10 PAS 10 140 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 5 KFRE 5 COMP -1
     OBJE LECT flui TERM REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL
     OBJE LECT flui TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT flui TERM REND
ENDPLAY
*======================================================================
FIN
```

flsr01s.epx

```
Post-treatment (animation from alice file)
ECHO
!CONV WIN
RESU SPLI ALIC 'flsr01.ali' GARD PSCR
SORT VISU NSTO 1
*======================================================================
PLAY
CAME   1 EYE   1.00000E+00 -5.74734E+00  4.91300E-01 ! Global view
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.00000E+00  0.00000E+00  4.91300E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
CAME   2 EYE   5.00000E-01 -5.74734E+00  4.00000E-01 ! Focus on structure
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   9.21120E+00
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  0.00000E+00  4.00000E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
```

```
!FAR    :  8.04627E+00
SCEN GEOM NAVI FREE
          LINE HEOU SSHA
     ISO  FILL FIEL VITE SCAL USER PROG 10 PAS 10 140 TERM
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 5 KFRE 5 COMP -1
     OBJE LECT flui TERM REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL
     OBJE LECT flui TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT flui TERM REND
ENDPLAY
*======================================================================
FIN
```

flsr01t.epx

```
Post-treatment (animation from alice file)
ECHO
!CONV WIN
RESU SPLI ALIC 'flsr01.ali' GARD PSCR
COMP GROU 1 'fluiy' LECT flui TERM COND YB GT 0.0
SORT VISU NSTO 1
*======================================================================
PLAY
CAME   1 EYE   1.00000E+00 -5.74734E+00  4.91300E-01 ! Global view
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.00000E+00  0.00000E+00  4.91300E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
CAME   2 EYE   5.00000E-01 -5.74734E+00  4.00000E-01 ! Focus on structure
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   9.21120E+00
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  0.00000E+00  4.00000E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
SCEN GEOM NAVI FREE
          LINE HEOU !SSHA
     ISO  FILL FIEL ECRO 1 SCAL USER PROG 0.25E5 PAS 0.25E5 3.5E5 TERM
          SUPP LECT fluiy TERM
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 5 KFRE 5 COMP -1
     OBJE LECT fluiy stru TERM REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL
     OBJE LECT fluiy stru TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT fluiy stru TERM REND
ENDPLAY
*======================================================================
FIN
```

flsr01u.epx

```
Post-treatment (animation from alice file)
ECHO
!CONV WIN
RESU SPLI ALIC 'flsr01.ali' GARD PSCR
SORT VISU NSTO 1
*======================================================================
PLAY
CAME   1 EYE   1.00000E+00 -5.74734E+00  4.91300E-01 ! Global side view
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.00000E+00  0.00000E+00  4.91300E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
CAME   2 EYE   5.00000E-01 -5.74734E+00  4.00000E-01 ! Focus on structure
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   9.21120E+00
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  0.00000E+00  4.00000E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
CAME   3 EYE   1.00000E+00  2.35760E-09 -5.25604E+00 ! Global from bottom
!        Q    -2.05104E-10  1.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00 -4.10207E-10  1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -1.00000E+00 -4.10207E-10
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.00000E+00  0.00000E+00  4.91300E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
SCEN GEOM NAVI FREE
          LINE HEOU !SSHA
     ISO  FILL FIEL ECRO 1 SCAL USER PROG 0.25E5 PAS 0.25E5 3.5E5 TERM
          SUPP LECT flui TERM
     LIMA ON
SLER CAM1 3 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 5 KFRE 5 COMP -1
     OBJE LECT flui TERM REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL
     OBJE LECT flui TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT flui TERM REND
ENDPLAY
*======================================================================
FIN
```

flsr01v.epx

```
Post-treatment (animation from alice file)
ECHO
!CONV WIN
RESU SPLI ALIC 'flsr01.ali' GARD PSCR
SORT VISU NSTO 1
*======================================================================
PLAY
CAME   1 EYE   1.00000E+00 -5.74734E+00  4.91300E-01 ! Global side view
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.00000E+00  0.00000E+00  4.91300E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
CAME   2 EYE   5.00000E-01 -5.74734E+00  4.00000E-01 ! Focus on structure
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   9.21120E+00
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  0.00000E+00  4.00000E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
CAME   3 EYE   1.00000E+00  2.35760E-09 -5.25604E+00 ! Global from bottom
!        Q    -2.05104E-10  1.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00 -4.10207E-10  1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -1.00000E+00 -4.10207E-10
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.00000E+00  0.00000E+00  4.91300E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
SCEN GEOM NAVI FREE
          FACE HFRO
          LINE HEOU SSHA
     VECT SCCO FIEL VITE SCAL USER PROG 30 PAS 30 420 TERM
          SUPP LECT flui TERM
          SIVE
SLER CAM1 3 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 5 KFRE 5 COMP -1
     OBJE LECT flui TERM REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL
     OBJE LECT flui TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT flui TERM REND
ENDPLAY
*======================================================================
FIN
```

flsr02.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'flsr02_mesh.ps';
opti sauv form 'flsr02.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.01;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
lsx = 0.04;
lsy = 0.04;
lsz = 0.80;
xs0 = 0.5 - (0.5*lsx);
ys0 = 0.0 - (0.5*lsy);
zs0 = 0.0;
dds = 0.02;
stru = pxbox3d xs0 ys0 zs0 lsx lsy lsz dds;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

flsr02.epx

```
FLSR02
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui CUB8 stru TERM
COMP GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT stru TERM COND Z LT 0.001
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT stru TERM COND Z GT 0.799
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 0.87E-2  ! R = 0.87 h_flui = 0.87 x 0.01
          HGRI 0.021 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

flsr02p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'flsr02.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT 1035712 TERM
COUR 2 'dx_2' DEPL COMP 1 NOEU LECT 1035713 TERM
COUR 3 'dx_3' DEPL COMP 1 NOEU LECT 1035714 TERM
COUR 4 'dx_4' DEPL COMP 1 NOEU LECT 1035715 TERM
COUR 5 'dx_5' DEPL COMP 1 NOEU LECT 1035716 TERM
COUR 6 'dx_6' DEPL COMP 1 NOEU LECT 1035717 TERM
COUR 7 'dx_7' DEPL COMP 1 NOEU LECT 1035718 TERM
COUR 8 'dx_8' DEPL COMP 1 NOEU LECT 1035719 TERM
COUR 9 'dx_9' DEPL COMP 1 NOEU LECT 1035720 TERM
COUR 10 'dx_mean' MEAN 9 1 2 3 4 5 6 7 8 9
TRAC 1 2 3 4 5 6 7 8 9 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 3 4 5 6 7 8 9 AXES 1.0 'DISP. [M]' YZER
TRAC 10 AXES 1.0 'DISP. [M]' YZER
LIST 10 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT 1035712 TERM
COUR 12 'vx_2' VITE COMP 1 NOEU LECT 1035713 TERM
COUR 13 'vx_3' VITE COMP 1 NOEU LECT 1035714 TERM
COUR 14 'vx_4' VITE COMP 1 NOEU LECT 1035715 TERM
COUR 15 'vx_5' VITE COMP 1 NOEU LECT 1035716 TERM
COUR 16 'vx_6' VITE COMP 1 NOEU LECT 1035717 TERM
COUR 17 'vx_7' VITE COMP 1 NOEU LECT 1035718 TERM
COUR 18 'vx_8' VITE COMP 1 NOEU LECT 1035719 TERM
COUR 19 'vx_9' VITE COMP 1 NOEU LECT 1035720 TERM
COUR 20 'vx_mean' MEAN 9 11 12 13 14 15 16 17 18 19
TRAC 11 12 13 14 15 16 17 18 19 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 12 13 14 15 16 17 18 19 AXES 1.0 'VELO. [M/S]' YZER
TRAC 20 AXES 1.0 'VELO. [M/S]' YZER
LIST 20 AXES 1.0 'VELO. [M/S]' YZER
TRAC 1 2 3 4 5 6 7 8 9 10 AXES 1.0 'DISP. [M]' YZER
COLO NOIR NOIR NOIR NOIR NOIR NOIR NOIR NOIR NOIR ROUG
TRAC 11 12 13 14 15 16 17 18 19 20 AXES 1.0 'VELO. [M/S]' YZER
COLO NOIR NOIR NOIR NOIR NOIR NOIR NOIR NOIR NOIR ROUG
RCOU 110 'dx_mean' FICH 'flsr01p.pun' RENA 'dx_mean_01'
RCOU 120 'vx_mean' FICH 'flsr01p.pun' RENA 'vx_mean_01'
TRAC 110 10 AXES 1.0 'DISP. [M]' YZER
COLO ROUG NOIR
TRAC 120 20 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG NOIR
FIN
```

flsr03.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'flsr03_mesh.ps';
opti sauv form 'flsr03.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
lsx = 0.04;
lsy = 0.04;
lsz = 0.80;
xs0 = 0.5 - (0.5*lsx);
ys0 = 0.0 - (0.5*lsy);
zs0 = 0.0;
dds = 0.04;
stru = pxbox3d xs0 ys0 zs0 lsx lsy lsz dds;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

flsr03.epx

```
FLSR03
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME ADAP NPOI 100000 FL38 100000 ENDA TERM
GEOM FL38 flui CUB8 stru TERM
COMP GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT stru TERM COND Z LT 0.001
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT stru TERM COND Z GT 0.799
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air _fl38 TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          HGRI 0.041 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
          ADAP LMAX 3 SCAL 2.0
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
```

```
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

flsr03p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'flsr03.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT 134007 TERM
COUR 2 'dx_2' DEPL COMP 1 NOEU LECT 134008 TERM
COUR 3 'dx_3' DEPL COMP 1 NOEU LECT 134009 TERM
COUR 4 'dx_4' DEPL COMP 1 NOEU LECT 134010 TERM
COUR 10 'dx_mean' MEAN 4 1 2 3 4
TRAC 1 2 3 4 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 3 4 AXES 1.0 'DISP. [M]' YZER
TRAC 10 AXES 1.0 'DISP. [M]' YZER
LIST 10 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT 134007 TERM
COUR 12 'vx_2' VITE COMP 1 NOEU LECT 134008 TERM
COUR 13 'vx_3' VITE COMP 1 NOEU LECT 134009 TERM
COUR 14 'vx_4' VITE COMP 1 NOEU LECT 134010 TERM
COUR 20 'vx_mean' MEAN 4 11 12 13 14
TRAC 11 12 13 14 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 12 13 14 AXES 1.0 'VELO. [M/S]' YZER
TRAC 20 AXES 1.0 'VELO. [M/S]' YZER
LIST 20 AXES 1.0 'VELO. [M/S]' YZER
TRAC 1 2 3 4 10 AXES 1.0 'DISP. [M]' YZER
COLO NOIR NOIR NOIR NOIR ROUG
TRAC 11 12 13 14 20 AXES 1.0 'VELO. [M/S]' YZER
COLO NOIR NOIR NOIR NOIR ROUG
RCOU 110 'dx_mean' FICH 'flsr01p.pun' RENA 'dx_mean_01'
RCOU 120 'vx_mean' FICH 'flsr01p.pun' RENA 'vx_mean_01'
RCOU 210 'dx_mean' FICH 'flsr02p.pun' RENA 'dx_mean_02'
RCOU 220 'vx_mean' FICH 'flsr02p.pun' RENA 'vx_mean_02'
TRAC 110 210 10 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT NOIR
TRAC 120 220 20 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT NOIR
FIN
```

flsw01.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'flsw01_mesh.ps';
opti sauv form 'flsw01.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
lsx = 0.04;
lsy = 0.04;
lsz = 0.80;
xs0 = 0.5 - (0.5*lsx);
ys0 = 0.0 - (0.5*lsy);
zs0 = 0.0;
dds = 0.04;
stru = pxbox3d xs0 ys0 zs0 lsx lsy lsz dds;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

flsw01.epx

```
FLSW01
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM CUVF flui CUB8 stru TERM
COMP GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 2 'nblo' LECT stru TERM COND Z LT 0.001
            'ntop' LECT stru TERM COND Z GT 0.799
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE GAZP RO 10.0 PINI 8.0E5 GAMM 1.4 PREF 0.8E5
          LECT expl TERM
     GAZP RO 1.0 PINI 0.8E5 GAMM 1.4 PREF 0.8E5
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
LINK DECO FLSW STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          HGRI 0.041 ! HGRI > max (h_fluid, h_stru)
          DGRI
          FACE
          BFLU 1
          FSCP 1
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 6
          ORDR 2
          OTPS 2
          RECO 1
CALC TINI 0. TEND 20.E-3
FIN
```

flsw01p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'flsw01.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT 134007 TERM
COUR 2 'dx_2' DEPL COMP 1 NOEU LECT 134008 TERM
COUR 3 'dx_3' DEPL COMP 1 NOEU LECT 134009 TERM
COUR 4 'dx_4' DEPL COMP 1 NOEU LECT 134010 TERM
COUR 10 'dx_mean' MEAN 4 1 2 3 4
TRAC 1 2 3 4 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 3 4 AXES 1.0 'DISP. [M]' YZER
TRAC 10 AXES 1.0 'DISP. [M]' YZER
LIST 10 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT 134007 TERM
COUR 12 'vx_2' VITE COMP 1 NOEU LECT 134008 TERM
COUR 13 'vx_3' VITE COMP 1 NOEU LECT 134009 TERM
COUR 14 'vx_4' VITE COMP 1 NOEU LECT 134010 TERM
COUR 20 'vx_mean' MEAN 4 11 12 13 14
TRAC 11 12 13 14 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 12 13 14 AXES 1.0 'VELO. [M/S]' YZER
TRAC 20 AXES 1.0 'VELO. [M/S]' YZER
LIST 20 AXES 1.0 'VELO. [M/S]' YZER
TRAC 1 2 3 4 10 AXES 1.0 'DISP. [M]' YZER
COLO NOIR NOIR NOIR NOIR ROUG
TRAC 11 12 13 14 20 AXES 1.0 'VELO. [M/S]' YZER
COLO NOIR NOIR NOIR NOIR ROUG
RCOU 110 'dx_mean' FICH 'flsr01p.pun' RENA 'dx_mean_r01'
RCOU 120 'vx_mean' FICH 'flsr01p.pun' RENA 'vx_mean_r01'
TRAC 110 10 AXES 1.0 'DISP. [M]' YZER
COLO ROUG NOIR
TRAC 120 20 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG NOIR
FIN
```

flsw01w.epx

```
Post-treatment (animation from alice file)
ECHO
!CONV WIN
RESU SPLI ALIC 'flsw01.ali' GARD PSCR
SORT VISU NSTO 1
*=======================================================================
PLAY
CAME   1 EYE   1.00000E+00 -5.74734E+00  4.91300E-01 ! Global side view
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.00000E+00  0.00000E+00  4.91300E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
CAME   2 EYE   5.00000E-01 -5.74734E+00  4.00000E-01 ! Focus on structure
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   9.21120E+00
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  0.00000E+00  4.00000E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
CAME   3 EYE   1.00000E+00  2.35760E-09 -5.25604E+00 ! Global from bottom
!        Q    -2.05104E-10  1.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00 -4.10207E-10  1.00000E+00
```

```
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -1.00000E+00 -4.10207E-10
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.00000E+00  0.00000E+00  4.91300E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
SCEN GEOM NAVI FREE
          FACE HFRO
          LINE HEOU SSHA
     VECT SCCO FIEL FDEC SCAL USER PROG 20 PAS 20 280 TERM
          SUPP LECT stru DIFF nblo TERM
          SIVE
SLER CAM1 2 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 5 KFRE 5 COMP -1
     OBJE LECT stru TERM REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL
     OBJE LECT stru TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT stru TERM REND
ENDPLAY
*=====================================================================
FIN
```

flsw02.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'flsw02_mesh.ps';
opti sauv form 'flsw02.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.01;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
lsx = 0.04;
lsy = 0.04;
lsz = 0.80;
xs0 = 0.5 - (0.5*lsx);
ys0 = 0.0 - (0.5*lsy);
zs0 = 0.0;
dds = 0.02;
stru = pxbox3d xs0 ys0 zs0 lsx lsy lsz dds;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

flsw02.epx

```
FLSW02
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM CUVF flui CUB8 stru TERM
COMP GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 2 'nblo' LECT stru TERM COND Z LT 0.001
            'ntop' LECT stru TERM COND Z GT 0.799
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE GAZP RO 10.0 PINI 8.0E5 GAMM 1.4 PREF 0.8E5
          LECT expl TERM
     GAZP RO 1.0 PINI 0.8E5 GAMM 1.4 PREF 0.8E5
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
LINK DECO FLSW STRU LECT stru TERM
          FLUI LECT flui TERM
          R 0.87E-2  ! R = 0.87 h_flui = 0.87 x 0.01
          HGRI 0.021 ! HGRI > max (h_fluid, h_stru)
          DGRI
          FACE
          BFLU 1
          FSCP 1
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 6
          ORDR 2
          OTPS 2
          RECO 1
          NTIL
CALC TINI 0. TEND 20.E-3
FIN
```

flsw02p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'flsw02.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT 1035712 TERM
COUR 2 'dx_2' DEPL COMP 1 NOEU LECT 1035713 TERM
COUR 3 'dx_3' DEPL COMP 1 NOEU LECT 1035714 TERM
COUR 4 'dx_4' DEPL COMP 1 NOEU LECT 1035715 TERM
COUR 5 'dx_5' DEPL COMP 1 NOEU LECT 1035716 TERM
COUR 6 'dx_6' DEPL COMP 1 NOEU LECT 1035717 TERM
COUR 7 'dx_7' DEPL COMP 1 NOEU LECT 1035718 TERM
COUR 8 'dx_8' DEPL COMP 1 NOEU LECT 1035719 TERM
COUR 9 'dx_9' DEPL COMP 1 NOEU LECT 1035720 TERM
COUR 10 'dx_mean' MEAN 9 1 2 3 4 5 6 7 8 9
TRAC 1 2 3 4 5 6 7 8 9 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 3 4 5 6 7 8 9 AXES 1.0 'DISP. [M]' YZER
TRAC 10 AXES 1.0 'DISP. [M]' YZER
LIST 10 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT 1035712 TERM
COUR 12 'vx_2' VITE COMP 1 NOEU LECT 1035713 TERM
COUR 13 'vx_3' VITE COMP 1 NOEU LECT 1035714 TERM
COUR 14 'vx_4' VITE COMP 1 NOEU LECT 1035715 TERM
COUR 15 'vx_5' VITE COMP 1 NOEU LECT 1035716 TERM
COUR 16 'vx_6' VITE COMP 1 NOEU LECT 1035717 TERM
COUR 17 'vx_7' VITE COMP 1 NOEU LECT 1035718 TERM
COUR 18 'vx_8' VITE COMP 1 NOEU LECT 1035719 TERM
COUR 19 'vx_9' VITE COMP 1 NOEU LECT 1035720 TERM
COUR 20 'vx_mean' MEAN 9 11 12 13 14 15 16 17 18 19
TRAC 11 12 13 14 15 16 17 18 19 20 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 12 13 14 15 16 17 18 19 20 AXES 1.0 'VELO. [M/S]' YZER
TRAC 20 AXES 1.0 'VELO. [M/S]' YZER
LIST 20 AXES 1.0 'VELO. [M/S]' YZER
TRAC 1 2 3 4 5 6 7 8 9 10 AXES 1.0 'DISP. [M]' YZER
COLO NOIR NOIR NOIR NOIR NOIR NOIR NOIR NOIR NOIR ROUG
TRAC 11 12 13 14 15 16 17 18 19 20 AXES 1.0 'VELO. [M/S]' YZER
COLO NOIR NOIR NOIR NOIR NOIR NOIR NOIR NOIR NOIR ROUG
RCOU 110 'dx_mean' FICH 'flsr02p.pun' RENA 'dx_mean_r02'
RCOU 120 'vx_mean' FICH 'flsr02p.pun' RENA 'vx_mean_r02'
TRAC 110 10 AXES 1.0 'DISP. [M]' YZER
COLO ROUG NOIR
TRAC 120 20 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG NOIR
FIN
```

flsw03.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'flsw03_mesh.ps';
opti sauv form 'flsw03.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
lsx = 0.04;
lsy = 0.04;
lsz = 0.80;
xs0 = 0.5 - (0.5*lsx);
ys0 = 0.0 - (0.5*lsy);
zs0 = 0.0;
dds = 0.04;
stru = pxbox3d xs0 ys0 zs0 lsx lsy lsz dds;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

flsw03.epx

```
FLSW03
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME ADAP NPOI 100000 CUVF 100000 NVFI 300000 ENDA TERM
GEOM CUVF flui CUB8 stru TERM
COMP GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 2 'nblo' LECT stru TERM COND Z LT 0.001
            'ntop' LECT stru TERM COND Z GT 0.799
```

```
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE GAZP RO 10.0 PINI 8.0E5 GAMM 1.4 PREF 0.8E5
          LECT expl TERM
     GAZP RO 1.0 PINI 0.8E5 GAMM 1.4 PREF 0.8E5
          LECT air _cuvf TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
LINK DECO FLSW STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          HGRI 0.041 ! HGRI > max (h_fluid, h_stru)
          DGRI
          FACE
          BFLU 1
          FSCP 1
          ADAP LMAX 3 SCAL 2.0
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 6
          ORDR 2
          OTPS 2
          RECO 1
          NTIL
CALC TINI 0. TEND 20.E-3
FIN
```

flsw03p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'flsw03.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT 134007 TERM
COUR 2 'dx_2' DEPL COMP 1 NOEU LECT 134008 TERM
COUR 3 'dx_3' DEPL COMP 1 NOEU LECT 134009 TERM
COUR 4 'dx_4' DEPL COMP 1 NOEU LECT 134010 TERM
COUR 10 'dx_mean' MEAN 4 1 2 3 4
TRAC 1 2 3 4 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 3 4 AXES 1.0 'DISP. [M]' YZER
TRAC 10 AXES 1.0 'DISP. [M]' YZER
LIST 10 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT 134007 TERM
COUR 12 'vx_2' VITE COMP 1 NOEU LECT 134008 TERM
COUR 13 'vx_3' VITE COMP 1 NOEU LECT 134009 TERM
COUR 14 'vx_4' VITE COMP 1 NOEU LECT 134010 TERM
COUR 20 'vx_mean' MEAN 4 11 12 13 14
TRAC 11 12 13 14 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 12 13 14 AXES 1.0 'VELO. [M/S]' YZER
TRAC 20 AXES 1.0 'VELO. [M/S]' YZER
LIST 20 AXES 1.0 'VELO. [M/S]' YZER
TRAC 1 2 3 4 10 AXES 1.0 'DISP. [M]' YZER
COLO NOIR NOIR NOIR NOIR ROUG
TRAC 11 12 13 14 20 AXES 1.0 'VELO. [M/S]' YZER
COLO NOIR NOIR NOIR NOIR ROUG
RCOU 110 'dx_mean' FICH 'flsw01p.pun' RENA 'dx_mean_01'
RCOU 120 'vx_mean' FICH 'flsw01p.pun' RENA 'vx_mean_01'
RCOU 210 'dx_mean' FICH 'flsw02p.pun' RENA 'dx_mean_02'
RCOU 220 'vx_mean' FICH 'flsw02p.pun' RENA 'vx_mean_02'
RCOU 310 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_mean_r03'
RCOU 320 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_mean_r03'
TRAC 110 210 10 310 AXES 1.0 'DISP. [M]' YZER
COLO VERT TURQ NOIR ROUG
TRAC 120 220 20 320 AXES 1.0 'VELO. [M/S]' YZER
COLO VERT TURQ NOIR ROUG
FIN
```

fsia01.epx

```
FSIA01
ECHO
 CONV WIN
ALE TRID
 DIME ADAP NPOI 33 FL38 16 ENDA TERM   ! For LMAX 2
!DIME ADAP NPOI 213 FL38 144 ENDA TERM ! For LMAX 3
GEOM LIBR POIN 14 FL38 2 POUT 1 TERM
 0 0 0  1 0 0  1 1 0  0 1 0
 0 0 1  1 0 1  1 1 1  0 1 1
 0 0 2  1 0 2  1 1 2  0 1 2
 0.50 0.50 0.25
 0.50 0.50 1.75
 1 2 3 4 5 6 7 8
 5 6 7 8 9 10 11 12
 13 14
COMP GROU 2 'flui' LECT 1 2 TERM
            'stru' LECT 3 TERM
     GEOP RECT VX 0 VY 1 VZ 0 AY 0.5 AZ 0.5
          LECT stru TERM
     COUL TURQ LECT flui TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT flui _fl38 TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 0.87
          HGRI 2.1 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
          ADAP LMAX 2 SCAL 1.0
ECRI DEPL VITE TFRE 2.E-4
     FICH ALIC FREQ 1
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3 NMAX 0
FIN
```

fsir04.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'fsir04_mesh.ps';
opti sauv form 'fsir04.msh';
lx = 8.0;
ly = 1.0;
lz = 4.0;
x0 = 0.0;
y0 = 0.0;
z0 = 0.0;
dd = 0.2;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
pp1 = lx 0 0;
pp2 = lx ly 0;
pp3 = lx ly lz;
pp4 = lx 0 lz;
c1 = pp1 d pp2;
c2 = pp2 d pp3;
c3 = pp3 d pp4;
c4 = pp4 d pp1;
abso = dall c1 c2 c3 c4 plan;
tol =0.001;
elim tol (flui et abso);
dds = 1.0;
dens dds;
xs0 = 3.0;
ys0 = 0.5;
zs0 = 2.0;
p0 = xs0 ys0 zs0;
xs1 = 7.0;
ys1 = 0.5;
zs1 = 2.0;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
nf1 = chan poi1 (enve flui);
nf2 = chan poi1 abso;
nf3 = chan poi1 (cont abso);
fsrn = (nf1 diff nf2) et nf3;
mesh = flui et stru et abso et fsrn;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
trac cach (toto et stru et abso);
fin;
```

fsir04.epx

```
FSIR04
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru CL3Q abso TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 2.0
            'air'  LECT flui DIFF expl TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
          JAUN LECT abso TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
```

```
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
     IMPE ABSI LECT abso TERM
!opti dump
LINK COUP SPLT NONE
     FSR      LECT fsrn TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-1  ! R = 0.87 h_flui = 0.87 x 0.2
          HGRI 1.1 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT p0 p1 TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT p0 p1 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

fsir04b.epx

```
FSIR04
ECHO
 CONV WIN
CAST 'fsir04.msh' mesh
ALE TRID
GEOM FL38 flui POUT stru CL3Q abso TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 2.0
            'air'  LECT flui DIFF expl TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
          JAUN LECT abso TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
     IMPE ABSI LECT abso TERM
!opti dump
LINK COUP SPLT NONE
     FSR      LECT fsrn TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-1  ! R = 0.87 h_flui = 0.87 x 0.2
          HGRI 1.1 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT p0 p1 TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT p0 p1 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3 NMAX 0
PLAY
CAME   1 EYE   4.00000E+00 -2.20000E+01  2.00000E+00
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  4.00000E+00  5.00000E-01  2.00000E+00
!RSPHERE:  4.50000E+00
!RADIUS :  2.25000E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.75500E+01
!FAR    :  3.15000E+01
SCEN OBJE USLM LECT flui TERM
          DHAS CGLA
     GEOM NAVI FREE
          LINE HEOU SSHA
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH BMP REND
STOP
ENDPLAY
FIN
```

fsir04p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'fsir04.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_p0' DEPL COMP 1 NOEU LECT p0 TERM
COUR 2 'dx_p1' DEPL COMP 1 NOEU LECT p1 TERM
TRAC 1 2 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_p0' VITE COMP 1 NOEU LECT p0 TERM
COUR 12 'vx_p1' VITE COMP 1 NOEU LECT p1 TERM
TRAC 11 12 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 12 AXES 1.0 'VELO. [M/S]' YZER
FIN
```

fsir05.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'fsir05_mesh.ps';
opti sauv form 'fsir05.msh';
lx = 8.0;
ly = 1.0;
lz = 4.0;
x0 = 0.0;
y0 = 0.0;
z0 = 0.0;
dd = 0.2;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
pp1 = lx 0 0;
pp2 = lx ly 0;
pp3 = lx ly lz;
pp4 = lx 0 lz;
c1 = pp1 d pp2;
c2 = pp2 d pp3;
c3 = pp3 d pp4;
c4 = pp4 d pp1;
abso = dall c1 c2 c3 c4 plan;
tol =0.001;
elim tol (flui et abso);
dds = 1.0;
dens dds;
xs0 = 3.0;
ys0 = 0.5;
zs0 = 2.0;
p0 = xs0 ys0 zs0;
xs1 = 7.0;
ys1 = 0.5;
zs1 = 2.0;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
nf1 = chan poi1 (enve flui);
nf2 = chan poi1 abso;
nf3 = chan poi1 (cont abso);
fsrn = (nf1 diff nf2) et nf3;
mesh = flui et stru et abso et fsrn;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
trac cach (toto et stru et abso);
fin;
```

fsir05.epx

```
FSIR05
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru CL3Q abso TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 2.0
            'air'  LECT flui DIFF expl TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
          JAUN LECT abso TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
     IMPE ABSI LECT abso TERM
!opti dump
LINK COUP SPLT NONE
     FSR      LECT fsrn TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-1  ! R = 0.87 h_flui = 0.87 x 0.2
          HGRI 1.1 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 0
ECRI DEPL VITE TFRE 2.E-4
```

```
     NOEL POIN LECT p0 p1 TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT p0 p1 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

fsir05p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'fsir05.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_p0' DEPL COMP 1 NOEU LECT p0 TERM
COUR 2 'dx_p1' DEPL COMP 1 NOEU LECT p1 TERM
TRAC 1 2 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_p0' VITE COMP 1 NOEU LECT p0 TERM
COUR 12 'vx_p1' VITE COMP 1 NOEU LECT p1 TERM
TRAC 11 12 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 12 AXES 1.0 'VELO. [M/S]' YZER
FIN
```

fsir06.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'fsir06_mesh.ps';
opti sauv form 'fsir06.msh';
lx = 8.0;
ly = 1.0;
lz = 4.0;
x0 = 0.0;
y0 = 0.0;
z0 = 0.0;
dd = 0.2;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
pp1 = lx 0 0;
pp2 = lx ly 0;
pp3 = lx ly lz;
pp4 = lx 0 lz;
c1 = pp1 d pp2;
c2 = pp2 d pp3;
c3 = pp3 d pp4;
c4 = pp4 d pp1;
abso = dall c1 c2 c3 c4 plan;
tol =0.001;
elim tol (flui et abso);
dds = 1.0;
dens dds;
xs0 = 5.0;
ys0 = 0.5;
zs0 = 0.5;
p0 = xs0 ys0 zs0;
xs1 = 5.0;
ys1 = 0.5;
zs1 = 3.5;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
nf1 = chan poi1 (enve flui);
nf2 = chan poi1 abso;
nf3 = chan poi1 (cont abso);
fsrn = (nf1 diff nf2) et nf3;
mesh = flui et stru et abso et fsrn;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
trac cach (toto et stru et abso);
fin;
```

fsir06.epx

```
FSIR06
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru CL3Q abso TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 2.0
            'air'  LECT flui DIFF expl TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
          JAUN LECT abso TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
     IMPE ABSI LECT abso TERM
!opti dump
LINK COUP SPLT NONE
     FSR      LECT fsrn TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-1  ! R = 0.87 h_flui = 0.87 x 0.2
          HGRI 1.1 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT p0 p1 TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT p0 p1 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

fsir06b.epx

```
FSIR06B
ECHO
 CONV WIN
CAST 'fsir06.msh' mesh
ALE TRID
GEOM FL38 flui POUT stru CL3Q abso TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 2.0
            'air'  LECT flui DIFF expl TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
          JAUN LECT abso TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
     IMPE ABSI LECT abso TERM
!opti dump
LINK COUP SPLT NONE
     FSR      LECT fsrn TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-1  ! R = 0.87 h_flui = 0.87 x 0.2
          HGRI 1.1 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT p0 p1 TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT p0 p1 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3 NMAX 0
PLAY
CAME   1 EYE   4.00000E+00 -2.20000E+01  2.00000E+00
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  4.00000E+00  5.00000E-01  2.00000E+00
!RSPHERE:  4.50000E+00
!RADIUS :  2.25000E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.75500E+01
!FAR    :  3.15000E+01
SCEN OBJE USLM LECT flui TERM
          DHAS CGLA
     GEOM NAVI FREE
          LINE HEOU SSHA
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH BMP REND
STOP
ENDPLAY
FIN
```

fsir06p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'fsir06.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_p0' DEPL COMP 1 NOEU LECT p0 TERM
COUR 2 'dx_p1' DEPL COMP 1 NOEU LECT p1 TERM
TRAC 1 2 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_p0' VITE COMP 1 NOEU LECT p0 TERM
COUR 12 'vx_p1' VITE COMP 1 NOEU LECT p1 TERM
TRAC 11 12 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 12 AXES 1.0 'VELO. [M/S]' YZER
FIN
```

fsir07.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'fsir07_mesh.ps';
opti sauv form 'fsir07.msh';
lx = 8.0;
ly = 1.0;
lz = 4.0;
x0 = 0.0;
y0 = 0.0;
z0 = 0.0;
dd = 0.2;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
pp1 = lx 0 0;
pp2 = lx ly 0;
pp3 = lx ly lz;
pp4 = lx 0 lz;
c1 = pp1 d pp2;
c2 = pp2 d pp3;
c3 = pp3 d pp4;
c4 = pp4 d pp1;
abso = dall c1 c2 c3 c4 plan;
tol =0.001;
elim tol (flui et abso);
dds = 1.0;
dens dds;
xs0 = 5.0;
ys0 = 0.5;
zs0 = 0.5;
p0 = xs0 ys0 zs0;
xs1 = 5.0;
ys1 = 0.5;
zs1 = 3.5;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
nf1 = chan poi1 (enve flui);
nf2 = chan poi1 abso;
nf3 = chan poi1 (cont abso);
fsrn = (nf1 diff nf2) et nf3;
mesh = flui et stru et abso et fsrn;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
trac cach (toto et stru et abso);
fin;
```

fsir07.epx

```
FSIR07
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru CL3Q abso TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 2.0
            'air'  LECT flui DIFF expl TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
          JAUN LECT abso TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
     IMPE ABSI LECT abso TERM
!opti dump
LINK COUP SPLT NONE
     FSR      LECT fsrn TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-1  ! R = 0.87 h_flui = 0.87 x 0.2
          HGRI 1.1 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 0
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT p0 p1 TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT p0 p1 TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

fsir07p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'fsir07.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_p0' DEPL COMP 1 NOEU LECT p0 TERM
COUR 2 'dx_p1' DEPL COMP 1 NOEU LECT p1 TERM
TRAC 1 2 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_p0' VITE COMP 1 NOEU LECT p0 TERM
COUR 12 'vx_p1' VITE COMP 1 NOEU LECT p1 TERM
TRAC 11 12 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 12 AXES 1.0 'VELO. [M/S]' YZER
RCOU 401 'dx_p0' FICH 'fsir04p.pun' RENA 'dx_p0_04'
RCOU 402 'dx_p1' FICH 'fsir04p.pun' RENA 'dx_p1_04'
RCOU 411 'vx_p0' FICH 'fsir04p.pun' RENA 'vx_p0_04'
RCOU 412 'vx_p1' FICH 'fsir04p.pun' RENA 'vx_p1_04'
RCOU 501 'dx_p0' FICH 'fsir05p.pun' RENA 'dx_p0_05'
RCOU 502 'dx_p1' FICH 'fsir05p.pun' RENA 'dx_p1_05'
RCOU 511 'vx_p0' FICH 'fsir05p.pun' RENA 'vx_p0_05'
RCOU 512 'vx_p1' FICH 'fsir05p.pun' RENA 'vx_p1_05'
RCOU 601 'dx_p0' FICH 'fsir06p.pun' RENA 'dx_p0_06'
RCOU 602 'dx_p1' FICH 'fsir06p.pun' RENA 'dx_p1_06'
RCOU 611 'vx_p0' FICH 'fsir06p.pun' RENA 'vx_p0_06'
RCOU 612 'vx_p1' FICH 'fsir06p.pun' RENA 'vx_p1_06'
TRAC 401 402 501 502 601 602 1 2 AXES 1.0 'DISP. [M]' YZER
COLO ROUG ROUG VERT VERT TURQ TURQ NOIR NOIR
TRAC 411 412 511 512 611 612 11 12 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG ROUG VERT VERT TURQ TURQ NOIR NOIR
FIN
```

pout01.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'pout01_mesh.ps';
opti sauv form 'pout01.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

pout01.epx

```
POUT01
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
```

```
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          !R 5.00E-2
          HGRI 0.081 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

pout01blo.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'pout01blo_mesh.ps';
opti sauv form 'pout01blo.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

pout01blo.epx

```
POUT01BLO
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     BLOQ 123456 LECT nblo TERM
     FSR         LECT nfsr TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          !R 5.00E-2
          HGRI 0.081 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

pout01blop.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'pout01blo.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout01p.pun' RENA 'dx_POUT01'
RCOU 211 'vx_1' FICH 'pout01p.pun' RENA 'vx_POUT01'
TRAC 101 201 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT NOIR
TRAC 111 211 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT NOIR
FIN
```

pout01p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'pout01.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
TRAC 101 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG NOIR
TRAC 111 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG NOIR
FIN
```

pout01t2.epx

```
Post-treatment (animation from alice file)
ECHO
!CONV WIN
RESU SPLI ALIC 'pout01.ali' GARD PSCR
COMP GROU 1 'fluiy' LECT flui TERM COND YB GT 0.0
SORT VISU NSTO 1
*=====================================================================
PLAY
CAME   1 EYE   1.00000E+00 -5.74734E+00  4.91300E-01 ! Global view
!         Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
          VIEW  0.00000E+00  1.00000E+00  2.05103E-10
          RIGH  1.00000E+00  0.00000E+00  0.00000E+00
          UP    0.00000E+00 -2.05103E-10  1.00000E+00
          FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.00000E+00  0.00000E+00  4.91300E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
CAME   2 EYE   5.00000E-01 -5.74734E+00  4.00000E-01 ! Focus on structure
!         Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
          VIEW  0.00000E+00  1.00000E+00  2.05103E-10
          RIGH  1.00000E+00  0.00000E+00  0.00000E+00
          UP    0.00000E+00 -2.05103E-10  1.00000E+00
          FOV   9.21120E+00
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  0.00000E+00  4.00000E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
```

```
!FAR    :  8.04627E+00
SCEN GEOM NAVI FREE
          LINE HEOU !SSHA
          FLSR DOMA
     ISO  FILL FIEL ECRO 1 SCAL USER PROG 0.25E5 PAS 0.25E5 3.5E5 TERM
          SUPP LECT fluiy TERM
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 5 KFRE 5 COMP -1
     OBJE LECT fluiy stru TERM REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL
     OBJE LECT fluiy stru TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT fluiy stru TERM REND
ENDPLAY
*=======================================================================
FIN
```

pout01t3.epx

```
Post-treatment (animation from alice file)
ECHO
!CONV WIN
RESU SPLI ALIC 'pout01.ali' GARD PSCR
COMP GROU 1 'fluiy' LECT flui TERM COND YB GT 0.0
SORT VISU NSTO 1
*=======================================================================
PLAY
CAME   1 EYE   1.00000E+00 -5.74734E+00  4.91300E-01 ! Global view
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.00000E+00  0.00000E+00  4.91300E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
CAME   2 EYE   5.00000E-01 -5.74734E+00  4.00000E-01 ! Focus on structure
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   9.21120E+00
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  0.00000E+00  4.00000E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
SCEN OBJE SELV FLSR
     GEOM NAVI FREE
          LINE HEOU !SSHA
          FLSR DOMA
     ISO  FILL FIEL ECRO 1 SCAL USER PROG 0.25E5 PAS 0.25E5 3.5E5 TERM
          SUPP LECT fluiy TERM
     LIMA ON
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 5 KFRE 5 COMP -1
     OBJE LECT fluiy stru _flsr TERM REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL
     OBJE LECT fluiy stru _flsr TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT fluiy stru _flsr TERM REND
ENDPLAY
*=======================================================================
FIN
```

pout01t4.epx

```
Post-treatment (animation from alice file)
ECHO
!CONV WIN
RESU SPLI ALIC 'pout01.ali' GARD PSCR
SORT VISU NSTO 1
*=======================================================================
PLAY
CAME   1 EYE   1.00000E+00 -5.74734E+00  4.91300E-01 ! Global view
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.00000E+00  0.00000E+00  4.91300E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
CAME   2 EYE   5.00000E-01 -5.74734E+00  4.00000E-01 ! Focus on structure
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   9.21120E+00
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  0.00000E+00  4.00000E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
SCEN OBJE USLM LECT flui TERM
          SELV FLSR
     GEOM NAVI FREE
          LINE HEOU !SSHA
          FLSR DOMA
     LIMA ON
SLER CAM1 2 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 5 KFRE 5 COMP -1
     REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL
     REND
GO
TRAC OFFS FICH AVI CONT
     REND
ENDPLAY
*=======================================================================
FIN
```

pout02.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'pout02_mesh.ps';
opti sauv form 'pout02.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

pout02.epx

```
POUT02
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME ADAP NPOI 30000 FL38 30000 ENDA TERM
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air _fl38 TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          !R 5.00E-2
```

```
          HGRI 0.081 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
          ADAP LMAX 3 SCAL 2.0
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

pout02p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'pout02.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
TRAC 101 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG NOIR
TRAC 111 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG NOIR
FIN
```

pout03.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'pout03_mesh.ps';
opti sauv form 'pout03.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

pout03.epx

```
POUT03
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME ADAP NPOI 10000 FL38 10000 ENDA TERM
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air _fl38 TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          !R 5.00E-2
          HGRI 0.081 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
          ADAP LMAX 2 SCAL 2.0
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

pout03p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'pout03.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
TRAC 101 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG NOIR
TRAC 111 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG NOIR
FIN
```

pout04.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'pout04_mesh.ps';
opti sauv form 'pout04.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

pout04.epx

```
POUT04
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
```

```
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          !R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          R 4.00E-2
          HGRI 0.081 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

pout04p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'pout04.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
TRAC 101 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG NOIR
TRAC 111 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG NOIR
FIN
```

pout05.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'pout05_mesh.ps';
opti sauv form 'pout05.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

pout05.epx

```
POUT05
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          !R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          R 2.00E-2
          HGRI 0.081 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

pout05p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'pout05.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
TRAC 101 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG NOIR
TRAC 111 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG NOIR
FIN
```

pout06.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'pout06_mesh.ps';
opti sauv form 'pout06.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.04;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

pout06.epx

```
POUT06
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          !R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          R 2.00E-2
          HGRI 0.041 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

pout06p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'pout06.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout05p.pun' RENA 'dx_POUT05'
RCOU 211 'vx_1' FICH 'pout05p.pun' RENA 'vx_POUT05'
TRAC 101 201 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT NOIR
TRAC 111 211 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT NOIR
FIN
```

pout07.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'pout07_mesh.ps';
opti sauv form 'pout07.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

pout07.epx

```
POUT07
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME ADAP NPOI 100000 FL38 100000 ENDA TERM
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air _fl38 TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     SOLV PARD
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          !R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          R 8.00E-2
          HGRI 0.081 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
          ADAP LMAX 3 SCAL 1.0
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

pout07p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'pout07.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout05p.pun' RENA 'dx_POUT05'
RCOU 211 'vx_1' FICH 'pout05p.pun' RENA 'vx_POUT05'
RCOU 301 'dx_1' FICH 'pout06p.pun' RENA 'dx_POUT06'
RCOU 311 'vx_1' FICH 'pout06p.pun' RENA 'vx_POUT06'
TRAC 101 201 301 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ NOIR
TRAC 111 211 311 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ NOIR
FIN
```

pout08.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'pout08_mesh.ps';
opti sauv form 'pout08.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
```

```
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

pout08.epx

```
POUT08
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME ADAP NPOI 15000 FL38 15000 ENDA TERM
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air _fl38 TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     SOLV PARD
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 2.00E-2
          HGRI 0.081 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
          ADAP LMAX 2 SCAL 2.0
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     LNKS STAT
CALC TINI 0. TEND 20.E-3
FIN
```

pout08p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'pout08.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout05p.pun' RENA 'dx_POUT05'
RCOU 211 'vx_1' FICH 'pout05p.pun' RENA 'vx_POUT05'
RCOU 301 'dx_1' FICH 'pout06p.pun' RENA 'dx_POUT06'
RCOU 311 'vx_1' FICH 'pout06p.pun' RENA 'vx_POUT06'
RCOU 401 'dx_1' FICH 'pout07p.pun' RENA 'dx_POUT07'
RCOU 411 'vx_1' FICH 'pout07p.pun' RENA 'vx_POUT07'
TRAC 101 201 301 401 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ ROSE NOIR
TRAC 111 211 311 411 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ ROSE NOIR
FIN
```

pout09.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'pout09_mesh.ps';
opti sauv form 'pout09.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

pout09.epx

```
POUT09
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME ADAP NPOI 30000 FL38 30000 ENDA TERM
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air _fl38 TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     SOLV PARD
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 3.42E-2
          HGRI 0.081 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
          ADAP LMAX 2 SCAL 2.0
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
!    LNKS STAT
CALC TINI 0. TEND 20.E-3
FIN
```

pout09p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'pout09.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout05p.pun' RENA 'dx_POUT05'
RCOU 211 'vx_1' FICH 'pout05p.pun' RENA 'vx_POUT05'
RCOU 301 'dx_1' FICH 'pout06p.pun' RENA 'dx_POUT06'
RCOU 311 'vx_1' FICH 'pout06p.pun' RENA 'vx_POUT06'
RCOU 401 'dx_1' FICH 'pout07p.pun' RENA 'dx_POUT07'
RCOU 411 'vx_1' FICH 'pout07p.pun' RENA 'vx_POUT07'
RCOU 501 'dx_1' FICH 'pout08p.pun' RENA 'dx_POUT08'
RCOU 511 'vx_1' FICH 'pout08p.pun' RENA 'vx_POUT08'
TRAC 101 201 301 401 501 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ ROSE BLEU NOIR
TRAC 111 211 311 411 511 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ ROSE BLEU NOIR
FIN
```

pout12.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'pout12_mesh.ps';
opti sauv form 'pout12.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

pout12.epx

```
POUT12
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME ADAP NPOI 30000 FL38 30000 ENDA TERM
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air _fl38 TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     SOLV PARD
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          !R 5.00E-2
          HGRI 0.081 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
          ADAP LMAX 3 SCAL 2.0
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
!    lnks stat
CALC TINI 0. TEND 20.E-3
FIN
```

pout12p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'pout12.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
TRAC 101 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG NOIR
TRAC 111 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG NOIR
FIN
```

pout13.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'pout13_mesh.ps';
opti sauv form 'pout13.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

pout13.epx

```
POUT13
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME ADAP NPOI 10000 FL38 10000 ENDA TERM
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
```

```
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air _fl38 TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     SOLV PARD
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          !R 5.00E-2
          HGRI 0.081 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 1
          ADAP LMAX 2 SCAL 2.0
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
!    lnks stat
CALC TINI 0. TEND 20.E-3
FIN
```

pout13p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'pout13.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout03p.pun' RENA 'dx_POUT03'
RCOU 211 'vx_1' FICH 'pout03p.pun' RENA 'vx_POUT03'
TRAC 101 201 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT NOIR
TRAC 111 211 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT NOIR
FIN
```

pout13t5.epx

```
Post-treatment (animation from alice file)
ECHO
!CONV WIN
RESU SPLI ALIC 'pout13.ali' GARD PSCR
SORT VISU NSTO 1
*=======================================================================
PLAY
CAME   1 EYE   5.00000E-01  0.00000E+00  9.73297E-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   8.87676E+00
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  0.00000E+00  4.00000E-01
!RSPHERE:  1.14659E+00
!RADIUS :  5.73297E-01
!ASPECT :  1.00000E+00
!NEAR   :  1.14659E-04
!FAR    :  2.86649E+00
CAME   2 EYE   5.00000E-01 -5.74734E+00  4.00000E-01 ! Focus on structure
!        Q      7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   9.21120E+00
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  0.00000E+00  4.00000E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
SCEN OBJE USLM LECT flui _fl38 TERM
          SELV FLSR
     GEOM NAVI FREE
          POIN DOT 6
          FLSR DOMA
     LIMA ON
SLER CAM1 2 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 5 KFRE 5 COMP -1
     REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL
     REND
GO
TRAC OFFS FICH AVI CONT
     REND
ENDPLAY
*=======================================================================
FIN
```

pout21.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'pout21_mesh.ps';
opti sauv form 'pout21.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

pout21.epx

```
POUT21
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM FL38 flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 3 'nblo' LECT p0 TERM
            'nfsr' LECT flui TERM COND ENVE
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE FLUT RO 10.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.0E5 GAMM 1.4 PB 0
          ITER 1 ALFO 1 BETO 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
!opti dump
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
     FSR      LECT nfsr TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          !R 5.00E-2
          HGRI 0.081 ! HGRI > max (h_fluid, h_stru)
          DGRI
          BFLU 0
          FSCP 0
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

pout21p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'pout21.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
```

```
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsr03p.pun' RENA 'dx_FLSR03'
RCOU 111 'vx_mean' FICH 'flsr03p.pun' RENA 'vx_FLSR03'
RCOU 201 'dx_1' FICH 'pout01p.pun' RENA 'dx_POUT01'
RCOU 211 'vx_1' FICH 'pout01p.pun' RENA 'vx_POUT01'
TRAC 101 201 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT NOIR
TRAC 111 211 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT NOIR
FIN
```

pouw01.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'pouw01_mesh.ps';
opti sauv form 'pouw01.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

pouw01.epx

```
POUW01
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM CUVF flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 2 'nblo' LECT p0 TERM
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE GAZP RO 10.0 PINI 8.0E5 GAMM 1.4 PREF 0.8E5
          LECT expl TERM
     GAZP RO 1.0 PINI 0.8E5 GAMM 1.4 PREF 0.8E5
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
LINK DECO FLSW STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          HGRI 0.041 ! HGRI > max (h_fluid, h_stru)
          DGRI
          FACE
          BFLU 1
          FSCP 1
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 6
          ORDR 2
          OTPS 2
          RECO 1
          NTIL
CALC TINI 0. TEND 20.E-3
FIN
```

pouw01p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'pouw01.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsw03p.pun' RENA 'dx_FLSW03'
RCOU 111 'vx_mean' FICH 'flsw03p.pun' RENA 'vx_FLSW03'
RCOU 201 'dx_1' FICH 'pout01p.pun' RENA 'dx_POUT01'
RCOU 211 'vx_1' FICH 'pout01p.pun' RENA 'vx_POUT01'
TRAC 101 201 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT NOIR
TRAC 111 211 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT NOIR
FIN
```

pouw01w.epx

```
Post-treatment (animation from alice file)
ECHO
!CONV WIN
RESU SPLI ALIC 'pouw01.ali' GARD PSCR
SORT VISU NSTO 1
*=======================================================================
PLAY
CAME   1 EYE   1.00000E+00 -5.74734E+00  4.91300E-01 ! Global side view
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.00000E+00  0.00000E+00  4.91300E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
CAME   2 EYE   5.00000E-01 -5.74734E+00  4.00000E-01 ! Focus on structure
!        Q     7.07107E-01  7.07107E-01  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  1.00000E+00  2.05103E-10
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -2.05103E-10  1.00000E+00
         FOV   9.21120E+00
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  5.00000E-01  0.00000E+00  4.00000E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
CAME   3 EYE   1.00000E+00  2.35760E-09 -5.25604E+00 ! Global from bottom
!        Q    -2.05104E-10  1.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00 -4.10207E-10  1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00 -1.00000E+00 -4.10207E-10
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  1.00000E+00  0.00000E+00  4.91300E-01
!RSPHERE:  1.14947E+00
!RADIUS :  5.74734E+00
!ASPECT :  1.00000E+00
!NEAR   :  4.48292E+00
!FAR    :  8.04627E+00
SCEN GEOM NAVI FREE
          FACE HFRO
          LINE !HEOU SSHA
     VECT SCCO FIEL FLIA SCAL USER PROG 20 PAS 20 280 TERM
          SUPP LECT stru DIFF nblo TERM
          SIVE
SLER CAM1 2 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 5 KFRE 5 COMP -1
     OBJE LECT stru TERM REND
GOTR LOOP 99 OFFS FICH AVI CONT NOCL
     OBJE LECT stru TERM REND
GO
TRAC OFFS FICH AVI CONT
     OBJE LECT stru TERM REND
ENDPLAY
*=======================================================================
FIN
```

pouw12.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'pouw12_mesh.ps';
opti sauv form 'pouw12.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
```

```
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

pouw12.epx

```
POUW12
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME ADAP NPOI 45000 CUVF 15000 NVFI 90000 ENDA TERM
GEOM CUVF flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 2 'nblo' LECT p0 TERM
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE GAZP RO 10.0 PINI 8.0E5 GAMM 1.4 PREF 0.8E5
          LECT expl TERM
     GAZP RO 1.0 PINI 0.8E5 GAMM 1.4 PREF 0.8E5
          LECT air _cuvf TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
LINK DECO FLSW STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          HGRI 0.041 ! HGRI > max (h_fluid, h_stru)
          DGRI
          FACE
          BFLU 1
          FSCP 1
          ADAP LMAX 3 SCAL 2.0
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 6
          ORDR 2
          OTPS 2
          RECO 1
          NTIL
CALC TINI 0. TEND 20.E-3
FIN
```

pouw12p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'pouw12.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsw03p.pun' RENA 'dx_FLSW03'
RCOU 111 'vx_mean' FICH 'flsw03p.pun' RENA 'vx_FLSW03'
RCOU 201 'dx_1' FICH 'pout12p.pun' RENA 'dx_POUT12'
RCOU 211 'vx_1' FICH 'pout12p.pun' RENA 'vx_POUT12'
RCOU 301 'dx_1' FICH 'pouw01p.pun' RENA 'dx_POUW01'
RCOU 311 'vx_1' FICH 'pouw01p.pun' RENA 'vx_POUW01'
TRAC 101 201 301 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ NOIR
TRAC 111 211 311 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ NOIR
FIN
```

pouw13.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'pouw13_mesh.ps';
opti sauv form 'pouw13.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

pouw13.epx

```
POUW13
ECHO
!CONV WIN
CAST mesh
ALE TRID
DIME ADAP NPOI 15000 CUVF 15000 NVFI 30000 ENDA TERM
GEOM CUVF flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 2 'nblo' LECT p0 TERM
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE GAZP RO 10.0 PINI 8.0E5 GAMM 1.4 PREF 0.8E5
          LECT expl TERM
     GAZP RO 1.0 PINI 0.8E5 GAMM 1.4 PREF 0.8E5
          LECT air _cuvf TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
LINK DECO FLSW STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          HGRI 0.041 ! HGRI > max (h_fluid, h_stru)
          DGRI
          FACE
          BFLU 1
          FSCP 1
          ADAP LMAX 2 SCAL 2.0
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 6
          ORDR 2
          OTPS 2
          RECO 1
          NTIL
CALC TINI 0. TEND 20.E-3
FIN
```

pouw13p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'pouw13.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
```

```
RCOU 101 'dx_mean' FICH 'flsw03p.pun' RENA 'dx_FLSW03'
RCOU 111 'vx_mean' FICH 'flsw03p.pun' RENA 'vx_FLSW03'
RCOU 201 'dx_1' FICH 'pout13p.pun' RENA 'dx_POUT13'
RCOU 211 'vx_1' FICH 'pout13p.pun' RENA 'vx_POUT13'
RCOU 301 'dx_1' FICH 'pouw01p.pun' RENA 'dx_POUW01'
RCOU 311 'vx_1' FICH 'pouw01p.pun' RENA 'vx_POUW01'
RCOU 401 'dx_1' FICH 'pouw12p.pun' RENA 'dx_POUW12'
RCOU 411 'vx_1' FICH 'pouw12p.pun' RENA 'vx_POUW12'
TRAC 101 201 301 401 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT TURQ ROSE NOIR
TRAC 111 211 311 411 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT TURQ ROSE NOIR
FIN
```

pouw21.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'pouw21_mesh.ps';
opti sauv form 'pouw21.msh';
lx = 2.0;
ly = 0.5;
lz = 1.0;
x0 = 0.0;
y0 = 0.0 - (0.5*ly);
z0 = 0.0;
dd = 0.02;
flui = pxbox3d x0 y0 z0 lx ly lz dd;
dds = 0.08;
dens dds;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
p0 = xs0 ys0 zs0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = flui et stru;
tass mesh noop;
sauv form mesh;
trac cach flui;
toto = aret flui;
trac cach (toto et stru);
fin;
```

pouw21.epx

```
POUW21
ECHO
!CONV WIN
CAST mesh
ALE TRID
GEOM CUVF flui POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     GROU 2 'expl' LECT flui TERM COND XB LT 0.25
            'air'  LECT flui DIFF expl TERM
     NGRO 2 'nblo' LECT p0 TERM
            'ntop' LECT p1 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE GAZP RO 10.0 PINI 8.0E5 GAMM 1.4 PREF 0.8E5
          LECT expl TERM
     GAZP RO 1.0 PINI 0.8E5 GAMM 1.4 PREF 0.8E5
          LECT air TERM
     LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
LINK DECO FLSW STRU LECT stru TERM
          FLUI LECT flui TERM
          R 1.74E-2  ! R = 0.87 h_flui = 0.87 x 0.02
          HGRI 0.041 ! HGRI > max (h_fluid, h_stru)
          DGRI
          FACE
          BFLU 1
          FSCP 0
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
     VFCC FCON 6
          ORDR 2
          OTPS 2
          RECO 1
          NTIL
CALC TINI 0. TEND 20.E-3
FIN
```

pouw21p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'pouw21.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT ntop TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT ntop TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 101 'dx_mean' FICH 'flsw03p.pun' RENA 'dx_FLSW03'
RCOU 111 'vx_mean' FICH 'flsw03p.pun' RENA 'vx_FLSW03'
RCOU 201 'dx_1' FICH 'pouw01p.pun' RENA 'dx_POUW01'
RCOU 211 'vx_1' FICH 'pouw01p.pun' RENA 'vx_POUW01'
TRAC 101 201 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG VERT NOIR
TRAC 111 211 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG VERT NOIR
FIN
```

pxbox3d.proc

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

pxracub8.proc

```
'DEBPROC' pxracub8 p1*'POINT' p2*'POINT' p3*'POINT' p4*'POINT'
                   n1*'ENTIER' n2*'ENTIER'
                   d*'FLOTTANT' tol*'FLOTTANT';
*
*--------------------------------------------------
* Generate raccord of 3d cubes between two rectangles of vertices
* p1,p2,p3,p4 and r1,r2,r3,r4. The first rectangle has n1xn2 elements
* along p1-p2 and p2-p3, respectively. The second rectangle (refined 2x)
* has 2*n1x2*n2 elements along r1-r2 and r2-r3, respectively.
* The first rectangle is oriented in such a way that its outwards
* normal points towards the second rectangle.
* The second rectangle is oriented in such a way that r1 is its closest
* point to p1, r2 to p2 etc.
* The second rectangle is obtained from the first one by a simple
* translation in space by d units along the normal to the first
* rectangle plus a refinement whereby from each quadrilateral
* of the first rectangle one obtains 2x2=4 quadrilaterals
* of the second rectangle.
*
* Input :
* -----
*  p1,p2,p3,p4 : vertices of the first rectangle (ordered
*                as explained above)
*  n1,n2       : n. of subdivisions along p1-p2 and p2-p3
*  d           : translation of first rectangle (along the normal)
*                to obtain the second one
* tol          : tolerance for nodes elimination
*
* Output :
* ------
*  racc        : mesh of cub8 elements joining the first
*                and second rectangles
*-------------------------------------------------
*
* compute unit normal vn1 to the first rectangle
*
x1 y1 z1 = COOR p1;
x2 y2 z2 = COOR p2;
```

```
x3 y3 z3 = COOR p3;
x4 y4 z4 = COOR p4;
x31 = x3 - x1;
y31 = y3 - y1;
z31 = z3 - z1;
x42 = x4 - x2;
y42 = y4 - y2;
z42 = z4 - z2;
x41 = x4 - x1;
y41 = y4 - y1;
z41 = z4 - z1;
x21 = x2 - x1;
y21 = y2 - y1;
z21 = z2 - z1;
v31 = x31 y31 z31;
v42 = x42 y42 z42;
v41 = x41 y41 z41;
v21 = x21 y21 z21;
vn = v31 PVEC v42;
vnorm = NORM vn;
vn1 = (1.0 / vnorm) * vn;
*
* compute intermediate points
*
q1 = p1 PLUS ((0.5 * d) * vn1);
q4 = p4 PLUS ((0.5 * d) * vn1);
*
* build up first surface to be extruded
*
dv41 = (1.0 / n2) * v41;
n = 0;
count = 0;
REPE loop1 n2;
  n = n + 1;
  pp1 = p1 PLUS ((n - 1) * dv41);
  pp2 = pp1 PLUS dv41;
  qq1 = q1 PLUS ((n - 1) * dv41);
  qq2 = qq1 PLUS dv41;
  cen = 0.25 * (pp1 PLUS qq1 PLUS pp2 PLUS qq2);
  qq12 = 0.5 * (qq1 PLUS qq2);
  mod = n - ((n / 2) * 2);
  SI (EGA mod 1);
    pq2 = 0.5 * (pp2 PLUS qq2);
    qua1 = MANU QUA4 pp1 cen pq2 pp2;
    qua2 = MANU QUA4 pp1 qq1 qq12 cen;
    qua3 = MANU QUA4 cen qq12 qq2 pq2;
    SI (EGA count 0);
      sur = qua1;
    SINON;
      sur = sur ET qua1;
    FINSI;
    sur = sur ET qua2 ET qua3;
    count = count + 3;
  SINON;
    pq1 = 0.5 * (pp1 PLUS qq1);
    qua1 = MANU QUA4 pp1 pq1 cen pp2;
    qua2 = MANU QUA4 pq1 qq1 qq12 cen;
    qua3 = MANU QUA4 cen qq12 qq2 pp2;
    SI (EGA count 0);
      sur = qua1;
    SINON;
      sur = sur ET qua1;
    FINSI;
    sur = sur ET qua2 ET qua3;
    count = count + 3;
  FINSI;
FIN loop1;
*
* extrude first surface to get first raccord volume
*
vol1 = sur VOLU TRAN n1 v21;
ELIM tol (vol1 ET p1 ET p2 ET p3 ET p4);
*
* build up second surface to be extruded
*
dv21 = (1.0 / n1) * v21;
n = 0;
count = 0;
REPE loop2 n1;
  n = n + 1;
  pp1 = p1 PLUS ((0.5 * d) * vn1) PLUS ((n - 1) * dv21);
  pp2 = pp1 PLUS dv21;
  qq1 = q1 PLUS ((0.5 * d) * vn1) PLUS ((n - 1) * dv21);
  qq2 = qq1 PLUS dv21;
  cen = 0.25 * (pp1 PLUS qq1 PLUS pp2 PLUS qq2);
  qq12 = 0.5 * (qq1 PLUS qq2);
  mod = n - ((n / 2) * 2);
  SI (EGA mod 1);
    pq2 = 0.5 * (pp2 PLUS qq2);
    qua1 = MANU QUA4 pp1 cen pq2 pp2;
    qua2 = MANU QUA4 pp1 qq1 qq12 cen;
    qua3 = MANU QUA4 cen qq12 qq2 pq2;
    SI (EGA count 0);
      sur = qua1;
    SINON;
      sur = sur ET qua1;
    FINSI;
    sur = sur ET qua2 ET qua3;
    count = count + 3;
  SINON;
    pq1 = 0.5 * (pp1 PLUS qq1);
    qua1 = MANU QUA4 pp1 pq1 cen pp2;
    qua2 = MANU QUA4 pq1 qq1 qq12 cen;
    qua3 = MANU QUA4 cen qq12 qq2 pp2;
    SI (EGA count 0);
      sur = qua1;
    SINON;
      sur = sur ET qua1;
    FINSI;
    sur = sur ET qua2 ET qua3;
    count = count + 3;
  FINSI;
FIN loop2;
*
* extrude second surface to get second raccord volume
*
vol2 = sur VOLU TRAN (2 * n2) v41;
*
racc = vol1 et vol2;
ELIM tol racc;
*
finproc racc;
```

stru01.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'stru01_mesh.ps';
opti sauv form 'stru01.msh';
lsx = 0.04;
lsy = 0.04;
lsz = 0.80;
xs0 = 0.5 - (0.5*lsx);
ys0 = 0.0 - (0.5*lsy);
zs0 = 0.0;
dds = 0.04;
stru = pxbox3d xs0 ys0 zs0 lsx lsy lsz dds;
mesh = stru;
tass mesh noop;
sauv form mesh;
trac cach mesh;
fin;
```

stru01.epx

```
STRU01
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM CUB8 stru TERM
COMP NGRO 2 'nblo' LECT stru TERM COND Z LT 0.001
            'ntop' LECT stru TERM COND Z GT 0.799
     COUL VERT LECT stru TERM
MATE LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
INIT VITE 1 10.0 LECT stru DIFF nblo TERM
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

stru01p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'stru01.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT 81 TERM
COUR 2 'dx_2' DEPL COMP 1 NOEU LECT 82 TERM
COUR 3 'dx_3' DEPL COMP 1 NOEU LECT 83 TERM
COUR 4 'dx_4' DEPL COMP 1 NOEU LECT 84 TERM
COUR 10 'dx_mean' MEAN 4 1 2 3 4
TRAC 1 2 3 4 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 3 4 AXES 1.0 'DISP. [M]' YZER
TRAC 10 AXES 1.0 'DISP. [M]' YZER
LIST 10 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT 81 TERM
COUR 12 'vx_2' VITE COMP 1 NOEU LECT 82 TERM
COUR 13 'vx_3' VITE COMP 1 NOEU LECT 83 TERM
COUR 14 'vx_4' VITE COMP 1 NOEU LECT 84 TERM
COUR 20 'vx_mean' MEAN 4 11 12 13 14
TRAC 11 12 13 14 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 12 13 14 AXES 1.0 'VELO. [M/S]' YZER
TRAC 20 AXES 1.0 'VELO. [M/S]' YZER
LIST 20 AXES 1.0 'VELO. [M/S]' YZER
TRAC 1 2 3 4 10 AXES 1.0 'DISP. [M]' YZER
COLO NOIR NOIR NOIR NOIR ROUG
TRAC 11 12 13 14 20 AXES 1.0 'VELO. [M/S]' YZER
COLO NOIR NOIR NOIR NOIR ROUG
FIN
```

stru02.dgibi

```
opti echo 0;
opti donn 'pxbox3d.proc';
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'stru02_mesh.ps';
opti sauv form 'stru02.msh';
lsx = 0.04;
lsy = 0.04;
lsz = 0.80;
xs0 = 0.5 - (0.5*lsx);
ys0 = 0.0 - (0.5*lsy);
zs0 = 0.0;
dds = 0.02;
stru = pxbox3d xs0 ys0 zs0 lsx lsy lsz dds;
mesh = stru;
tass mesh noop;
sauv form mesh;
trac cach mesh;
fin;
```

stru02.epx

```
STRU02
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM CUB8 stru TERM
COMP NGRO 2 'nblo' LECT stru TERM COND Z LT 0.001
            'ntop' LECT stru TERM COND Z GT 0.799
     COUL VERT LECT stru TERM
MATE LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT nblo TERM
INIT VITE 1 10.0 LECT stru DIFF nblo TERM
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

stru02p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'stru02.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT 361 TERM
COUR 2 'dx_2' DEPL COMP 1 NOEU LECT 362 TERM
COUR 3 'dx_3' DEPL COMP 1 NOEU LECT 363 TERM
COUR 4 'dx_4' DEPL COMP 1 NOEU LECT 364 TERM
COUR 5 'dx_5' DEPL COMP 1 NOEU LECT 365 TERM
COUR 6 'dx_6' DEPL COMP 1 NOEU LECT 366 TERM
COUR 7 'dx_7' DEPL COMP 1 NOEU LECT 367 TERM
COUR 8 'dx_8' DEPL COMP 1 NOEU LECT 368 TERM
COUR 9 'dx_9' DEPL COMP 1 NOEU LECT 369 TERM
COUR 10 'dx_mean' MEAN 9 1 2 3 4 5 6 7 8 9
TRAC 1 2 3 4 5 6 7 8 9 AXES 1.0 'DISP. [M]' YZER
LIST 1 2 3 4 5 6 7 8 9 AXES 1.0 'DISP. [M]' YZER
TRAC 10 AXES 1.0 'DISP. [M]' YZER
LIST 10 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT 361 TERM
COUR 12 'vx_2' VITE COMP 1 NOEU LECT 362 TERM
COUR 13 'vx_3' VITE COMP 1 NOEU LECT 363 TERM
COUR 14 'vx_4' VITE COMP 1 NOEU LECT 364 TERM
COUR 15 'vx_5' VITE COMP 1 NOEU LECT 365 TERM
COUR 16 'vx_6' VITE COMP 1 NOEU LECT 366 TERM
COUR 17 'vx_7' VITE COMP 1 NOEU LECT 367 TERM
COUR 18 'vx_8' VITE COMP 1 NOEU LECT 368 TERM
COUR 19 'vx_9' VITE COMP 1 NOEU LECT 369 TERM
COUR 20 'vx_mean' MEAN 9 11 12 13 14 15 16 17 18 19
TRAC 11 12 13 14 15 16 17 18 19 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 12 13 14 15 16 17 18 19 AXES 1.0 'VELO. [M/S]' YZER
TRAC 20 AXES 1.0 'VELO. [M/S]' YZER
LIST 20 AXES 1.0 'VELO. [M/S]' YZER
TRAC 1 2 3 4 5 6 7 8 9 10 AXES 1.0 'DISP. [M]' YZER
COLO NOIR NOIR NOIR NOIR NOIR NOIR NOIR NOIR NOIR ROUG
TRAC 11 12 13 14 15 16 17 18 19 20 AXES 1.0 'VELO. [M/S]' YZER
COLO NOIR NOIR NOIR NOIR NOIR NOIR NOIR NOIR NOIR ROUG
RCOU 110 'dx_mean' FICH 'stru01p.pun' RENA 'dx_mean_01'
RCOU 120 'vx_mean' FICH 'stru01p.pun' RENA 'vx_mean_01'
TRAC 110 10 AXES 1.0 'DISP. [M]' YZER
COLO ROUG NOIR
TRAC 120 20 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG NOIR
FIN
```

stru03.dgibi

```
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'stru03_mesh.ps';
opti sauv form 'stru03.msh';
lsx = 0.04;
lsy = 0.04;
lsz = 0.80;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
dds = 0.08;
dens dds;
p0 = xs0 ys0 zs0;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = stru;
tass mesh noop;
sauv form mesh;
trac cach mesh;
fin;
```

stru03.epx

```
STRU03
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     NGRO 2 'nblo' LECT p0 TERM
            'ntop' LECT p1 TERM
     COUL VERT LECT stru TERM
MATE LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123456 LECT nblo TERM
INIT VITE 1 10.0 LECT stru DIFF nblo TERM
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

stru03p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'stru03.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT p1 TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT p1 TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 110 'dx_mean' FICH 'stru01p.pun' RENA 'dx_mean_01'
RCOU 120 'vx_mean' FICH 'stru01p.pun' RENA 'vx_mean_01'
RCOU 210 'dx_mean' FICH 'stru02p.pun' RENA 'dx_mean_02'
RCOU 220 'vx_mean' FICH 'stru02p.pun' RENA 'vx_mean_02'
TRAC 110 210 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG NOIR VERT
TRAC 120 220 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG NOIR VERT
FIN
```

stru04.dgibi

```
opti echo 1;
opti dime 3 elem cub8;
opti trac psc ftra 'stru04_mesh.ps';
opti sauv form 'stru04.msh';
lsx = 0.04;
lsy = 0.04;
lsz = 0.80;
xs0 = 0.5;
ys0 = 0.0;
zs0 = 0.0;
xs1 = 0.5;
ys1 = 0.0;
zs1 = 0.8;
dds = 0.04;
dens dds;
p0 = xs0 ys0 zs0;
p1 = xs1 ys1 zs1;
stru = p0 d p1;
mesh = stru;
tass mesh noop;
sauv form mesh;
trac cach mesh;
fin;
```

stru04.epx

```
STRU04
ECHO
!CONV WIN
CAST mesh
LAGR TRID
GEOM POUT stru TERM
COMP GEOP RECT VX 0 VY 1 VZ 0 AY 0.04 AZ 0.04
          LECT stru TERM
     NGRO 2 'nblo' LECT p0 TERM
            'ntop' LECT p1 TERM
     COUL VERT LECT stru TERM
MATE LINE RO 2000. YOUN 2.D9 NU 0.3
          LECT stru TERM
LINK COUP SPLT NONE
     BLOQ 123456 LECT nblo TERM
INIT VITE 1 10.0 LECT stru DIFF nblo TERM
ECRI DEPL VITE TFRE 2.E-4
     NOEL POIN LECT ntop TERM
     FICH SPLI ALIC TFRE 2.E-4
     FICH ALIC TEMP FREQ 1
          POIN LECT ntop TERM
OPTI PAS AUTO NOTE CSTA 0.5 LOG 1
CALC TINI 0. TEND 20.E-3
FIN
```

stru04p.epx

```
Post-treatment (time curves from alice temp file)
ECHO
RESU ALIC TEMP 'stru04.alt' GARD PSCR
SORT GRAP
AXTE 1.0 'Time [s]'
COUR 1 'dx_1' DEPL COMP 1 NOEU LECT p1 TERM
TRAC 1 AXES 1.0 'DISP. [M]' YZER
LIST 1 AXES 1.0 'DISP. [M]' YZER
COUR 11 'vx_1' VITE COMP 1 NOEU LECT p1 TERM
TRAC 11 AXES 1.0 'VELO. [M/S]' YZER
LIST 11 AXES 1.0 'VELO. [M/S]' YZER
RCOU 110 'dx_mean' FICH 'stru01p.pun' RENA 'dx_mean_01'
RCOU 120 'vx_mean' FICH 'stru01p.pun' RENA 'vx_mean_01'
RCOU 210 'dx_mean' FICH 'stru02p.pun' RENA 'dx_mean_02'
RCOU 220 'vx_mean' FICH 'stru02p.pun' RENA 'vx_mean_02'
RCOU 310 'dx_1' FICH 'stru03p.pun' RENA 'dx_1_03'
RCOU 320 'vx_1' FICH 'stru03p.pun' RENA 'vx_1_03'
TRAC 110 210 310 1 AXES 1.0 'DISP. [M]' YZER
COLO ROUG NOIR VERT TURQ
TRAC 120 220 320 11 AXES 1.0 'VELO. [M/S]' YZER
COLO ROUG NOIR VERT TURQ
FIN
```

List of input files

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.