Accepted Manuscript

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PII: S0045-7825(18)30211-1
DOI: https://doi.org/10.1016/j.cma.2018.04.032
Reference: CMA 11883

To appear in: *Comput. Methods Appl. Mech. Engrg.*

Received date : 22 November 2017
Revised date : 16 April 2018
Accepted date : 18 April 2018

Please cite this article as: C. Jiang, J.-.Y Yao. J.-.Y Yao, Z.-Q. Zhang, G.-J. Gao, G.R. Liu, A sharp-interface immersed smoothed finite element method for interactions between incompressible flows and large deformation solids, *Comput. Methods Appl. Mech. Engrg.* (2018), https://doi.org/10.1016/j.cma.2018.04.032

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A Sharp-Interface Immersed Smoothed Finite Element Method for Interactions between incompressible flows and large deformation solids

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Abstract

A sharp-interface algorithm developed for immersed smoothed finite element method (Sharp-ISFEM) is proposed for fluid-structure interaction (FSI) problems. In Sharp-ISFEM, a line normal approach is used for unstructured meshes to reconstruct the solutions near interface. Advanced smoothed finite element models describes the finite deformation of immersed solid structures. Well-developed characteristic-based split method is employed to simulate the incompressible laminar flow. The coupling of fluid and solid is treated by the modified weak partitioned fictitious domain method with different time steps for two phases. To handle large-scale FSI problems, octree and neighbor-neighbor searching algorithms have been implemented. Meanwhile, parallelization has been implemented for the time-consuming parts of in-house codes. The effectiveness of proposed Sharp-ISFEM is validated by several benchmarking problems, including: fixed rigid body, flow over square cylinder; moving rigid body, flow induced by 2D hovering wing; large deformed solid, a beam with large deformation induced by flow; 3D deformable solid-fluid interaction, and lid-driven cavity flow with a rubber wall. Good agreements are shown in all test cases, comparing with existed experimental data and reference solutions. With the improvement of local velocity reconstruction, advanced searching algorithms and code parallelization, the proposed method has shown great promises for complex engineering flows with higher Reynolds number. A large-scale FSI problem of a hummingbird with flexible wing in hovering is finally simulated using more than one million nodes.

Keyword: Fluid-structure interaction; Immersed finite element method; Sharp-interface; Local

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