A New Embedding Finite Element Method for Viscous Incompressible Flows with Complex Immersed Boundaries on Cartesian Grids

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We develop an innovative numerical method for solving the two-dimensional incompressible viscous Navier-Stokes equations in complex physical domains. Our method is based on an underlying non-uniform Cartesian grid and finite element discretizations of the Navier-Stokes equations in velocity-pressure variables form. Geometry representing stationary solid obstacles in the flow domain is embedded in the Cartesian grid and special discretizations near the embedded boundary ensure the accuracy of the solution in the cut cells. In order to comprehend the complexities of the viscous flows with immersed boundaries, we adopt a new compact interpolation scheme near the immersed boundaries that allows us to retain second-order accuracy and conservation property of the solver. The interpolation scheme is designed in the spirit of the shape function of finite element. In order to verify the proposed methodology, a first step attempted is the simulation of the low and moderately high Reynolds number of flow past a circular cylinder. The results obtained of the drag and left coefficients show excellent agreement with the results available in the literature. Then, uniform flow around a pair of staggered cylinders is investigated. We simulate time-based variation of the flow phenomena for uniform flow past a pair of cylinders with various streamwise and transverse gaps between two cylinders. Additionally, the detail flow characteristics, such as velocity distribution, pressure and vorticity fields are sketched in this study. Thus, it is convinced that the combined an interpolation scheme and FE discretizations are robustness and accuracy of solving 2D fluid flow with complex immersed boundaries.

Keywords: finite element, interpolation scheme, immersed boundaries, drag and left coefficients.