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# Preface: Simulation of Fluid-Structure Interaction Problems

**Zhilin Li[1], X. Sheldon Wang[2, *] and Lucy T. Zhang[3]**

In recent years, there has been a major surge of interest in the development of simulation techniques and strategies for fluid-structure interaction (FSI) problems, mainly driven by a large spectrum of applications in physiology, medical sciences, material sciences, manufacturing processes, and many other engineering disciplines. Numerous methodologies have been proposed to more accurately and more efficiently capture the coupled interactions between fluid and structures. There are several different ways to classify FSI modeling, for example, monolithic and partitioned, or conforming and non-conforming meshes. Along the line of conforming and non-conforming classification, Arbitrary Lagrangian Eulerian (ALE) method is a typical example of conforming mesh; while the immersed methods, e.g. immersed boundary method, immersed finite element method, are good examples of non-conforming meshes. There are advantages and disadvantages for each chosen approach. The computational mathematics and mechanics communities have been working together in search for the optimal strategies.

A series of international conferences/workshops with focus on FSI modeling were organized and proposed. In this special issue, we gather the contributions from some recent developments of FSI modeling along with selected speakers from the Fifth International Workshop on Modeling, Analysis, Simulations and Applications of Interfacial Dynamics and FSI Problems, Sanya Mathematical Forum, June 4-8, 2018 in China. The topics of this special issue include mathematical modeling, analysis, numerical methods, applications, and inter-disciplinary fields. It contains the state-of-the-art research in FSI modeling with new discoveries and research results. To push forward resource sharing within research community and to ensure research accountability and repeatability, we also include a couple of contributions on the software development for FSI modeling.

In summary, cut-cell method was presented for the simulation of two-dimensional incompressible flows past obstacles in the manuscript [Bouchon, Dubois and James

[1]Department of Mathematics, 2108 SAS Hall, NC State, Raleigh, NC 27695, USA.
[2]McCoy School of Engineering, Midwestern State University, 3410 Taft Boulevard, Wichita Falls, TX 76308, USA.
[3]Department of Mechanical, Aerospace & Nuclear Engineering, Rensselaer Polytechnic Institute, 110 8th St., Troy, NY 12180, USA.
*Corresponding Author: X. Sheldon Wang. Email: sheldon.wang@msutexas.edu.

(2019)]. Numerical results of flows around an impulsively started circular cylinder were presented in the contribution confirmed the efficiency, for Reynolds numbers 1000 and 3000 [Bouchon, Dubois and James (2019)]. An extension of the IB framework for FSI problems was proposed for non-Newtonian fluids with power-law, Oldroyd-B, and FENE-P fluids in three dimensions in the manuscript [Zhu (2019)]. The motions of the non-Newtonian fluids were modelled in the contribution with the lattice Boltzmann equations (D3Q19 model) [Zhu (2019)]. The multi-scale hybrid-mixed (MHM) method was applied to the numerical approximation of two-dimensional matrix fluid flow in porous media with fractures in the manuscript [Zhang (2019)]. The two-dimensional fluid flow in the reservoir and the one-dimensional flow in the discrete fractures were approximated in the contribution using mixed finite elements and the coupling of the two-dimensional matrix flow with the one-dimensional fracture flow was enforced using the pressure of the one-dimensional flow as a Lagrange multiplier to express the conservation of fluid transfer between the fracture flow and the divergence of the one-dimensional fracture flux [Zhang (2019)]. The distributed Lagrangemultiplier/fictitious domain (DLM/FD)-mixed finite element method was developed and analyzed for a transient Stokes interface problem with jump coefficients in the manuscript [Lundberg, Sun, Wang et al. (2019)]. The semi and fully discrete DLM/FD mixed finite element scheme were developed for the first time with a moving interface, where the arbitrary Lagrangian-Eulerian (ALE) technique is employed to deal with the moving and immersed sub-domain in the contribution [Lundberg, Sun, Wang et al. (2019)]. An immersed boundary augmented method has been developed for linear elliptic boundary value problems on arbitrary domains (exterior or interior) with a Dirichlet boundary condition in the manuscript [Li, Dong, Tong et al. (2019)]. The new method presented inherited the simplicity, robustness, and first order convergence of the IB method but also provides asymptotic first order convergence of partial derivatives in the contribution [Li, Dong, Tong et al. (2019)]. A numerical method was proposed for solving parabolic interface problems with nonhomogeneous flux jump condition and nonlinear jump condition in the manuscript [Hou, Wang and Shi (2019)]. The main idea was to use traditional finite element method on semi-Cartesian mesh coupled with Newton's method to handle nonlinearity [Hou, Wang and Shi (2019)]. It is easy to implement even though variable coefficients are used in the jump condition instead of constant in previous work for elliptic interface problem. A high performance modularly-built open-source software, namely, OpenIFEM, was introduced for FSI problems using the algorithm developed in the modified immersed finite element method (mIFEM) [Cheng, Yu and Zhang (2019)]. This software was developed with C++ language to perform multiple tasks including fluid dynamics (incompressible and slightly compressible fluid models), linear and nonlinear solid mechanics, and FSI analysis, as presented in the contribution [Cheng, Yu and Zhang (2019)]. Singular Value Decomposition (SVD) based model reduction methods and mode superposition methods were presented and elaborated with the presence of random noise [Wang, Yang and Wu (2019)]. For acoustoelastic FSI systems, with a three-field mixed finite element formulation with displacement, pressure, and vorticity moment unknowns to effectively enforce the irrotationality constraint, a new inf-sup test was proposed based on the lowest non-zero singular value of the coupling matrix for the selection of reliable sets of finite element discretizations for displacement and pressure as well as vorticity moment in the contribution [Hou, Wang and Shi (2019)].

## References

**Bouchon, F.; Dubois, T.; James, N.** (2019): An immersed method based on cut-cells for the simulation of 2d incompressible fluid flows past solid structures. *Computer Modeling in Engineering & Sciences*, vol. 119, no. 1, pp. 165-184.

**Cheng, J.; Yu, F.; Zhang, L.** (2019): OpenIFEM: a high performance modular open-source software of the immersed finite element method for fluid-structure interactions. *Computer Modeling in Engineering & Sciences*, vol. 119, no. 1, pp. 91-124.

**Hou, S.; Wang, L.; Shi, L.** (2019): A simple FEM for solving two-dimensional diffusion equation with nonlinear interface jump conditions. *Computer Modeling in Engineering & Sciences*, vol. 119, no. 1, pp. 73-90.

**Li, Z.; Dong, B.; Tong, F.; Wang, W.** (2019): An augmented IB method & analysis for elliptic BVP on irregular domains. *Computer Modeling in Engineering & Sciences*, vol. 119, no. 1, pp. 63-72.

**Lundberg, A.; Sun, P.; Wang, C.; Zhang, C.** (2019): Distributed Lagrange multiplier/fictitious domain finite element method for a transient Stokes interface problem with jump coefficients. *Computer Modeling in Engineering & Sciences*, vol. 119, no. 1, pp. 35-62.

**Wang, X.; Yang, Y.; Wu, T.** (2019): Model studies of fluid-structure interaction problems. *Computer Modeling in Engineering & Sciences*, vol. 119, no. 1, pp. 5-34.

**Zhang, C.** (2019): Multiscale hybrid-mixed finite element method for flow simulation in fractured porous media. *Computer Modeling in Engineering & Sciences*, vol. 119, no. 1, pp. 145-163.

**Zhu, L.** (2019): An IB method for non-Newtonian-fluid flexible-structure interaction in three-dimensions. *Computer Modeling in Engineering & Sciences*, vol. 119, no. 1, pp. 125-143.