Special Program in Applied Mathematics and Applied Mechanics

A Spectral Element-Immersed Boundary Method for Fluid-Structure Interaction Problems

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To simulate the two-way coupling problems between a rigid body and a fluid, we combine the immersed-boundary type method with the spectral element method; the former is employed for efficiently capturing the two-way FSI (fluid-structure interaction) and the geometric flexibility of the latter is utilized for any possibly co-existing stationary and complicated solid or flow boundary. Two different immersed-boundary type methods are chosen in this work. The first one is the FD (fictitious domain) method. In this method, the solid region is filled with a fictitious fluid having a density as the same as the solid, and the entire fluid-solid domain is treated as an incompressible fluid with non-uniform density. The momentum inside the solid region is used to estimate the rigid-body motion and the no-slip boundary condition at the rigid body surface is enforced by the penalization method. The second one is the DFFD (direct forcing fictitious domain) method. The fluid in the fluid region is extended into the solid region and pseudo body force is imposed within the solid domain to enforce the rigid body motion in this method. In this work, a Lagrangian mesh composed of triangular elements is employed for tracing the rigid body. In particular, a so called sub-cell scheme is proposed to smooth the discontinuity at the fluid-solid interface and to execute integrations involving Eulerian variables over the moving-solid domain. The accuracy of the proposed method is verified through an observed agreement of the simulation results of some typical flows with analytical solutions or existing literatures.

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