An explicit PFEM-FEM Coupling for Lagrangian Fluid-Structure Interaction Problems

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The efficient numerical simulation of fluid-structure interaction (FSI) problems is of interest in many engineering fields. In the present work we propose a staggered approach that couples an explicit Particle Finite Element Method (PFEM) [1, 2] for the fluid subdomain with an explicit Finite Element Method, for the structural one. Thanks to the Lagrangian formulation of PFEM, the fluid boundaries are directly defined by the current position of the particles, which is very effective in the case of free surface flows and large structural displacements. The commercial software Abaqus/Explicit from Dassault Systèmes is employed for the structural subdomain. This allows to include in the model all its advanced functionalities, such as the wide library of material constitutive models and the possibility to introduce nonlinear features such as crack propagation, contact interactions and large deformations.
The coupling algorithm is based on the Domain Decomposition Method proposed by Gravouil and Combescure (GC algorithm) [3]. The GC scheme allows to use different time step sizes in each subdomain, which increases the efficiency of the explicit solver in the presence of different materials in different subdomains. Applying the GC algorithm to FSI problems, the fluid and structural domain are solved independently, as if there was no interaction between them. The two separated analyses are then synchronized by considering a small system of constraint equations at the fluid-structure interface, ensuring the strong coupling of the staggered approach. Moreover, in the present case involving explicit fluid and structural solvers, the constraint equations are decoupled. The resulting fully explicit solver is appealing for its possible application in a large variety of large scale engineering problems with fast dynamics and/or a high degree of non-linearity. The comparison of 2D-examples with analytical, experimental and numerical results presented in the literature shows the effectiveness of the proposed coupling method.

References

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