Development of an efficient immersed boundary method for simulation of flows around stationary and moving bodies

Doctoral Thesis
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# Thesis Abstract

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**Thesis Title**

Development of an efficient immersed boundary method for simulation of flows around stationary and moving bodies

**Thesis Summary**

This thesis aims at developing an immersed boundary method to provide an accurate imposition of the boundary conditions while keeping the simplicity of implementation. In this regard, first we attempt to develop a unified interpolation stencil that is used for a ghost-cell and reconstruction immersed boundary methods to satisfy wall boundary conditions in Cartesian-based numerical simulation of fluid flow with arbitrary boundaries. As other existing ghost-cell and reconstruction methods do, the numerical boundary point is considered near the physical boundary and the required flow properties are interpolated directly from the proximate points in the fluid region.

In this research, we propose a unified interpolation scheme based on a sequence of one-dimensional interpolations. In contrast to typical standard stencils, the proposed ones are versatile and do not require to be altered according to the irregularities in boundary shape. Namely, the boundary condition can be accurately imposed with a unique stencil for all numerical boundary points while preserving the convergence rate of the flow solver.

Performance of the proposed method is studied by solving incompressible flows and heat transfer around stationary and moving boundaries. As for the moving boundaries, it has been reported that despite the adequate accuracy of the primary and secondary variables computed by immersed boundary, an intolerable amount of oscillations are observed in the surface stresses and thus in the non-dimensional forces, particularly in the drag force. In order to decrease the non-physical oscillation, we make a comparison between the ghost-cell method and reconstruction-based direct forcing, which reveals the superiority of reconstruction method in suppressing the spurious force oscillations which are produced near the boundary. Then, we opt for the reconstruction approach combined with the unified interpolation stencil. Comparison of our numerical results with the existing numerical and experimental data shows general agreement, which confirms the capability of the proposed method. Finally, the proposed immersed boundary method is applied to simulate a set of cylinders falling under the gravity force. This sedimentation process has been a highly challenging problem for moving immersed boundary methods.

This work addressed some difficulties regarding the implementation of the immersed boundary method to solve Navier-Stokes equations and provide second-order accuracy. The obtained results demonstrated the capability of the interpolation scheme to satisfy the boundary conditions for arbitrary geometries.