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Fully Explicit Three-Dimensional Lagrangian Simulation of Fluid-Structure-Interaction Problems

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ABSTRACT

A partitioned fully Lagrangian and fully explicit approach for the simulation of FSI problems is presented. Partitioned approaches are particularly interesting for the application to real engineering problems because of the possibility to make use of existing software. Moreover, explicit methods can be advantageous in many large scale applications characterized by fast dynamics and/or a high degree of nonlinearity. In this work, we propose an explicit version of the Particle Finite Element Method (PFEM) [1] for the weakly compressible fluid domain, coupled with the commercial software Abaqus/Explicit for the structural one. The Gravouil and Combescure approach [2] has been chosen to enforce a strong coupling together with a global system of fully decoupled (explicit) equations [3]. Nonconforming meshes and time increments in the fluid and solid subdomains can be used to optimize the discretization for the overall efficiency of the coupled solver. The use of a commercial software as structural solver allows including in the model its advanced functionalities, such as the libraries of material constitutive models and finite elements and other advanced features. Furthermore, the fully Lagrangian framework of the coupled PFEM-FEM approach makes this method particularly suitable for applications with free-surface fluid flows and large displacements of the solid partition. In 3D problems, a frequent remeshing of the fluid domain is required by the PFEM. The resulting new mesh is often of a bad quality, with many slivers (tetrahedra with almost zero volume), leading to a vanishing critical time step size. A novel efficient mesh smoothing technique has been developed to produce a regular mesh, with a reasonably large stable time increment for the explicit solver. This smoothing algorithm is fully explicit and parallelizable, because it exploits the same architecture of the fluid solver thanks to an elastic analogy. Several three-dimensional examples have been considered to validate the approach against available analytical, experimental and numerical solutions, confirming the robustness and effectiveness of the proposed method. [1] E. Onate, S. Idelsohn, “The particle finite element method: an overview.” Int J Comput Meth, 2004;2:267-307. [2] A. Gravouil , A. Combescure, “Multi-time-step explicit-implicit method for non-linear structural dynamics.” Int J Numer Meth Engng. 2001;50:199-225. [3] S. Meduri et al. “A partitioned fully explicit Lagrangian finite element method for highly nonlinear fluid-structure interaction problems.” Int J Numer Meth Engng. 2018;113:43–64.