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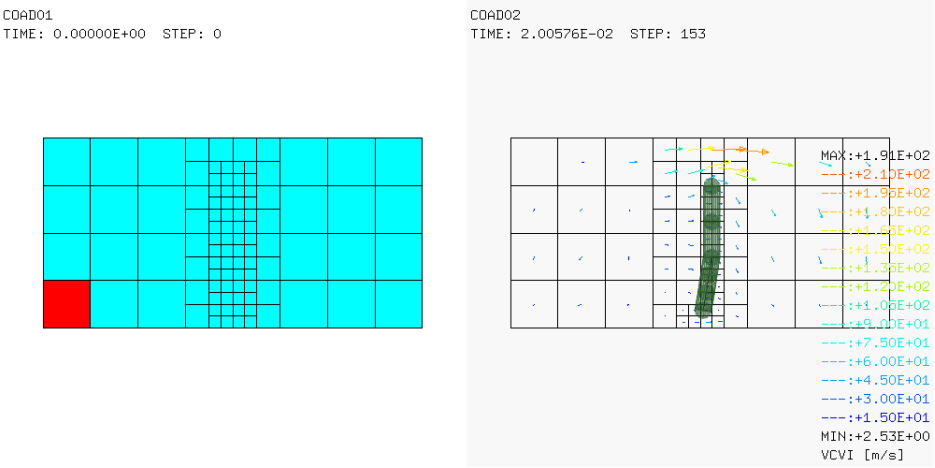

EUROPLEXUS Software

Joint Research Centre

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1. Introduction

This report is a sequel to reports and publications [1-15] on mesh adaptivity in fast transient dynamics and presents the formulation and implementation of mesh adaptivity in both the fluid and the structure domain in combination with Fluid-Structure Interaction (FSI) algorithms in fast transient dynamics. The algorithms are implemented in the EUROPLEXUS code.

EUROPLEXUS [21] is a computer code for fast explicit transient dynamic analysis of fluid-structure systems jointly developed by the French Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA Saclay) and by the Joint Research Centre of the European Commission (JRC Ispra).

Reference [1] presented the first implementation in EUROPLEXUS of an adaptive mesh refinement and un-refinement procedure, in two space dimensions (element shape QUA4) for solid mechanics. The procedure was extended to fluid mechanics (FE formulation) in 2D in reference [2]. Then, reference [3] applied a similar refinement and un-refinement procedure in three space dimensions to the CUB8 element shape, both in solids mechanics and in fluid mechanics (FE formulation).

All numerical examples presented in references [1-3] with a variable mesh used a so-called "manual" mesh adaptation directive, the `WAVE` directive (see the code manual in reference [21]), first introduced in reference [1]. This directive refines the mesh along "wavefronts" that are specified by the user, e.g. according to a known analytical solution to the problem considered. This technique was used with success to simulate a bar problem (in solid mechanics) and a shock tube problem (in fluid mechanics) both in 2D and in 3D [1-3].

However, those solutions cannot be qualified as "true" adaptive solutions, because in (true) adaptivity mesh refinement and un-refinement should be completely automatic, based upon suitable *error estimators* or *error indicators*. The formulation of error estimators in fast transient dynamics is challenging and is still a subject of research. The use of so-called error indicators, however, is much simpler. For this reason, subsequent work in EUROPLEXUS focused on error indicators. References [4] and [5] document a first prototype implementation of adaptivity based upon error indicators in EUROPLEXUS, limited to 2D problems in continuum and fluid mechanics. An extension of the indicator technique to 3D is under development but has not been completed and documented yet.

Publications [6-7] focus on the natural quantities of interest in goal-oriented error assessment and adaptivity, but limited to the case of linear elasto-dynamics.

The adaptive technique was then applied to Cell-Centred Finite Volumes (CCFV) for the description of the fluid domain, first in 2D (see [8]) and then also in 3D [9]. More recently, the technique has also been extended for use with the CDEM combustion model which makes use of the CCFV formu-

lation [10]. A complete description of the element refinement and un-refinement techniques used in mesh adaptation has been published in a paper [11].

A first contribution towards combination of mesh adaptivity with Fluid-Structure Interaction (FSI) was given in reference [12], in which a model is described that automatically refines the fluid mesh in the vicinity of an embedded structure which can move and deform until and beyond rupture (but without being itself subjected to adaptivity).

In [13] adaptivity was activated for simplex elements (triangles in 2D and tetrahedra in 3D). The report [14] extends adaptivity to CEA's family of fluid elements. Finally, reference [15] extends adaptivity to shell, beam and bar structural elements. It becomes therefore possible to have mesh adaptivity both in a fluid and at the same time in a structure (typically made of shells) embedded in the fluid.

The present work extends the automatic fluid mesh adaptation of reference [12] to the case where adaptation of the structure according to the techniques described in [15] occurs simultaneously. This technique is particularly useful in conjunction with FSI algorithms of the *embedded* or *immersed* type, such as the FLSR or FLSW algorithms available in EUROPLEXUS.

With these algorithms, the interacting fluid and structure are discretized in a completely independent way at the topological level. Typically, the fluid is represented by a uniform and regular (even structured) mesh fixed in space (Eulerian description) used as a "background" mesh. The structure is meshed independently and then it is "embedded" or "immersed" in the fluid mesh. The two meshes are therefore simply superposed.

A description of the FLSR and FLSW algorithms can be found in references [16-20].

Clearly, the precision of Fluid-Structure coupling depends very much on the use of a sufficiently fine fluid mesh, at least in the vicinity of the structure, and this is precisely the scope of adaptivity: to refine the fluid mesh only where it is needed, in this case close to the structure. However, if the structure undergoes large deformations and may locally fail, it becomes important to activate adaptivity also in the structure, by using some dedicated criteria, in order to better follow the damage and failure mechanism of the structure itself. Then, the FSI algorithm must be able to deal simultaneously with adaptivity both in the structure and in the fluid sub-domains.

This document is organized as follows:

- Section 2 presents the formulation of FSI in conjunction with adaptivity in the structure. The strategy for refining and un-refining the fluid mesh in the vicinity of the structure had been already described in [12].

- Section 3 presents some numerical examples for the verification of the proposed algorithms.

The Appendix contains a listing of all the input files mentioned in the present report.

2. Formulation and implementation

We consider a general FSI problem in which the structural mesh is automatically adapted [15] by some algorithm which tries to catch the structural damage and failure, while at the same time the fluid mesh is automatically adapted close to the embedded structure [12].

We assume a FSI algorithm of the embedded (or immersed) type: FLSR if the fluid sub-domain is discretized via Finite Elements (FE), or FLSW if the fluid sub-domain is discretized via Cell-Centred Finite Volumes (VFCC).

Embedded FSI algorithms make use of the notion of "influence domain" of the structure. The influence domain is formed by the union of geometrical "entities": spheres (in 3D, or circles in 2D) centred at the structural nodes, and other more complex shapes built starting from the spheres (or circles): quadrilaterals in 2D and cones/prisms/hexahedra in 3D. See references [16-20] for a detailed description.

In the adaptive FSI models available prior to the present work the structure was not adapted and consequently the structural influence domain was built only once, at the beginning of the calculation (routine BUILD_FLSW in module M_LINK_FLSW). Of course, some geometrical quantities in the structural domain entities had to be updated at every step (routine UPDATE_FLSW in module M_LINK_FLSW) due to structure motion. Also, due to possible failure and erosion of the structural elements, some parts of the structure, and the corresponding influence domain entities, could became inactive. However, the influence domain data structure was a relatively "static" one. For example, the number and the nature of the entities forming the influence domain were constant during the calculation.

With adaptivity (also) in the structure, it is clear that the structural influence domain becomes much more "dynamic". The number and nature of the influence domain entities may vary during the calculation. Therefore, the corresponding part of the data structure must be re-built each time there are adaptive refinements or un-refinements of the structure during the calculation.

2.1 Mesh adaptation sequence

Since both the structure and the fluid mesh have to be potentially adapted at each time step of the calculation, it is necessary to decide the order in which mesh adaptation should occur. In typical FSI-driven fluid mesh adaptation strategies the refinement and un-refinement of the fluid mesh depends upon the current position (and shape) of the structure. The opposite case, in which structure refinement and un-refinement would depend upon the fluid (in particular, upon the local size of the fluid mesh), although perhaps not impossible, looks much less interesting.

For these reasons, it seems preferable to always perform the adaptation of the structural mesh first, at each time step, and then, immediately after, to perform adaptation of the fluid mesh. The adopted logical sequence of operations is as follows:

I *Perform adaptation of the structure mesh according to criteria related only to the structure itself (damage, failure or other conditions).*

II *Then, if the structure mesh has changed with respect to the previous step (i.e., if any structural element has been either refined or un-refined), re-build the structural influence domain. This is not a simple update like in reference [15], since the number of structural influence entities may change. If no structural element has been adapted during the first part of the algorithm, then perform a simple update of the structural influence domain like in [15].*

III *Finally, perform adaptation of the fluid mesh according to the (possibly new) structural mesh's influence domain according to the algorithm of reference [15].*

Figure 1 shows a (simplified) flowchart of the calls related to the FLSW model for FSI in conjunction with adaptivity. Figure 2 shows the same flowchart for the FLSR model.

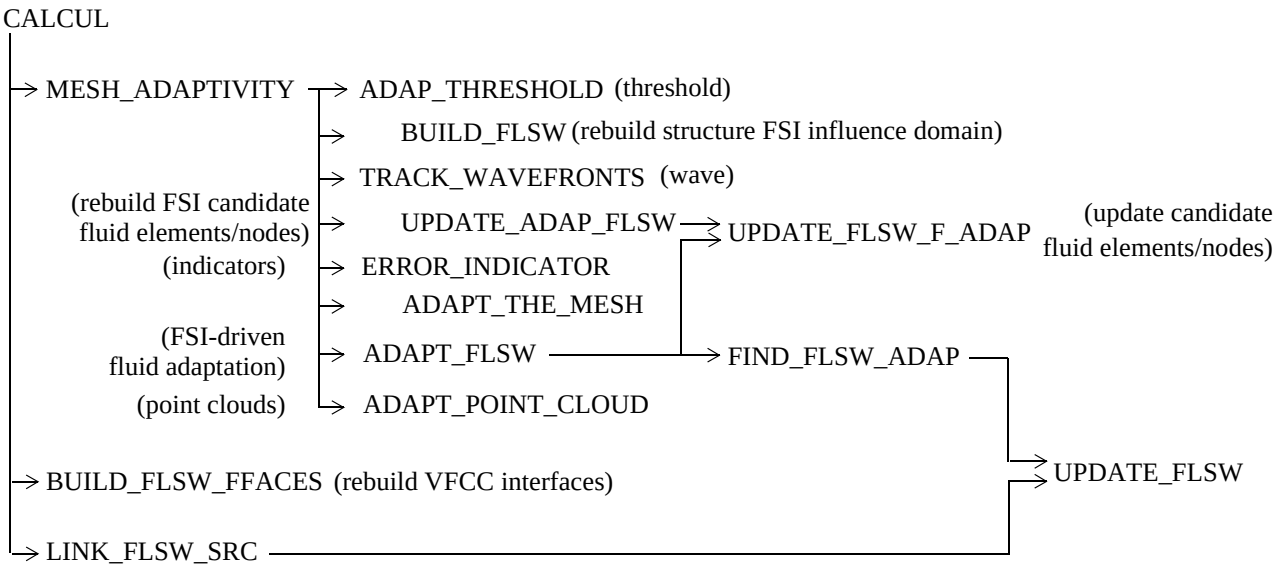


Figure 1 - Flowchart of FLSW model with adaptivity

In the case of FLSW (Figure 1) the MESH_ADAPTIVITY routine is called at the beginning of each step, in order to perform any required adaptations of the mesh (both in the structure and in the fluid, in general). The various possible types of adaptation are then called (see Figure and short description below). Then, if the fluid mesh (made of VFCCs) has been adapted, the call to BUILD_FLSW_FFACES (in module M_LINK_FLSW) re-builds the VFCC interfaces in order to compute the fluxes in the fluid sub-domain. Finally, the call to LINK_FLSW_SRC (in module

M_LINK_FLSW) searches the fluid entities (volume centroids or directly the interfaces, depending upon an input option) which are located “within” the influence domain of the structure.

In the MESH_ADAPTIVITY routine, several possible types of mesh adaptation are possible: threshold-based adaptation (most commonly in the structure, but thresholds for the fluid are also under implementation), wavefront-tracking adaptation, error indicator based adaptation, and FSI-based adaptation. The indicator-based adaptation may be used via the classical indicators or by means of a point-cloud based formulation. The wavefront-based, indicator-based (either in the classical or in the point-cloud form) and FSI-based adaptations may not be combined at the moment. However, the threshold-based adaptation (typically in the structure) may indeed be combined, say, with an FSI-driven adaptation in the fluid, by means of the model described in this report.

The FLSR case (Figure 2) is quite similar to the FLSW case and needs no further comments.

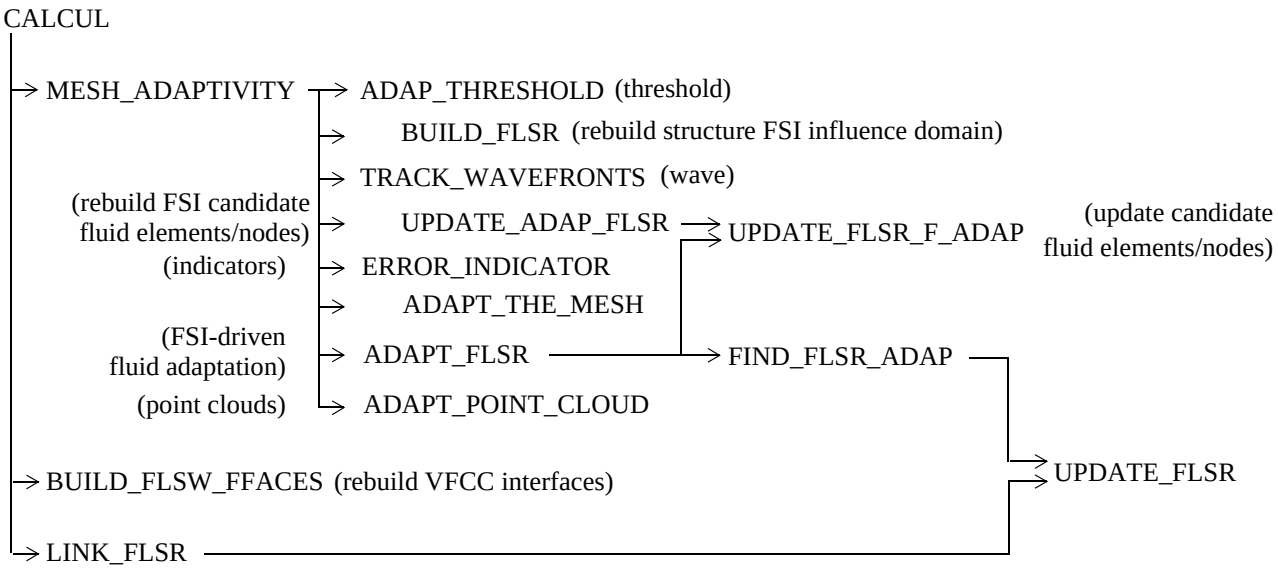


Figure 2 - Flowchart of FLSR model with adaptivity

2.2 Implementation notes

As concerns the data structure, the following scalars and arrays have been added in the module M_LINK_FLSW_DATA:

- N_FLSW_SELEMS_BASE : the number of base FLSW structural elements given in input
- FLSW_SELEMS_NBASE : the list of such elements given in input

In the input file of calculations with mesh adaptivity, the user deals only with base elements. Since, due to adaptivity in the structure, the structural elements forming the influence domain may vary

during the transient, it is necessary to “remember” the list of such elements that was specified in the input. Of course, these are all “base” elements in adaptivity.

Whenever the structure influence is re-built, the list of (current) FLSW structural elements is re-constructed as the union of all active descendents of the base elements in the list given in input. Of course, if a base element has no descendents (it is active), it is also added to the list.

The BUILD_FLSW routine in module M_LINK_FLSW is modified, An extra input parameter (REBUILD, a logical variable) indicating whether this is the first build-up of the data structure (the influence domain of the structural mesh) or it is a re-build due to an adaptation of the structural mesh. The BUILD_FLSW routine is still called at the initial time by READ_FLSW, in order to build the data structure for the first time (REBUILD=.FALSE.). It is also called from MESH_ADAPTIVITY directly after the CALL ADAP_THRESHOLD, whenever any changes occur in the mesh due to the threshold-based adaptation model. In this case, REBUILD=.TRUE. so that the routine first destroys the old data structure, and then builds it up again.

2.2.1 ALE adaptive calculations

Another set of changes has been performed due to the fact that this is the first time that adaptivity in both the structure and the fluid is activated simultaneously in the same run. In such a case the calculation must be declared ALE, and in this case use is made of the MVGRIL array in order to move the mesh (in particular, to compute the grid velocities in NVVGRIL).

Porting the MVGRIL data structure with related arrays and all the available mesh rezoning models to the case with adaptivity would be a huge task. For the moment, a simplified (but partial) solution has been adopted.

The proposed solution allows to use a mix of Eulerian (for the fluid) or Lagrangian (for the structure) descendent (adaptive) nodes, but does not allow the use of ALE descendent nodes. This provides already useful functionality and does not require too many changes nor a complete re-writing of the rezoning-related data structure in the code.

The assumed rules are the following:

- All nodes I in the memory extension zone are initially considered as Eulerian (MVGRIL(I,1)=0). They are therefore all counted in the MSHEUL global counter, and listed in the MVGRIL(I,2) part of the table in the corresponding order.
- As one of this nodes becomes used, it automatically inherits the status from its “parent” nodes, <u>if such nodes have all the same status</u>. For example, the child of 4 Lagrangian nodes becomes Lagrangian. Otherwise, the child node remains (tentatively) Eulerian.

- When a descendent node gets unused again, it returns Eulerian.
- An extra loop is added in the NVVGRIL routine. Initially, the routine treats all nodes in the extension zone as Eulerian because it does not examine their MVGRIL(I,1) value, but uses instead the MSHEUL counter and the MVGRIL(I,2) table (for efficiency reasons). Rebuilding the MVGRIL(I,2) table as the nature of extension nodes changes would be very expensive. We just add an extra loop (in the adaptive case) which passes over all extension nodes and treats them appropriately in case they are Lagrangian.

2.2.2 Variable number of dofs

Another new aspect that has emerged during this implementation is the fact that the number of (effective) degrees of freedom (dofs) of extension nodes can vary in time. In fact, if adaptivity affects both the fluid and the structure, a descendent node might at some time belong to the fluid, and at another time belong to the structure. In the fluid, only continuum elements are used, so that the number of degrees of freedom per node equals the space dimension IDIM (2 or 3). In the structure, if shells or other “structural” elements are used, the nodes also have rotational degrees of freedom in addition to translational ones.

For simplicity, when adaptive nodes dimensioning is declared in the input, the code assumes the same number of dofs for each of these nodes, which is the maximum needed: IDIM if there is no adaptivity in the structure, otherwise one takes the maximum number of dofs per node needed by any structural element for which adaptivity is possible.

Some memory is wasted in general, but this organization is much simpler than having to rebuild all nodal tables each time the mesh is adapted.

The routines SET_NEW_NODE and UNUSE_NODE in module M_ADAPTIVITY_UTIL have been generalized so that now they accept nodes with a variable number of degrees of freedom.

3. Numerical examples

We now present some numerical examples in order to check the model that has been described in the previous Section.

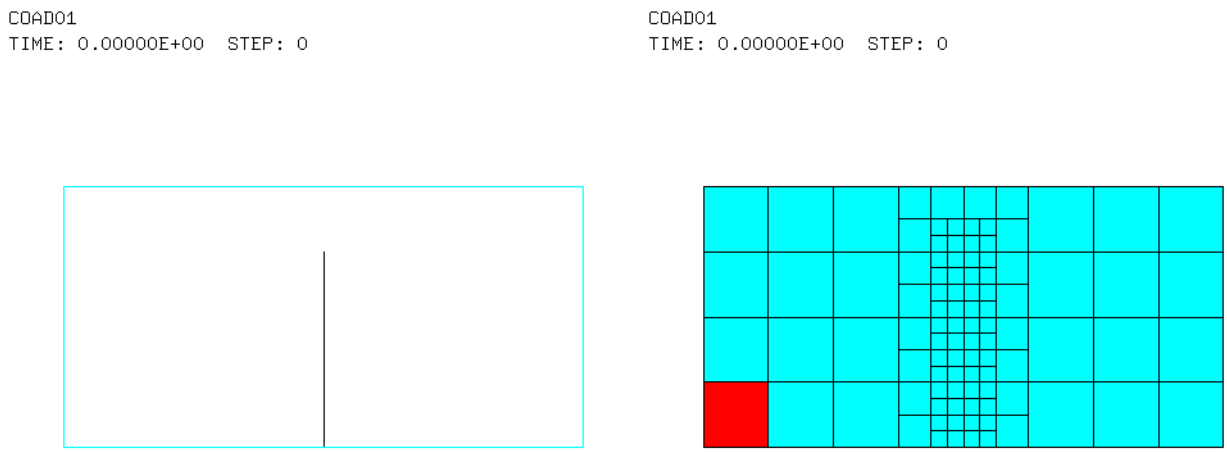
3.1 Combined Threshold / FLSW adaptivity

We first consider an extremely simplified fluid-structure problem, a 2D box with rigid walls containing an internal deformable diaphragm, see Figure 3. An explosion takes place in a corner of the box and the generated pressure waves load the internal structure. The base discretization is extremely crude: only 8×4 quadrilateral (Q4VF) elements in the fluid and 2 shell elements (ED01) in the structure. In this case we use VFCCs for the fluid and the FLSW algorithm to treat FSI.

The simulations performed are summarized in Table 1.

Case	Fluid	Structure	FSI	Notes
COAD01	Adaptive	Not adaptive	FLSW	Base calculation (adaptive fluid)
COAD02	Adaptive	Adaptive	FLSW	Add adaptivity in structure
COAD03	Not adaptive	Adaptive	FLSW	Remove adaptivity in fluid

Table 1 - Box simulations with VFCCs and FLSW



Fluid contour and internal structure

Initial mesh adapted in the fluid

Figure 3 - Fluid box with internal diaphragm

COAD01

The first simulation uses adaptivity only in the fluid sub-domain, according to the model presented in reference [12], and is considered as a reference solution. The adaptation of the fluid domain is done by specifying some dimensioning at the beginning of the input file:

```
DIME
  ADAP NPOI 81 Q4VF 88 NVFI 206 ENDA
  NALE 1 NBLE 1
TERM
```

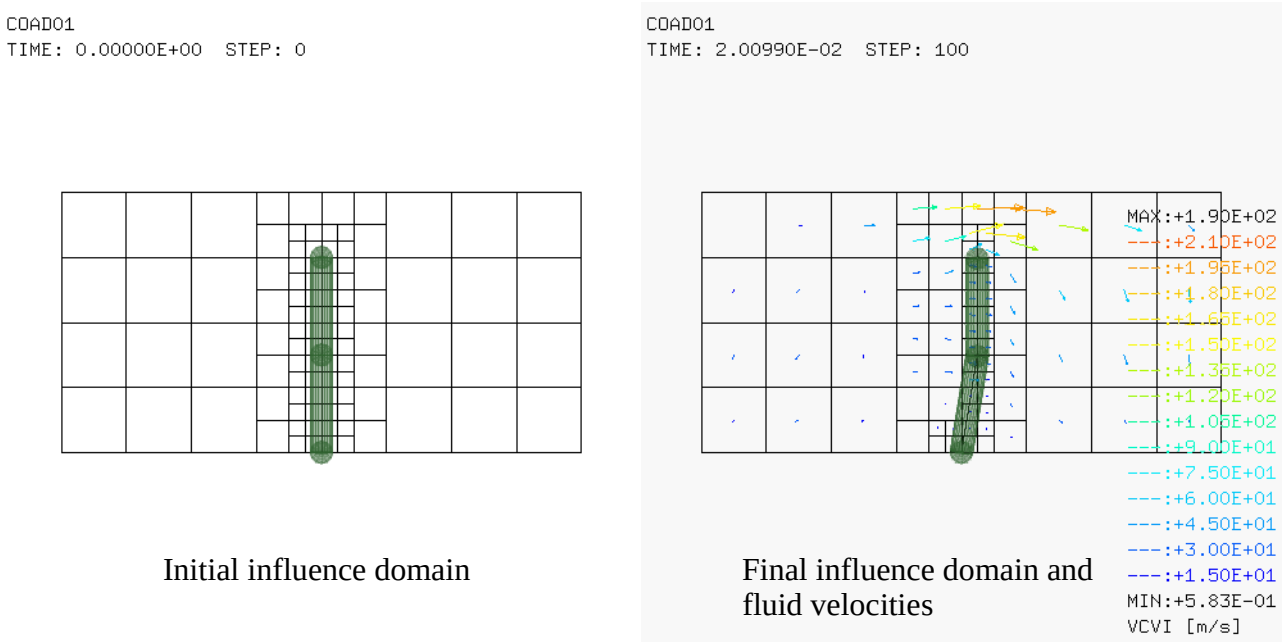
and by adding the ADAP optional keyword to the FLSW directive:

```
LINK DECO
     FLSW STRU LECT stru TERM
          FLUI LECT flui TERM
          R 0.71    ! flui mesh size 1.0 : 1.0*0.71 = 0.71
          HGRI 1.6  ! stru mesh size 1.5
          DGRI
          FACE
          BFLU 2 FSCP 1
          ADAP LMAX 3
```

The RCON option is also added in order to keep the fluid mesh transition smooth:

```
OPTI PAS AUTO NOTE LOG 1
     CSTA 0.5
     ADAP RCON
```

Some results of this calculation are shown in Figure 4. The initial influence domain of the structure is shown in the left picture. The right picture presents the final influence domain, which follows the motion and deformation of the structure, and the fluid velocities around the diaphragm. Note that also the fluid mesh refinement follows the structure. Although failure of the structural material is specified and erosion is activated (EROS 1.0), no structural element is eroded until the final time.



Initial influence domain

Final influence domain and fluid velocities

Figure 4 - Results of case COAD01

COAD02

The next simulation adds adaptivity in the structure by means of the THRS (threshold) directive: The mesh adaptivity dimensioning must be updated:

```
DIME
  ADAP NPOI 81 Q4VF 88 ED01 8 NVFI 206 ENDA
  NALE 1 NBLE 1
TERM
```

A VM23 material is used in the structure with a failure criterion on von Mises equivalent stress:

```
MATE VM23 RO 8000. YOUN 1.D11 NU 0.3 ELAS 2.D8
          FAIL VMIS LIMI 7.5E7
          TRAC 3 2.D8 2.D-3 3.D8 1. 3.1D8 2.
          LECT stru _ed01 TERM
```

The ECR(6) value for this material (see User's Manual [21]) is a failure flag, which assumes the value 0 for a virgin Gauss point and the value 1 for a failed Gauss point. Since a shell element has several Gauss points (10 points by default in the case of ED01) the "average" global failure flag for the whole element may assume values between 0.0 and 1.0, depending on how many Gauss points have failed. When the global failure flag reaches the limit set in the input for erosion (1.0 in this case), the element is eroded and it is no longer considered in the calculation.

The threshold directive for adaptivity in the structure is specified as follows:

```
ADAP THRS ECRO 6 TMIN 0.1 TMAX 0.5 MAXL 3
          LECT stru TERM
```

That is, the ECR(6) value is monitored in the structure (stru object) and structure mesh refinement from level 1 (base level, no refinement) up to level 3 (two successive refinements) is performed as the value passes from 0.1 to 0.5. Of course, the structure mesh must be refined when some damage (incomplete failure) takes place, i.e. well before the element has reached complete failure (according to the EROS parameter value) and is eroded. Only in this way can structure mesh adaptivity help to better capture the structural failure mechanism.

In order to precisely follow on the listing the mesh adaptation (in particular in the structure) in this calculation, we add the option:

```
OPTI ... ADAP dump stat RCON
```

The calculation takes 121 time steps to reach the final time of 20 ms. In the listing, we find the following messages concerning the splitting of structural elements:

```
SPLIT ELEMENT    33 AT STEP    75 AT TIME  1.50472D-02
SPLIT ELEMENT    35 AT STEP    75 AT TIME  1.50472D-02
SPLIT ELEMENT    36 AT STEP    75 AT TIME  1.50472D-02
SPLIT ELEMENT    34 AT STEP    75 AT TIME  1.50472D-02
```

Element number 33 is the lower base shell element, while element 34 is the upper one. Elements 35 and 36 result from the splitting of element 33, and are further split.

We also learn from a message on the listing that element 40 (a descendent structural element) completely fails and is eroded at step 137:

```
** ATTENTION 3 IN PUT_FAILED_ELEM : STEP 137 T = 1.84387E-02
   ELEMENT 37 BECOMES ERODED (MATERIAL)
```

This is the only eroded element in the whole calculation up to the final time. The fact that no element completely failed and was eroded in the “reference” solution (case COAD01) should not be surprising since of course the solution may depend slightly upon whether the structural mesh is adapted or not.

Interpretation of results

It is important to note the following detail: the step number and the time printed in the listing at each element splitting (with OPTI ADAP DUMP active) are the values <u>at the beginning</u> of the step at which the splitting occurs. In fact, MESH_ADAPTIVITY is called by CALCUL <u>just before incrementing the step number and the time</u> (see e.g. Figure 1) so that the step number and the time appearing in the message are in reality those pertaining to the previous (just completed) time step. Thus, in the present example, if we would visualize the structural mesh at step 75, we would still see element 33 in place (and not his children elements 35 and 36).

This (apparent) discrepancy of 1 time step is not critical in an explicit code such as EPX where the time increment is very small anyway due to stability constraints. However, it is important that the user be aware of such details.

In the light of these considerations, some results of this calculation are presented below in Figure 5.

At step 75 we still see 2 face domains, but they become 6 at step 76 as the structure is refined. At step 136 all domains are still visible but starting from step 137 the failed element (eroded at step 137) and the corresponding face domain have disappeared. The final result (step 153) is also shown.

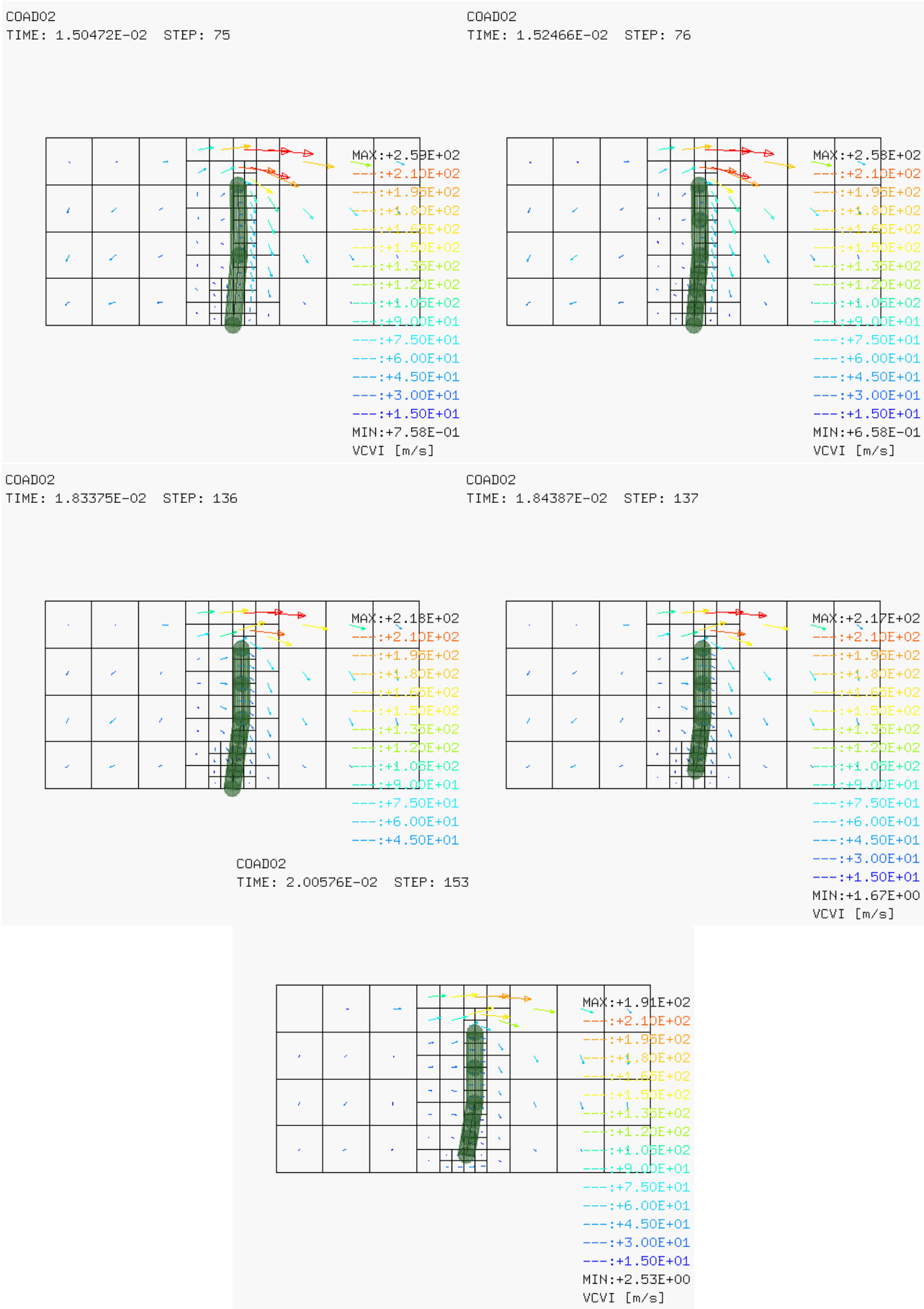


Figure 5 - Results of case COAD02

COAD03

The next and final simulation is similar to case COAD02 but adaptivity in the fluid is removed. There is adaptivity only in the structure. As a consequence, the structural influence domain must be rebuilt like in case 02. Of course, this type of model is not recommended since, as the structure mesh is refined, it becomes even finer than the fluid mesh (which is not adapted in this case). However, we want to make sure that the code works even in an extreme (and ill-posed) situation like the present one.

This is indeed the case and some results of this (weird) simulation are presented in Figure 6. Element 44 is eroded at step 130 and the calculation terminates normally at step 149.

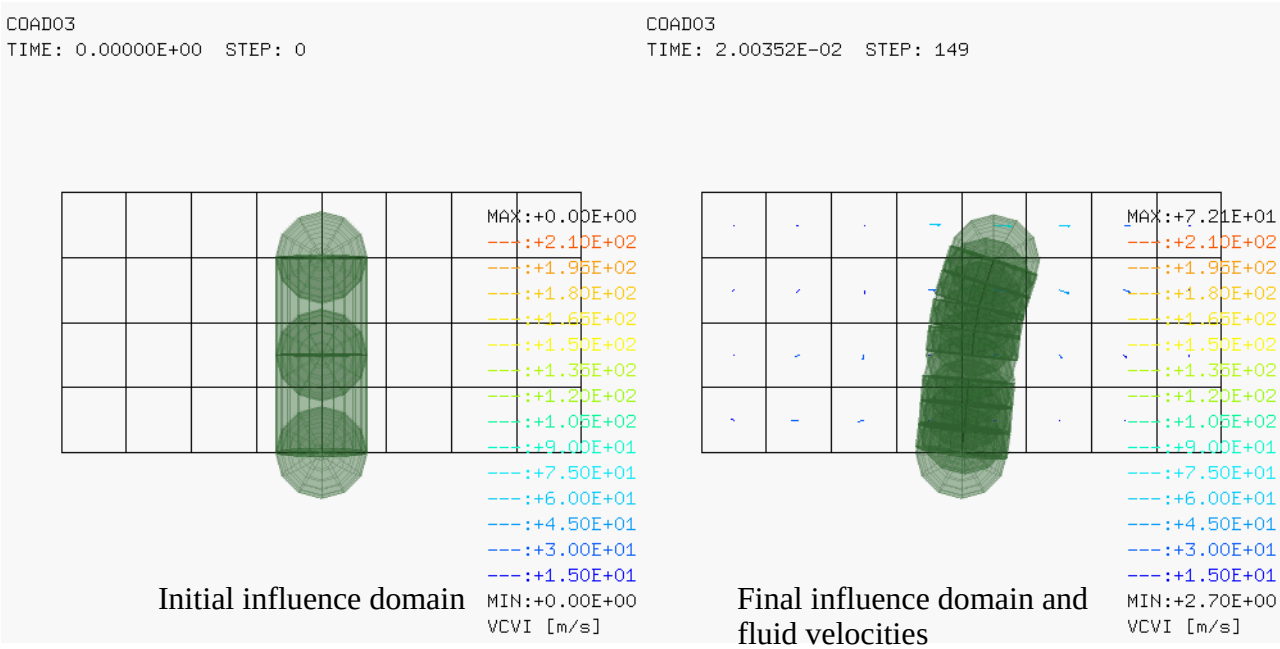


Figure 6 - Results of case COAD03

3.2 Combined Threshold / FLSR adaptivity

We now consider the same problem as before but we discretize the fluid domain by means of FE instead of VFCC and we use the FLSR model instead of FLSW for FSI.

The simulations performed are summarized in Table 2.

Case	Fluid	Structure	FSI	Notes
COAD04	Adaptive	Not adaptive	FLSR	Base calculation (adaptive fluid)
COAD07	Adaptive	Not adaptive	FLSR	Twice finer meshes
COAD05	Adaptive	Adaptive	FLSR	Add adaptivity in structure

Table 2 - Box simulations with FE and FLSR

Case	Fluid	Structure	FSI	Notes
COAD06	Not adaptive	Adaptive	FLSR	Remove adaptivity in fluid

Table 2 - Box simulations with FE and FLSR

COAD04

This is similar to case COAD01 (adaptivity only in the fluid domain). With FE now to model the fluid domain, it becomes necessary to block the whole contour of the fluid domain along the appropriate direction(s) in order to simulate rigid walls (this was automatic with FLSW in the previous examples). Therefore the boundary conditions become:

```
LINK COUP SPLT NONE
     BLOQ 1 LECT 1 PAS 9 37 9 PAS 9 45 TERM
     BLOQ 2 LECT 1 PAS 1 9 37 PAS 1 45 TERM
     BLOQ 123 LECT base TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 0.71    ! flui mesh size 1.0 : 1.0*0.71 = 0.71
          HGRI 1.6  ! stru mesh size 1.5
          DGRI
          BFLU 2 FSCP 1
          ADAP LMAX 3
```

The solution reaches normally the final time after 143 time steps. However, by visualizing the results an apparently strange phenomenon is observed. At a certain point of the calculation (step 93, time 13.77 ms) the structure gets completely blocked (structural “locking”), see for example the plot in Figure 7 which shows the horizontal displacement of the structure tip.

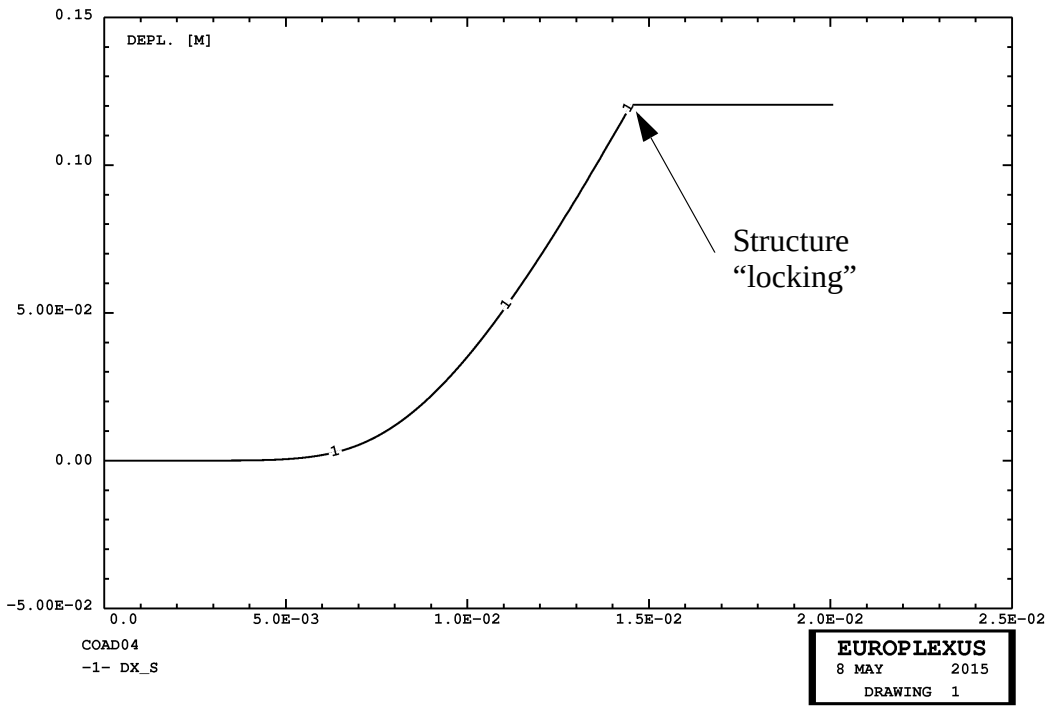


Figure 7 - Results of case COAD04

This phenomenon occurs since in this problem the mesh is very coarse and the number of constraints which arise at a certain moment of the solution is too large with respect to the number of degrees of freedom (dofs) of the problem.

Recall that in this case we have three different types of constraints:

- Blockages along the fluid boundary and at the base of the structure.
- FSI conditions (which are also imposed strongly in a coupled manner in this case)
- Further constraints at hanging nodes due to adaptivity (these are not needed with VFCCs).

To confirm this analysis, the same calculation is repeated by using a different solver for the links system, the SPLIB solver. This is activated by adding the keywords SOLV SPLI to the LINK COUP directive. In this case, the code stops with an error message saying that “NO CONVERGENCE IS REACHED in 1000 ITERATIONS”.

This is a clear indication that the system of constraints to be solved is singular (too many constraints). The fact that the standard solver (Cholesky) is able to continue the calculation is due to the special implementation of this solver in EPX, which is able to get rid of (a limited number of) redundant constraints. However, in this case the solution obtained is unphysical.

The FLSW model combined with VFCCs of the previous simulations did not suffer of this problem. In that case in fact, the only “strong” constraint imposed were the blockages at the base of the structure. No blockages on the contour of the fluid are necessary in that case. The FSI model uses a weak formulation (direct pressure application), which again introduces no constraints. Finally, even the adaptive hanging nodes introduce no additional constraints with the VFCC model (because velocities are expressed at the cell centers and not at the nodes).

COAD07

This simulation is similar to COAD04 but uses twice finer meshes, both for the fluid and for the structure domain. The hope is that the balance between constraints and dofs becomes more favorable so that a (meaningful) solution to the problem can be found.

The locking occurs later than in case 04, but it is still visible as can be seen in Figure 8.

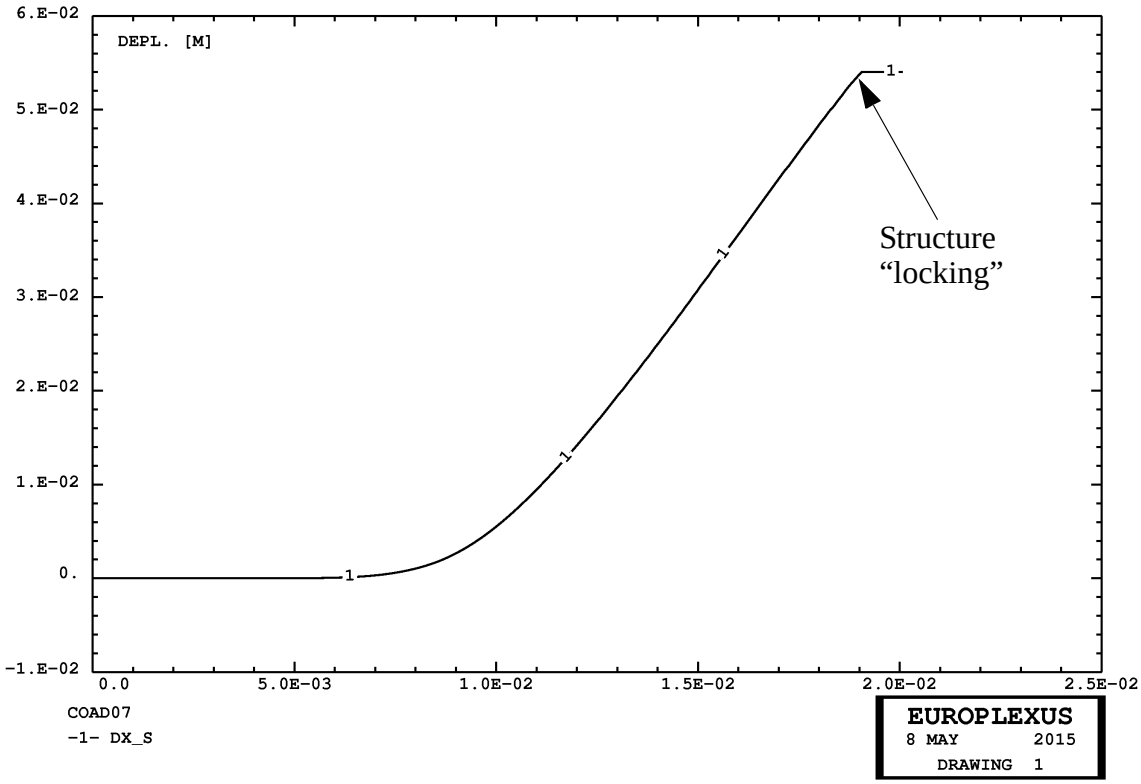


Figure 8 - Results of case COAD07

COAD05

This simulation is similar to COAD04 for the initial meshes (fluid and structure) but adaptivity in the structure is added (like in case COAD02). Two elements fail completely and are eroded in this calculation: element 38 at step 151 (17.14 ms) and element 37 at step 185 (18.97 ms).

Perhaps due to this, no locking is observed, see Figure 9.

The new combined adaptivity model seems to work correctly, as can be seen in Figure 10.

COAD06

This simulation is similar to 05 but we remove the adaptivity in the fluid (although as already explained this is not good practice). The model works and there is no locking. Some results are presented in Figures 11 and 12.

Two elements fail in this case: element 40 at step 102 (16.88 ms) and element 39 at step 112 (17.90 ms).

Figures 13 and 14 compare the horizontal displacements at the structure tip and the fluid pressures in the "explosive" element, respectively, in solutions 01 to 06.

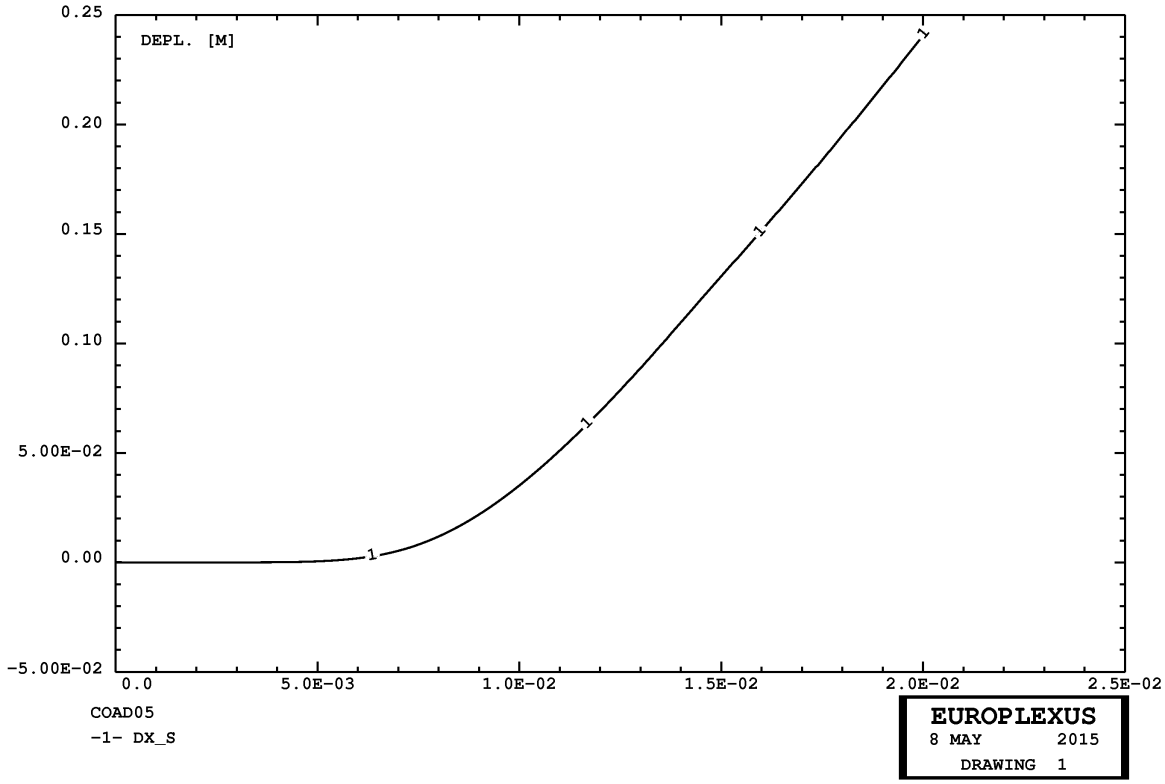


Figure 9 - Some results of case COAD05

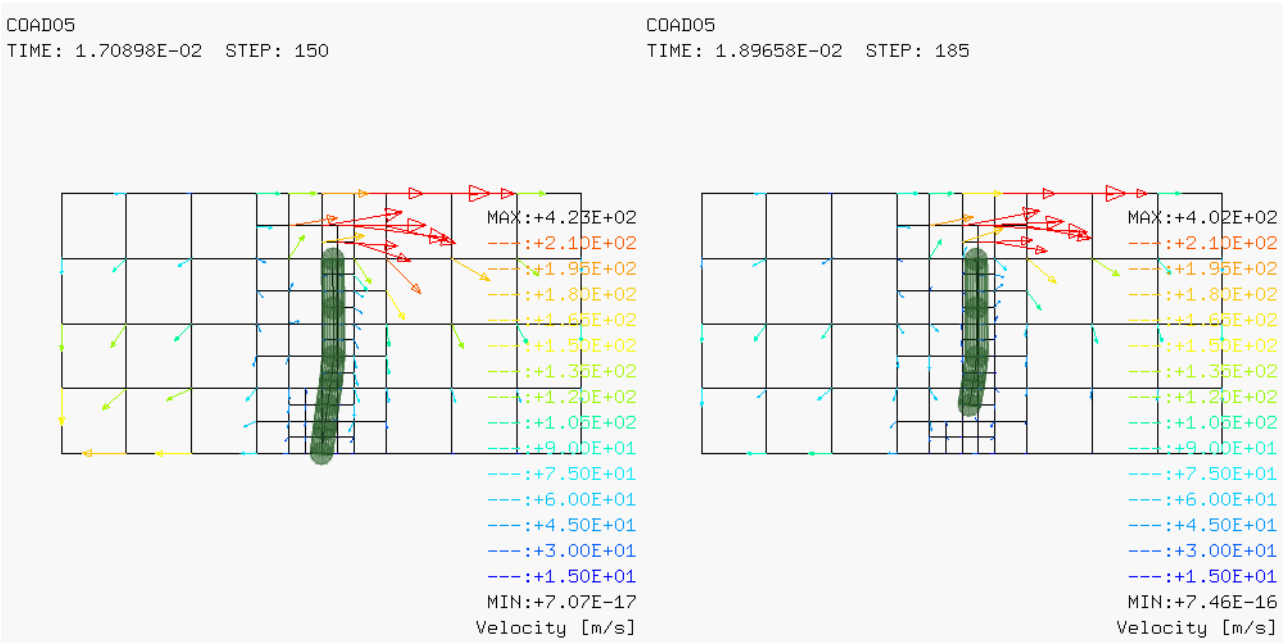


Figure 10 - Further results of case COAD05

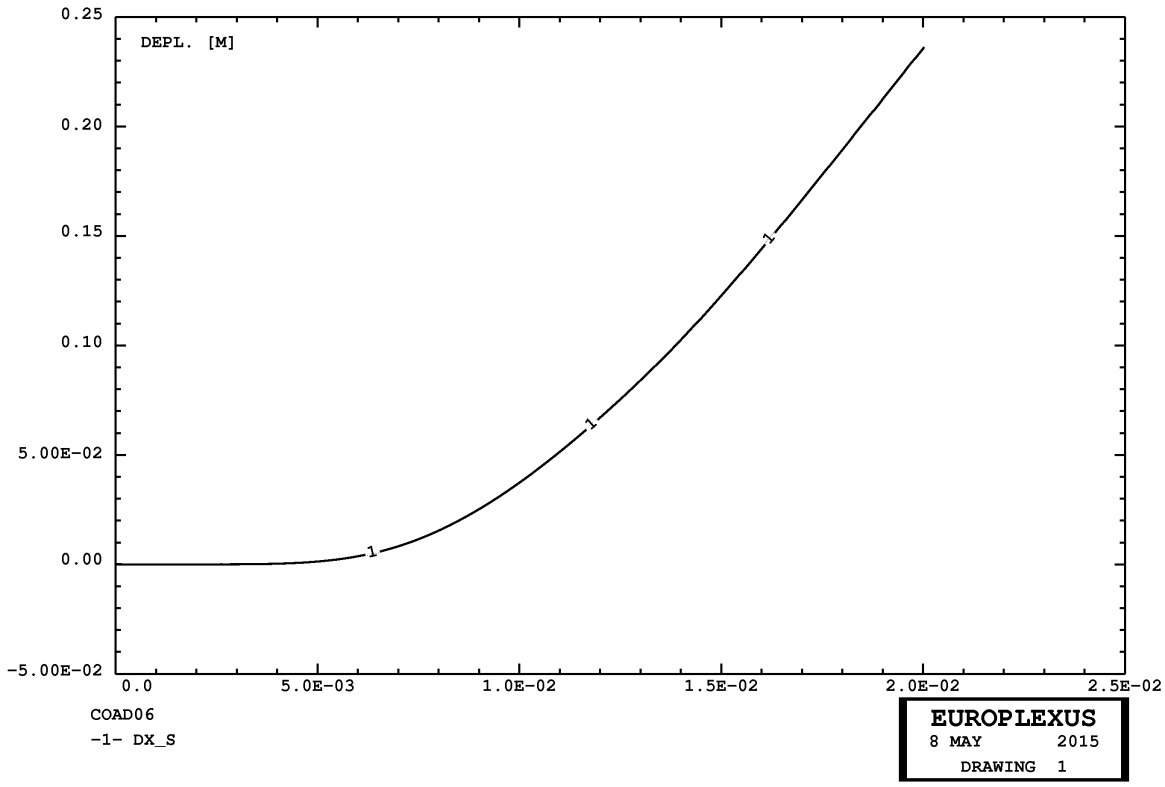


Figure 11 - Some results of case COAD06

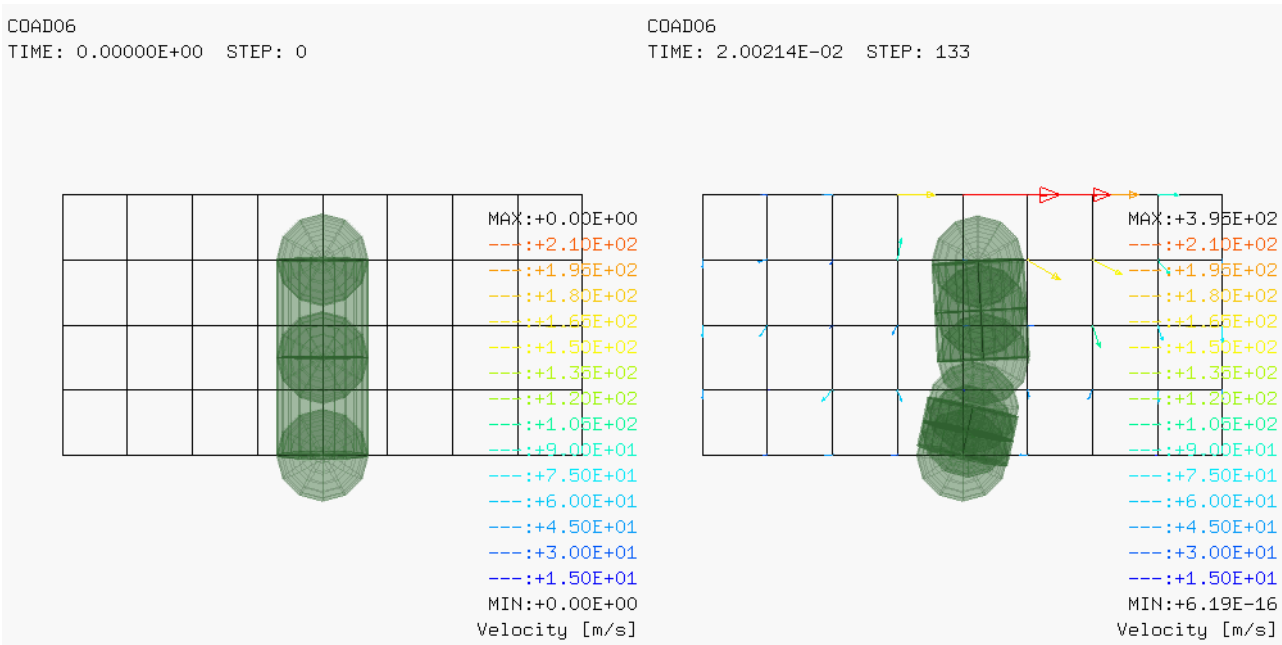


Figure 12 - Further results of case COAD06

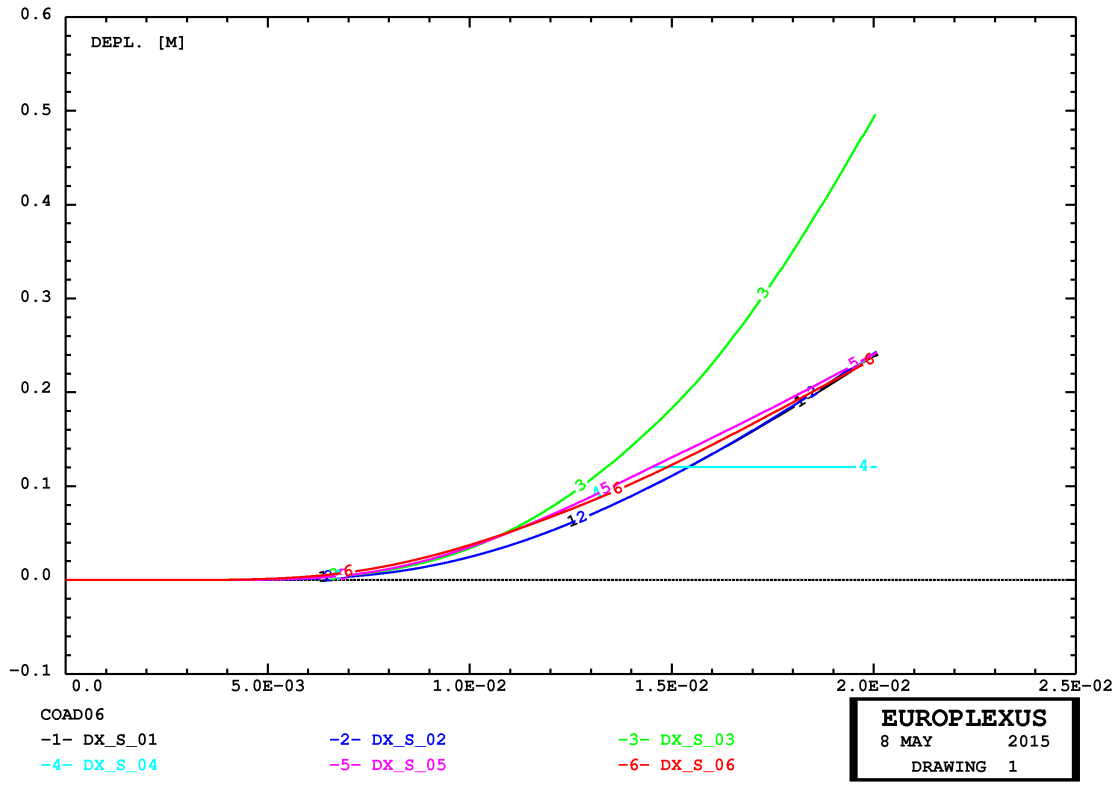


Figure 13 - Comparison of tip structural displacements

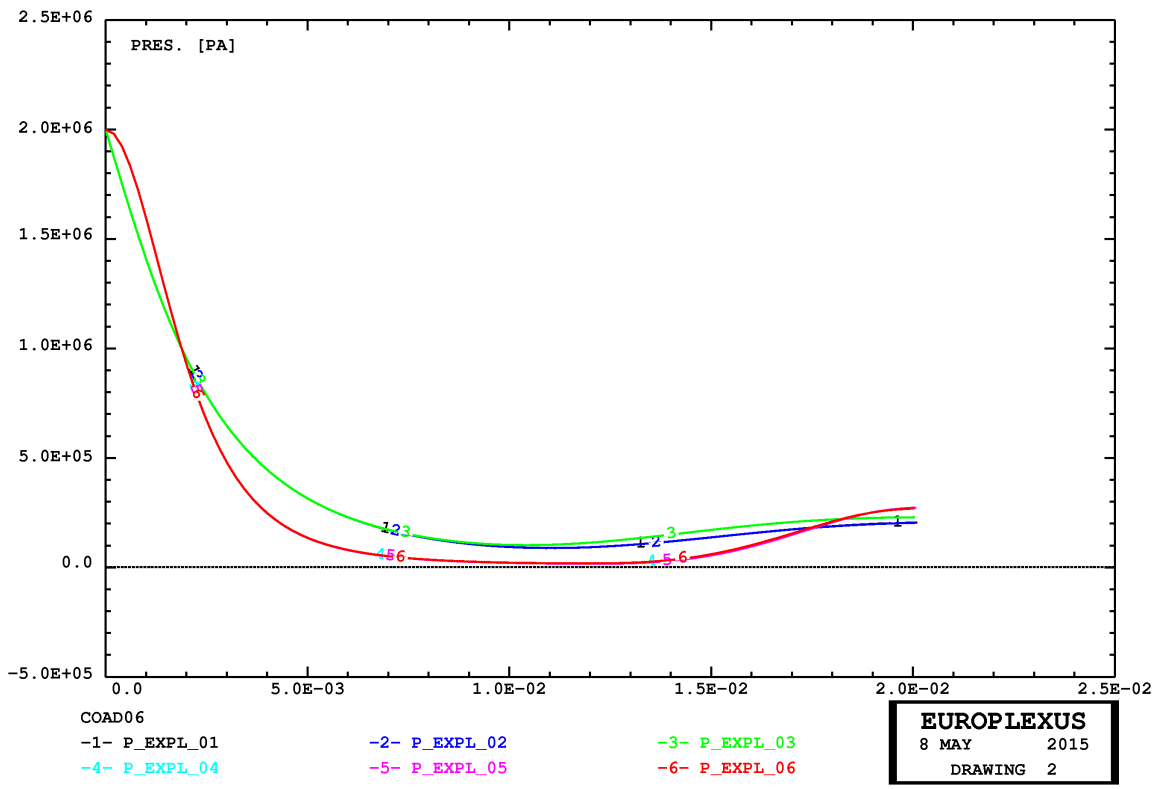


Figure 14 - Comparison of fluid pressures

4. References

[1] F. CASADEI, P. DÍEZ, F. VERDUGO: "A Data Structure for Adaptivity in EUROPLEXUS", JRC Technical Note PUBSY N. JRC60795, September 2010.

[2] F. CASADEI, P. DÍEZ, F. VERDUGO: "Adaptivity in FE Models for Fluids in EUROPLEXUS", JRC Technical Note PUBSY N. JRC61622, November 2010.

[3] F. CASADEI, P. DÍEZ, F. VERDUGO: "Adaptive 3D Refinement and Un-refinement of 8-node Solid and Fluid Hexahedra in EUROPLEXUS", JRC Technical Note PUBSY N. JRC63833, March 2011.

[4] F. CASADEI, P. DÍEZ, F. VERDUGO: "Implementation of a 2D Adaptivity Indicator for Fast Transient Dynamics in EUROPLEXUS", JRC Technical Note PUBSY N. JRC64506, April 2011.

[5] F. CASADEI, P. DÍEZ, F. VERDUGO: "Further Development of 2D Adaptivity Error Indicators in EUROPLEXUS", JRC Technical Note, PUBSY No. JRC66337, September 2011.

[6] F. VERDUGO, P. DÍEZ, F. CASADEI: "Natural quantities of interest in linear elastodynamics for goal oriented error estimation and adaptivity", Proceedings of the V International Conference on Adaptive Modeling and Simulation (ADMOS 2011), D. Aubry and P. Díez (Eds), Paris, France, 6-8 June 2011.

[7] F. VERDUGO, P. DÍEZ, F. CASADEI: "General form of the natural quantities of interest for goal oriented error assessment and adaptivity in linear elastodynamics", Submitted for publication in the International Journal for Numerical Methods in Engineering, DOI: 10.1002/nme, PUBSY No. JRC65788, July 2011.

[8] F. CASADEI, G. VALSAMOS, P. DÍEZ, F. VERDUGO: "Implementation of Adaptivity in 2D Cell Centred Finite Volumes in EUROPLEXUS", Technical Note, PUBSY No. JRC67859, December 2011.

[9] F. CASADEI, P. DÍEZ, F. VERDUGO: "Implementation of Adaptivity in 3D Cell Centred Finite Volumes in EUROPLEXUS", Technical Note, PUBSY No. JRC68168, December 2011.

[10] F. CASADEI, P. DÍEZ, F. VERDUGO: "Testing Adaptivity in 2D Cell Centred Finite Volumes with the CDEM Combustion Model in EUROPLEXUS", Technical Note, PUBSY No. JRC68333, December 2011.

[11] F. CASADEI, P. DÍEZ, F. VERDUGO: "An algorithm for mesh refinement and un-refinement in fast transient dynamics", International Journal of Computational Methods, DOI 10.1142/S0219876213500187, Vol. 10, No. 4, pp. 1350018-1 / 1350018-31, 2013.

[12] F. CASADEI, G. VALSAMOS, M. LARCHER, A. BECCANTINI: "Combination of Mesh Adaptivity

with Fluid-Structure Interaction in Europlexus". Technical Note, PUBSY No. JRC89728, EUR Report 26617 EN, 2014.

[13] F. CASADEI, M. LARCHER, G. VALSAMOS: "*Adaptivity with Simplex Elements in Europlexus*". Technical Note, PUBSY No. JRC89894, EUR Report 26630 EN, 2014.

[14] F. CASADEI, M. LARCHER, G. VALSAMOS: "*Adaptivity in CEA's Fluid Elements in Europlexus*". Technical Note, PUBSY No. JRC89953, EUR Report 26632 EN, 2014.

[15] M. LARCHER, F. CASADEI, G. VALSAMOS: "*Adaptivity in Shell/Beam/Bar Elements in Europlexus*". Technical Note, PUBSY No. JRC90456, EUR Report 26697 EN, 2014.

[16] F. CASADEI: "Fast Transient Fluid-Stucture Interaction with Failure and Fragmentation", Extended abstract submitted for presentation at the 8th World Congress on Computational Mechanics (WCCM8), Venice, Italy, June 30 - July 5, 2008.

[17] F. CASADEI, N. LECONTE: "Use of FLSR Fluid-Structure Interaction with Node-Centered Finite Volumes in EUROPLEXUS. Technical Note, PUBSY No. JRC59686, August 2010.

[18] F. CASADEI, N. LECONTE: "FLSW : A Weak, Embedded-Type Fluid-Structure Interaction Model with CCFV in EUROPLEXUS", Technical Note, PUBSY No. JRC65826, July 2011.

[19] F. CASADEI, M. LARCHER, N. LECONTE: "Strong and weak forms of a fully non-conforming FSI algorithm in fast transient dynamics for blast loading of structures", PUBSY No. JRC60824. COMPDYN 2011, III ECCOMAS Thematic Conference on Computational Methods in Structural Dynamics and Earthquake Engineering, Corfu, Greece, May 25{28, 2011.

[20] A. BECCANTINI, F. CASADEI, P. GALON: "Improvement of the FLSW model for Cell-Centered Finite Volumes in EUROPLEXUS. Report DEN/DANS/DM2S/STMF/LATF/NT/13-019/A, April 2013.

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

List of input files

Appendix

Sample input files

This Section contains, in alphabetical file order, the listings of all input files related to the examples which were proposed in the previous Sections.

coad01.epx

```
COAD01
ECHO
!CONV WIN
DPLA ALE
EROS 1.0
DIME
  ADAP NPOI 81 Q4VF 88 NVFI 206 ENDA
  NALE 1 NBLE 1
TERM
GEOM LIBR POIN 48 Q4VF 32 ED01 2 TERM
  0 0  1 0  2 0  3 0  4 0  5 0  6 0  7 0  8 0
  0 1  1 1  2 1  3 1  4 1  5 1  6 1  7 1  8 1
  0 2  1 2  2 2  3 2  4 2  5 2  6 2  7 2  8 2
  0 3  1 3  2 3  3 3  4 3  5 3  6 3  7 3  8 3
  0 4  1 4  2 4  3 4  4 4  5 4  6 4  7 4  8 4
  4 0  4 1.5  4 3
  1 2 11 10
  2 3 12 11
  3 4 13 12
  4 5 14 13
  5 6 15 14
  6 7 16 15
  7 8 17 16
  8 9 18 17
  10 11 20 19
  11 12 21 20
  12 13 22 21
  13 14 23 22
  14 15 24 23
  15 16 25 24
  16 17 26 25
  17 18 27 26
  19 20 29 28
  20 21 30 29
  21 22 31 30
  22 23 32 31
  23 24 33 32
  24 25 34 33
  25 26 35 34
  26 27 36 35
  28 29 38 37
  29 30 39 38
  30 31 40 39
  31 32 41 40
  32 33 42 41
  33 34 43 42
  34 35 44 43
  35 36 45 44
  46 47
  47 48
COMP GROU 4 'flui' LECT 1 PAS 1 32 TERM
            'stru' LECT 33 34 TERM
            'expl' LECT 1 TERM
            'air'  LECT flui DIFF expl TERM
     NGRO 2 'base' LECT 46 TERM
            'p5s'  LECT 48 TERM
     EPAI 1.E-2 LECT stru TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air  TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE VM23 RO 8000. YOUN 1.D11 NU 0.3 ELAS 2.D8
          FAIL VMIS LIMI 7.5E7
          TRAC 3 2.D8 2.D-3 3.D8 1. 3.1D8 2.
          LECT stru TERM
     GAZP RO 20.0 PINI 20.E5 GAMM 1.4 PREF 1.E5
          LECT expl TERM
     GAZP RO 1.0 PINI 1.E5 GAMM 1.4 PREF 1.E5
          LECT air _q4vf TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT base TERM
LINK DECO
     FLSW STRU LECT stru TERM
          FLUI LECT flui TERM
          R 0.71    ! flui mesh size 1.0 : 1.0*0.71 = 0.71
          HGRI 1.6  ! stru mesh size 1.5
          DGRI
          FACE
          BFLU 2 FSCP 1
          ADAP LMAX 3
ECRI DEPL VITE ACCE FINT FEXT FLIA FDEC CONT ECRO VFCC TFRE 1.D0
     FICH ALIC FREQ 1
OPTI PAS AUTO NOTE LOG 1
     CSTA 0.5
     ADAP RCON
CALC TINI 0. TEND 20.D-3
SUIT
*==============================================================================
COAD01A
ECHO
 CONV WIN
OPTI PRIN
RESU ALIC GARD PSCR
SORT VISU NSTO 1
*------------------------------------------------------------------------------
PLAY
CAME   1 EYE   4.00000E+00  2.00000E+00  2.23607E+01
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  4.00000E+00  2.00000E+00  0.00000E+00
!RSPHERE:  4.47214E+00
!RADIUS :  2.23607E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.74413E+01
!FAR    :  3.13050E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          FLSW DOMA
     VECT SCCO FIEL VCVI SCAL USER PROG 15 PAS 15 210 TERM
          SUPP LECT flui TERM
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 101 FPS 15 KFRE 10 COMP -1 NFAI REND
FREQ 1
GOTR LOOP 99 OFFS FICH AVI CONT NOCL NFAI REND
GO
TRAC OFFS FICH AVI CONT NFAI REND
ENDPLAY
*------------------------------------------------------------------------------
SUIT
*==============================================================================
COAD01C
ECHO
OPTI PRIN
RESU ALIC GARD PSCR
SORT GRAP
PERF 'coad01.pun'
COUR 1 'dx_s'   DEPL COMP 1 NOEU LECT p5s  TERM
COUR 2 'p_expl' ECRO COMP 1 ELEM LECT expl TERM
TRAC 1 AXES 1.0 'DEPL. [M]'
TRAC 2 AXES 1.0 'PRES. [PA]'
LIST 1 AXES 1.0 'DEPL. [M]'
LIST 2 AXES 1.0 'PRES. [PA]'
QUAL DEPL COMP 1 LECT p5s  TERM REFE  2.40365E-01 TOLE 5.E-2
     ECRO COMP 1 LECT expl TERM REFE  2.05255E+05 TOLE 1.E-2
*------------------------------------------------------------------------------
FIN
```

coad02.epx

```
COAD02
ECHO
!CONV WIN
DPLA ALE
EROS 1.0
DIME
  ADAP NPOI 81 Q4VF 88 ED01 8 NVFI 206 ENDA
  NALE 1 NBLE 1
TERM
GEOM LIBR POIN 48 Q4VF 32 ED01 2 TERM
  0 0  1 0  2 0  3 0  4 0  5 0  6 0  7 0  8 0
  0 1  1 1  2 1  3 1  4 1  5 1  6 1  7 1  8 1
  0 2  1 2  2 2  3 2  4 2  5 2  6 2  7 2  8 2
  0 3  1 3  2 3  3 3  4 3  5 3  6 3  7 3  8 3
  0 4  1 4  2 4  3 4  4 4  5 4  6 4  7 4  8 4
  4 0  4 1.5  4 3
  1 2 11 10
  2 3 12 11
  3 4 13 12
  4 5 14 13
  5 6 15 14
  6 7 16 15
  7 8 17 16
  8 9 18 17
  10 11 20 19
  11 12 21 20
  12 13 22 21
  13 14 23 22
  14 15 24 23
  15 16 25 24
  16 17 26 25
  17 18 27 26
  19 20 29 28
  20 21 30 29
  21 22 31 30
  22 23 32 31
  23 24 33 32
  24 25 34 33
  25 26 35 34
  26 27 36 35
  28 29 38 37
  29 30 39 38
  30 31 40 39
  31 32 41 40
  32 33 42 41
  33 34 43 42
  34 35 44 43
  35 36 45 44
  46 47
  47 48
COMP GROU 4 'flui' LECT 1 PAS 1 32 TERM
            'stru' LECT 33 34 TERM
            'expl' LECT 1 TERM
            'air'  LECT flui DIFF expl TERM
     NGRO 2 'base' LECT 46 TERM
            'p5s'  LECT 48 TERM
     EPAI 1.E-2 LECT stru _ed01 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air  TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
ADAP THRS ECRO 6 TMIN 0.1 TMAX 0.5 MAXL 3
          LECT stru TERM
MATE VM23 RO 8000. YOUN 1.D11 NU 0.3 ELAS 2.D8
          FAIL VMIS LIMI 7.5E7
          TRAC 3 2.D8 2.D-3 3.D8 1. 3.1D8 2.
```

```
          LECT stru _ed01 TERM
     GAZP RO 20.0 PINI 20.E5 GAMM 1.4 PREF 1.E5
          LECT expl TERM
     GAZP RO 1.0 PINI 1.E5 GAMM 1.4 PREF 1.E5
          LECT air _q4vf TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT base TERM
LINK DECO
     FLSW STRU LECT stru TERM
          FLUI LECT flui TERM
          R 0.71    ! flui mesh size 1.0 : 1.0*0.71 = 0.71
          HGRI 1.6  ! stru mesh size 1.5
          DGRI
          FACE
          BFLU 2 FSCP 1
          ADAP LMAX 3
ECRI DEPL VITE ACCE FINT FEXT FLIA FDEC CONT ECRO VFCC TFRE 1.D0
     FICH ALIC FREQ 1
OPTI PAS AUTO NOTE LOG 1
     CSTA 0.5
     ADAP dump stat RCON
CALC TINI 0. TEND 20.D-3
SUIT
*==============================================================================
COAD02A
ECHO
 CONV WIN
OPTI PRIN
RESU ALIC GARD PSCR
SORT VISU NSTO 1
*------------------------------------------------------------------------------
PLAY
CAME   1 EYE   4.00000E+00  2.00000E+00  2.23607E+01
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  4.00000E+00  2.00000E+00  0.00000E+00
!RSPHERE:  4.47214E+00
!RADIUS :  2.23607E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.74413E+01
!FAR    :  3.13050E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          FLSW DOMA
     VECT SCCO FIEL VCVI SCAL USER PROG 15 PAS 15 210 TERM
          SUPP LECT flui TERM
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 154 FPS 15 KFRE 10 COMP -1 NFAI REND
FREQ 1
GOTR LOOP 152 OFFS FICH AVI CONT NOCL NFAI REND
GO
TRAC OFFS FICH AVI CONT NFAI REND
ENDPLAY
*------------------------------------------------------------------------------
SUIT
*==============================================================================
COAD02C
ECHO
OPTI PRIN
RESU ALIC GARD PSCR
SORT GRAP
PERF 'coad02.pun'
COUR 1 'dx_s'   DEPL COMP 1 NOEU LECT p5s  TERM
COUR 2 'p_expl' ECRO COMP 1 ELEM LECT expl TERM
TRAC 1 AXES 1.0 'DEPL. [M]'
TRAC 2 AXES 1.0 'PRES. [PA]'
LIST 1 AXES 1.0 'DEPL. [M]'
LIST 2 AXES 1.0 'PRES. [PA]'
QUAL DEPL COMP 1 LECT p5s  TERM REFE  2.43285E-01 TOLE 5.E-2
     ECRO COMP 1 LECT expl TERM REFE  2.03872E+05 TOLE 1.E-2
*------------------------------------------------------------------------------
FIN
```

coad03.epx

```
COAD03
ECHO
!CONV WIN
DPLA ALE
EROS 1.0
DIME
  ADAP NPOI 6 ED01 12 ENDA
  NALE 1 NBLE 1
TERM
GEOM LIBR POIN 48 Q4VF 32 ED01 2 TERM
  0 0  1 0  2 0  3 0  4 0  5 0  6 0  7 0  8 0
  0 1  1 1  2 1  3 1  4 1  5 1  6 1  7 1  8 1
  0 2  1 2  2 2  3 2  4 2  5 2  6 2  7 2  8 2
  0 3  1 3  2 3  3 3  4 3  5 3  6 3  7 3  8 3
  0 4  1 4  2 4  3 4  4 4  5 4  6 4  7 4  8 4
  4 0  4 1.5  4 3
  1 2 11 10
  2 3 12 11
  3 4 13 12
  4 5 14 13
  5 6 15 14
  6 7 16 15
  7 8 17 16
  8 9 18 17
  10 11 20 19
  11 12 21 20
  12 13 22 21
  13 14 23 22
  14 15 24 23
  15 16 25 24
  16 17 26 25
  17 18 27 26
  19 20 29 28
  20 21 30 29
  21 22 31 30
  22 23 32 31
  23 24 33 32
  24 25 34 33
  25 26 35 34
  26 27 36 35
  28 29 38 37
  29 30 39 38
  30 31 40 39
  31 32 41 40
  32 33 42 41
  33 34 43 42
  34 35 44 43
  35 36 45 44
  46 47
  47 48
COMP GROU 4 'flui' LECT 1 PAS 1 32 TERM
            'stru' LECT 33 34 TERM
            'expl' LECT 1 TERM
            'air'  LECT flui DIFF expl TERM
     NGRO 2 'base' LECT 46 TERM
            'p5s'  LECT 48 TERM
     EPAI 1.E-2 LECT stru _ed01 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air  TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
ADAP THRS ECRO 6 TMIN 0.1 TMAX 0.5 MAXL 3
          LECT stru TERM
MATE VM23 RO 8000. YOUN 1.D11 NU 0.3 ELAS 2.D8
          FAIL VMIS LIMI 7.5E7
          TRAC 3 2.D8 2.D-3 3.D8 1. 3.1D8 2.
          LECT stru _ed01 TERM
     GAZP RO 20.0 PINI 20.E5 GAMM 1.4 PREF 1.E5
          LECT expl TERM
     GAZP RO 1.0 PINI 1.E5 GAMM 1.4 PREF 1.E5
          LECT air _q4vf TERM
LINK COUP SPLT NONE
     BLOQ 123 LECT base TERM
LINK DECO
     FLSW STRU LECT stru TERM
          FLUI LECT flui TERM
          R 0.71    ! flui mesh size 1.0 : 1.0*0.71 = 0.71
          HGRI 1.6  ! stru mesh size 1.5
          DGRI
          FACE
          BFLU 2 FSCP 1
ECRI DEPL VITE ACCE FINT FEXT FLIA FDEC CONT ECRO VFCC TFRE 1.D0
     FICH ALIC FREQ 1
OPTI PAS AUTO NOTE LOG 1
     CSTA 0.5
     ADAP RCON
CALC TINI 0. TEND 20.D-3
SUIT
*==============================================================================
COAD03A
ECHO
 CONV WIN
OPTI PRIN
RESU ALIC GARD PSCR
SORT VISU NSTO 1
*------------------------------------------------------------------------------
PLAY
CAME   1 EYE   4.00000E+00  2.00000E+00  2.23607E+01
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  4.00000E+00  2.00000E+00  0.00000E+00
!RSPHERE:  4.47214E+00
!RADIUS :  2.23607E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.74413E+01
!FAR    :  3.13050E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          FLSW DOMA
     VECT SCCO FIEL VCVI SCAL USER PROG 15 PAS 15 210 TERM
          SUPP LECT flui TERM
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 150 FPS 15 KFRE 10 COMP -1 NFAI REND
FREQ 1
GOTR LOOP 148 OFFS FICH AVI CONT NOCL NFAI REND
GO
TRAC OFFS FICH AVI CONT NFAI REND
ENDPLAY
*------------------------------------------------------------------------------
SUIT
*==============================================================================
COAD03C
ECHO
OPTI PRIN
RESU ALIC GARD PSCR
SORT GRAP
PERF 'coad03.pun'
COUR 1 'dx_s'   DEPL COMP 1 NOEU LECT p5s  TERM
COUR 2 'p_expl' ECRO COMP 1 ELEM LECT expl TERM
TRAC 1 AXES 1.0 'DEPL. [M]'
TRAC 2 AXES 1.0 'PRES. [PA]'
LIST 1 AXES 1.0 'DEPL. [M]'
LIST 2 AXES 1.0 'PRES. [PA]'
QUAL DEPL COMP 1 LECT p5s  TERM REFE  4.96136E-01 TOLE 5.E-2
     ECRO COMP 1 LECT expl TERM REFE  2.28921E+05 TOLE 1.E-2
*------------------------------------------------------------------------------
FIN
```

coad04.epx

```
COAD04
ECHO
!CONV WIN
DPLA ALE
```

```
EROS 1.0
DIME
  ADAP NPOI 81 FL24 88 ENDA
  NALE 1 NBLE 1
TERM
GEOM LIBR POIN 48 FL24 32 ED01 2 TERM
  0 0  1 0  2 0  3 0  4 0  5 0  6 0  7 0  8 0
  0 1  1 1  2 1  3 1  4 1  5 1  6 1  7 1  8 1
  0 2  1 2  2 2  3 2  4 2  5 2  6 2  7 2  8 2
  0 3  1 3  2 3  3 3  4 3  5 3  6 3  7 3  8 3
  0 4  1 4  2 4  3 4  4 4  5 4  6 4  7 4  8 4
  4 0  4 1.5  4 3
  1 2 11 10
  2 3 12 11
  3 4 13 12
  4 5 14 13
  5 6 15 14
  6 7 16 15
  7 8 17 16
  8 9 18 17
  10 11 20 19
  11 12 21 20
  12 13 22 21
  13 14 23 22
  14 15 24 23
  15 16 25 24
  16 17 26 25
  17 18 27 26
  19 20 29 28
  20 21 30 29
  21 22 31 30
  22 23 32 31
  23 24 33 32
  24 25 34 33
  25 26 35 34
  26 27 36 35
  28 29 38 37
  29 30 39 38
  30 31 40 39
  31 32 41 40
  32 33 42 41
  33 34 43 42
  34 35 44 43
  35 36 45 44
  46 47
  47 48
COMP GROU 4 'flui' LECT 1 PAS 1 32 TERM
            'stru' LECT 33 34 TERM
            'expl' LECT 1 TERM
            'air'  LECT flui DIFF expl TERM
     NGRO 2 'base' LECT 46 TERM
            'p5s'  LECT 48 TERM
     EPAI 1.E-2 LECT stru TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air  TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE VM23 RO 8000. YOUN 1.D11 NU 0.3 ELAS 2.D8
          FAIL VMIS LIMI 7.5E7
          TRAC 3 2.D8 2.D-3 3.D8 1. 3.1D8 2.
          LECT stru TERM
     FLUT RO 20.0 EINT 2.5E5 GAMM 1.4 PB 0 PREF 1.E5
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.5E5 GAMM 1.4 PB 0 PREF 1.E5
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air _fl24 TERM
LINK COUP SPLT NONE
     BLOQ 1 LECT 1 PAS 9 37 9 PAS 9 45 TERM
     BLOQ 2 LECT 1 PAS 1 9 37 PAS 1 45 TERM
     BLOQ 123 LECT base TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 0.71    ! flui mesh size 1.0 : 1.0*0.71 = 0.71
          HGRI 1.6  ! stru mesh size 1.5
          DGRI
          BFLU 2 FSCP 1
          ADAP LMAX 3
ECRI DEPL VITE ACCE FINT FEXT FLIA FDEC CONT ECRO TFRE 1.D0
     FICH ALIC FREQ 1
OPTI PAS AUTO NOTE LOG 1
     CSTA 0.5
     ADAP RCON
CALC TINI 0. TEND 20.D-3
SUIT
*==============================================================================
COAD04A
ECHO
 CONV WIN
OPTI PRIN
RESU ALIC GARD PSCR
SORT VISU NSTO 1
*------------------------------------------------------------------------------
PLAY
CAME   1 EYE   4.00000E+00  2.00000E+00  2.23607E+01
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  4.00000E+00  2.00000E+00  0.00000E+00
!RSPHERE:  4.47214E+00
!RADIUS :  2.23607E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.74413E+01
!FAR    :  3.13050E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          FLSR DOMA
     VECT SCCO FIEL VITE SCAL USER PROG 15 PAS 15 210 TERM
          SUPP LECT flui TERM
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 144 FPS 15 KFRE 10 COMP -1 NFAI REND
FREQ 1
GOTR LOOP 142 OFFS FICH AVI CONT NOCL NFAI REND
GO
TRAC OFFS FICH AVI CONT NFAI REND
ENDPLAY
*------------------------------------------------------------------------------
SUIT
*==============================================================================
COAD04C
ECHO
OPTI PRIN
RESU ALIC GARD PSCR
SORT GRAP
PERF 'coad04.pun'
COUR 1 'dx_s'   DEPL COMP 1 NOEU LECT p5s  TERM
COUR 2 'p_expl' ECRO COMP 1 ELEM LECT expl TERM
TRAC 1 AXES 1.0 'DEPL. [M]'
TRAC 2 AXES 1.0 'PRES. [PA]'
LIST 1 AXES 1.0 'DEPL. [M]'
LIST 2 AXES 1.0 'PRES. [PA]'
QUAL DEPL COMP 1 LECT p5s  TERM REFE  1.20486E-01 TOLE 5.E-2
     ECRO COMP 1 LECT expl TERM REFE  2.73005E+05 TOLE 1.E-2
*------------------------------------------------------------------------------
FIN
```

coad05.epx

```
COAD05
ECHO
!CONV WIN
DPLA ALE
EROS 1.0
DIME
  ADAP NPOI 81 FL24 88 ED01 8 ENDA
  NALE 1 NBLE 1
TERM
GEOM LIBR POIN 48 FL24 32 ED01 2 TERM
  0 0  1 0  2 0  3 0  4 0  5 0  6 0  7 0  8 0
  0 1  1 1  2 1  3 1  4 1  5 1  6 1  7 1  8 1
  0 2  1 2  2 2  3 2  4 2  5 2  6 2  7 2  8 2
  0 3  1 3  2 3  3 3  4 3  5 3  6 3  7 3  8 3
  0 4  1 4  2 4  3 4  4 4  5 4  6 4  7 4  8 4
  4 0  4 1.5  4 3
  1 2 11 10
  2 3 12 11
  3 4 13 12
  4 5 14 13
  5 6 15 14
  6 7 16 15
  7 8 17 16
  8 9 18 17
  10 11 20 19
  11 12 21 20
  12 13 22 21
  13 14 23 22
  14 15 24 23
  15 16 25 24
  16 17 26 25
  17 18 27 26
  19 20 29 28
  20 21 30 29
  21 22 31 30
  22 23 32 31
  23 24 33 32
  24 25 34 33
  25 26 35 34
  26 27 36 35
  28 29 38 37
  29 30 39 38
  30 31 40 39
  31 32 41 40
  32 33 42 41
  33 34 43 42
  34 35 44 43
  35 36 45 44
  46 47
  47 48
COMP GROU 4 'flui' LECT 1 PAS 1 32 TERM
            'stru' LECT 33 34 TERM
            'expl' LECT 1 TERM
            'air'  LECT flui DIFF expl TERM
     NGRO 2 'base' LECT 46 TERM
            'p5s'  LECT 48 TERM
     EPAI 1.E-2 LECT stru _ed01 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air  TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
ADAP THRS ECRO 6 TMIN 0.1 TMAX 0.5 MAXL 3
          LECT stru TERM
MATE VM23 RO 8000. YOUN 1.D11 NU 0.3 ELAS 2.D8
          FAIL VMIS LIMI 7.5E7
          TRAC 3 2.D8 2.D-3 3.D8 1. 3.1D8 2.
          LECT stru _ed01 TERM
     FLUT RO 20.0 EINT 2.5E5 GAMM 1.4 PB 0 PREF 1.E5
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.5E5 GAMM 1.4 PB 0 PREF 1.E5
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air _fl24 TERM
LINK COUP SPLT NONE
     BLOQ 1 LECT 1 PAS 9 37 9 PAS 9 45 TERM
     BLOQ 2 LECT 1 PAS 1 9 37 PAS 1 45 TERM
     BLOQ 123 LECT base TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 0.71    ! flui mesh size 1.0 : 1.0*0.71 = 0.71
          HGRI 1.6  ! stru mesh size 1.5
          DGRI
          BFLU 2 FSCP 1
          ADAP LMAX 3
ECRI DEPL VITE ACCE FINT FEXT FLIA FDEC CONT ECRO TFRE 1.D0
```

```
     FICH ALIC FREQ 1
OPTI PAS AUTO NOTE LOG 1
     CSTA 0.5
     ADAP dump stat RCON
     LNKS STAT DIAG
CALC TINI 0. TEND 20.D-3
SUIT
*==============================================================================
COAD05A
ECHO
 CONV WIN
OPTI PRIN
RESU ALIC GARD PSCR
SORT VISU NSTO 1
*------------------------------------------------------------------------------
PLAY
CAME   1 EYE   4.00000E+00  2.00000E+00  2.23607E+01
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  4.00000E+00  2.00000E+00  0.00000E+00
!RSPHERE:  4.47214E+00
!RADIUS :  2.23607E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.74413E+01
!FAR    :  3.13050E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          FLSR DOMA
     VECT SCCO FIEL VITE SCAL USER PROG 15 PAS 15 210 TERM
          SUPP LECT flui TERM
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 186 FPS 15 KFRE 10 COMP -1 NFAI REND
FREQ 1
GOTR LOOP 184 OFFS FICH AVI CONT NOCL NFAI REND
GO
TRAC OFFS FICH AVI CONT NFAI REND
ENDPLAY
*------------------------------------------------------------------------------
SUIT
*==============================================================================
COAD05C
ECHO
OPTI PRIN
RESU ALIC GARD PSCR
SORT GRAP
PERF 'coad05.pun'
COUR 1 'dx_s'   DEPL COMP 1 NOEU LECT p5s  TERM
COUR 2 'p_expl' ECRO COMP 1 ELEM LECT expl TERM
TRAC 1 AXES 1.0 'DEPL. [M]'
TRAC 2 AXES 1.0 'PRES. [PA]'
LIST 1 AXES 1.0 'DEPL. [M]'
LIST 2 AXES 1.0 'PRES. [PA]'
QUAL DEPL COMP 1 LECT p5s  TERM REFE  2.42487E-01 TOLE 5.E-2
     ECRO COMP 1 LECT expl TERM REFE  2.72789E+05 TOLE 1.E-2
*------------------------------------------------------------------------------
FIN
```

coad06.epx

```
COAD06
ECHO
!CONV WIN
DPLA ALE
EROS 1.0
DIME
  ADAP NPOI 4 ED01 8 ENDA
  NALE 1 NBLE 1
TERM
GEOM LIBR POIN 48 FL24 32 ED01 2 TERM
  0 0  1 0  2 0  3 0  4 0  5 0  6 0  7 0  8 0
  0 1  1 1  2 1  3 1  4 1  5 1  6 1  7 1  8 1
  0 2  1 2  2 2  3 2  4 2  5 2  6 2  7 2  8 2
  0 3  1 3  2 3  3 3  4 3  5 3  6 3  7 3  8 3
  0 4  1 4  2 4  3 4  4 4  5 4  6 4  7 4  8 4
  4 0  4 1.5  4 3
  1 2 11 10
  2 3 12 11
  3 4 13 12
  4 5 14 13
  5 6 15 14
  6 7 16 15
  7 8 17 16
  8 9 18 17
  10 11 20 19
  11 12 21 20
  12 13 22 21
  13 14 23 22
  14 15 24 23
  15 16 25 24
  16 17 26 25
  17 18 27 26
  19 20 29 28
  20 21 30 29
  21 22 31 30
  22 23 32 31
  23 24 33 32
  24 25 34 33
  25 26 35 34
  26 27 36 35
  28 29 38 37
  29 30 39 38
  30 31 40 39
  31 32 41 40
  32 33 42 41
  33 34 43 42
  34 35 44 43
  35 36 45 44
  46 47
  47 48
COMP GROU 4 'flui' LECT 1 PAS 1 32 TERM
          'stru' LECT 33 34 TERM
          'expl' LECT 1 TERM
          'air'  LECT flui DIFF expl TERM
     NGRO 2 'base' LECT 46 TERM
            'p5s'  LECT 48 TERM
     EPAI 1.E-2 LECT stru _ed01 TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air  TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
ADAP THRS ECRO 6 TMIN 0.1 TMAX 0.5 MAXL 3
          LECT stru TERM
MATE VM23 RO 8000. YOUN 1.D11 NU 0.3 ELAS 2.D8
          FAIL VMIS LIMI 7.5E7
          TRAC 3 2.D8 2.D-3 3.D8 1. 3.1D8 2.
          LECT stru _ed01 TERM
     FLUT RO 20.0 EINT 2.5E5 GAMM 1.4 PB 0 PREF 1.E5
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.5E5 GAMM 1.4 PB 0 PREF 1.E5
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air _fl24 TERM
LINK COUP SPLT NONE
     BLOQ 1 LECT 1 PAS 9 37 9 PAS 9 45 TERM
     BLOQ 2 LECT 1 PAS 1 9 37 PAS 1 45 TERM
     BLOQ 123 LECT base TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 0.71    ! flui mesh size 1.0 : 1.0*0.71 = 0.71
          HGRI 1.6  ! stru mesh size 1.5
          DGRI
          BFLU 2 FSCP 1
ECRI DEPL VITE ACCE FINT FEXT FLIA FDEC CONT ECRO TFRE 1.D0
     FICH ALIC FREQ 1
OPTI PAS AUTO NOTE LOG 1
     CSTA 0.5
     ADAP dump stat RCON
     LNKS STAT DIAG
CALC TINI 0. TEND 20.D-3
SUIT
*==============================================================================
COAD06A
ECHO
 CONV WIN
OPTI PRIN
RESU ALIC GARD PSCR
SORT VISU NSTO 1
*------------------------------------------------------------------------------
PLAY
CAME   1 EYE   4.00000E+00  2.00000E+00  2.23607E+01
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  4.00000E+00  2.00000E+00  0.00000E+00
!RSPHERE:  4.47214E+00
!RADIUS :  2.23607E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.74413E+01
!FAR    :  3.13050E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          FLSR DOMA
     VECT SCCO FIEL VITE SCAL USER PROG 15 PAS 15 210 TERM
          SUPP LECT flui TERM
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 134 FPS 15 KFRE 10 COMP -1 NFAI REND
FREQ 1
GOTR LOOP 132 OFFS FICH AVI CONT NOCL NFAI REND
GO
TRAC OFFS FICH AVI CONT NFAI REND
ENDPLAY
*------------------------------------------------------------------------------
SUIT
*==============================================================================
COAD06C
ECHO
OPTI PRIN
RESU ALIC GARD PSCR
SORT GRAP
PERF 'coad06.pun'
COUR 1 'dx_s'   DEPL COMP 1 NOEU LECT p5s  TERM
COUR 2 'p_expl' ECRO COMP 1 ELEM LECT expl TERM
TRAC 1 AXES 1.0 'DEPL. [M]'
TRAC 2 AXES 1.0 'PRES. [PA]'
LIST 1 AXES 1.0 'DEPL. [M]'
LIST 2 AXES 1.0 'PRES. [PA]'
QUAL DEPL COMP 1 LECT p5s  TERM REFE  2.35154E-01 TOLE 5.E-2
     ECRO COMP 1 LECT expl TERM REFE  2.68996E+05 TOLE 1.E-2
*------------------------------------------------------------------------------
FIN
```

coad07.dgibi

```
opti echo 1;
opti dime 2 elem qua4;
opti trac psc ftra 'coad07_mesh.ps';
opti sauv form 'coad07.msh';
p0 = 0 0;
p1 = 8 0;
p2 = 8 4;
p3 = 0 4;
c1 = p0 d 16 p1;
c2 = p1 d  8 p2;
c3 = p2 d 16 p3;
c4 = p3 d  8 p0;
flui = dall c1 c2 c3 c4 plan;
fsrn = cont flui;
p4s = 4 0;
```

```
p5s = 4 3;
stru = p4s d 4 p5s;
mesh = flui et stru et fsrn;
tass mesh;
trac qual mesh;
sauv form mesh;
fin;
```

coad07.epx

```
COAD07
ECHO
!CONV WIN
DPLA ALE
CAST mesh
EROS 1.0
DIME
  ADAP NPOI 144 FL24 160 ENDA
  NALE 1 NBLE 1
TERM
GEOM FL24 flui ED01 stru TERM
COMP GROU 2 'expl' LECT flui TERM COND NEAR NODE LECT p0 TERM
            'air'  LECT flui DIFF expl TERM
     NGRO 1 'base' LECT p4s TERM
     EPAI 1.E-2 LECT stru TERM
     COUL ROUG LECT expl TERM
          TURQ LECT air  TERM
          VERT LECT stru TERM
GRIL LAGR LECT stru TERM
     EULE LECT flui TERM
MATE VM23 RO 8000. YOUN 1.D11 NU 0.3 ELAS 2.D8
          FAIL VMIS LIMI 7.5E7
          TRAC 3 2.D8 2.D-3 3.D8 1. 3.1D8 2.
          LECT stru TERM
     FLUT RO 20.0 EINT 2.5E5 GAMM 1.4 PB 0 PREF 1.E5
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT expl TERM
     FLUT RO 1.0 EINT 2.5E5 GAMM 1.4 PB 0 PREF 1.E5
          ITER 1 ALF0 1 BET0 1 KINT 0 AHGF 0 CL 0.5
          CQ 2.56 PMIN 0 NUM 1
          LECT air _fl24 TERM
LINK COUP SPLT NONE
     FSR  LECT fsrn TERM
     BLOQ 123  LECT base TERM
     FLSR STRU LECT stru TERM
          FLUI LECT flui TERM
          R 0.355   ! flui mesh size 0.5 : 0.5*0.71 = 0.355
          HGRI 0.8  ! stru mesh size 0.75
          DGRI
          BFLU 2 FSCP 1
          ADAP LMAX 3
ECRI DEPL VITE ACCE FINT FEXT FLIA FDEC CONT ECRO TFRE 1.D0
     FICH ALIC FREQ 1
OPTI PAS AUTO NOTE LOG 1
     CSTA 0.5
     ADAP RCON
CALC TINI 0. TEND 20.D-3
SUIT
*==============================================================================
COAD07A
ECHO
 CONV WIN
OPTI PRIN
RESU ALIC GARD PSCR
SORT VISU NSTO 1
*------------------------------------------------------------------------------
PLAY
CAME   1 EYE   4.00000E+00  2.00000E+00  2.23607E+01
!        Q     1.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
         VIEW  0.00000E+00  0.00000E+00 -1.00000E+00
         RIGH  1.00000E+00  0.00000E+00  0.00000E+00
         UP    0.00000E+00  1.00000E+00  0.00000E+00
         FOV   2.48819E+01
!NAVIGATION MODE: ROTATING CAMERA
!CENTER :  4.00000E+00  2.00000E+00  0.00000E+00
!RSPHERE:  4.47214E+00
!RADIUS :  2.23607E+01
!ASPECT :  1.00000E+00
!NEAR   :  1.74413E+01
!FAR    :  3.13050E+01
SCEN GEOM NAVI FREE
          FACE HFRO
          FLSR DOMA
     VECT SCCO FIEL VITE SCAL USER PROG 15 PAS 15 210 TERM
          SUPP LECT flui TERM
     TEXT VSCA
     COLO PAPE
SLER CAM1 1 NFRA 1
TRAC OFFS FICH AVI NOCL NFTO 206 FPS 15 KFRE 10 COMP -1 NFAI REND
FREQ 1
GOTR LOOP 204 OFFS FICH AVI CONT NOCL NFAI REND
GO
TRAC OFFS FICH AVI CONT NFAI REND
ENDPLAY
*------------------------------------------------------------------------------
SUIT
*==============================================================================
COAD07C
ECHO
OPTI PRIN
RESU ALIC GARD PSCR
SORT GRAP
PERF 'coad07.pun'
COUR 1 'dx_s'   DEPL COMP 1 NOEU LECT p5s  TERM
COUR 2 'p_expl' ECRO COMP 1 ELEM LECT expl TERM
TRAC 1 AXES 1.0 'DEPL. [M]'
TRAC 2 AXES 1.0 'PRES. [PA]'
LIST 1 AXES 1.0 'DEPL. [M]'
LIST 2 AXES 1.0 'PRES. [PA]'
QUAL DEPL COMP 1 LECT p5s  TERM REFE  5.40360E-02 TOLE 5.E-2
     ECRO COMP 1 LECT expl TERM REFE  1.84645E+05 TOLE 1.E-2
*------------------------------------------------------------------------------
FIN
```

resume.epx

```
RESUME
ECHO
OPTI PRIN
RESU ALIC 'coad06.ali' GARD PSCR
SORT GRAP
RCOU 11 'dx_s'   FICH 'coad01.pun' RENA 'dx_s_01'
RCOU 12 'p_expl' FICH 'coad01.pun' RENA 'p_expl_01'
RCOU 21 'dx_s'   FICH 'coad02.pun' RENA 'dx_s_02'
RCOU 22 'p_expl' FICH 'coad02.pun' RENA 'p_expl_02'
RCOU 31 'dx_s'   FICH 'coad03.pun' RENA 'dx_s_03'
RCOU 32 'p_expl' FICH 'coad03.pun' RENA 'p_expl_03'
RCOU 41 'dx_s'   FICH 'coad04.pun' RENA 'dx_s_04'
RCOU 42 'p_expl' FICH 'coad04.pun' RENA 'p_expl_04'
RCOU 51 'dx_s'   FICH 'coad05.pun' RENA 'dx_s_05'
RCOU 52 'p_expl' FICH 'coad05.pun' RENA 'p_expl_05'
RCOU 61 'dx_s'   FICH 'coad06.pun' RENA 'dx_s_06'
RCOU 62 'p_expl' FICH 'coad06.pun' RENA 'p_expl_06'
TRAC 11 21 31 41 51 61 AXES 1.0 'DEPL. [M]' YZER
COLO NOIR BLEU VERT TURQ ROSE ROUG
TRAC 12 22 32 42 52 62 AXES 1.0 'PRES. [PA]' YZER
COLO NOIR BLEU VERT TURQ ROSE ROUG
*------------------------------------------------------------------------------
FIN
```

European Commission
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Title: Combined Fluid and Structure Mesh Adaptivity with Fluid-Structure Interaction in EUROPLEXUS

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Abstract

The present work extends the automatic fluid mesh adaptation to the case where adaptation of the structure occurs simultaneously. This technique is particularly useful in conjunction with FSI algorithms of the embedded or immersed type, such as the FLSR or FLSW algorithms available in EUROPLEXUS.

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