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AN ALE-EULERIAN EMBEDDED BOUNDARY METHOD FOR TRACKING BOUNDARY LAYERS IN TURBULENT FLUID-STRUCTURE INTERACTION PROBLEMS

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Embedded Boundary Methods (EBMs) for Computational Fluid Dynamics (CFD) are usually Eulerian solution methods. They are particularly attractive for complex Fluid-Structure Interaction (FSI) problems characterized by large structural motions and deformations. They are also critical for flow problems with topological changes such as those that arise in some optimization problems and in FSI problems with crack propagation. For all of these applications, alternative Arbitrary Lagrangian-Eulerian (ALE) methods are often unfeasible because of the issue of mesh crossovers. However for viscous flows, Eulerian EBMs do not track the boundary layers around dynamic bodies. Consequently, their application to viscous FSI problems requires either a high mesh resolution in a large part of the computational fluid domain, or adaptive mesh refinement. Unfortunately, the first option is computationally inefficient, and the second one is labor intensive. For these reasons, a simple and computationally reasonable alternative is proposed here for maintaining all moving boundary layers resolved during the simulation of a turbulent FSI problem using an EBM. In the proposed approach, the underlying non body-fitted mesh is rigidly translated and/or rotated in order to track the rigid component of the motion of the dynamic obstacle. Then, the flow computations away from the embedded surface are performed using the ALE framework, and the wall boundary conditions are treated by the chosen Eulerian EBM. Therefore, the proposed approach can be described as an ALE-Eulerian EBM. Its basic features are illustrated with the Large Eddy Simulation using a non body-fitted mesh of a turbulent flow past an airfoil in heaving motion. Its strong potential for the accurate solution of challenging FSI problems at reasonable computational costs is also demonstrated with the simulation of turbulent flows past a family of highly flexible flapping wings for which wind tunnel data is available.