A phase-field method in full Eulerian framework for fluid-structure interaction in biological systems

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ABSTRACT

We present a phase-field method in a full Eulerian framework for modeling a dynamic fluid-structure-interaction (FSI) in biological systems. The resulted model solves for a unified set of governing equations consisting of the Navier-Stokes equation, Cahn-Hilliard equation and equation for deformation gradient for structure on a fixed grid. The phase-field method describes a multiphase system by minimizing the free energy functional consisting both the cohesive and the elastic energy [1] obeying the second thermodynamics law. Thus, it can capture the rheology and morphology changes of different phases accurately and intrinsically. The equations are solved in time with a splitting scheme that decouples the flow variable, phase-field variable and displacement variable for structure. The spectral/hp method is employed in space discretization and backward differentiation for time discretization. To test the accuracy of the method, we simulate flow in a cavity with an elastic wall, a deformable disk in a lid-driven cavity and a thin leaflet in an oscillating channel flow and compare the results with those from an existing validated Arbitrary Lagrangian-Eulerian (ALE) code and also literature [2]. Finally, we present three-dimensional simultion results about thrombus-blood flow interaction to demonstrate that our model can handle FSI problems on complex geometry for long time simulation efficiently and accurately.

REFERENCES

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