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An immersed-boundary-type simulator based on the spectral element method for 2D Fluid-Structure Interaction problems

Li-Chieh Chen[1]*, Chien-Ta Lin[2], and Mei-Jiau Huang[3]

Mechanical Engineering Department,
National Taiwan University, Taipei 10617, Taiwan
[1]b91502126@ntu.edu.tw
[2]b97505056@ntu.edu.tw
[3]mjhuang@ntu.edu.tw

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We propose an immersed-boundary-type simulation tool for flow induced by a moving rigid solid in an incompressible viscous fluid. In this two dimensional simulator, the entire fluid-solid domain is modeled as an incompressible fluid with non-uniform density. The no-slip boundary condition at the rigid body surface is enforced by adding a penalization term, which vanishes outside the rigid body, into the momentum equation. The modeled equations are discretized by spectral element method in space and by the mixed explicit/implicit scheme in time. The discretized equations are solve by a 3-step fractional step method. A smoothing scheme called "sub-cell scheme" which is proposed to take care of the discontinuity at the fluid-solid interface.

The sedimentation of a circular cylinder in a channel was simulated for verifying the validity and accuracy of the proposed FSI scheme. A spectral accuracy was observed based on the obtained terminal velocities, although low-order accuracy was expected in the neighborhood of the solid-fluid interface. Cylinders with triangular, square, and elliptic cross sections were also simulated; results agree well with the existing literatures. An extension of the present simulator to Neo-Hookean solids is under investigation.