FLUID-STRUCTURE INTERACTIONS USING A SHARP-INTERFACE METHOD

S. Marella*, J.W.Garvin*, B. Jeffrey* and H.S.Udaykumar*†

*Department of Mechanical and Industrial Engineering
The University of Iowa, Iowa City, IA-52242
†Corresponding Author: ush@icaen.uiowa.edu

ABSTRACT

In this paper we present a sharp-interface computational method applied to various fluid-structure interaction problems. The method relies on a Cartesian grid with objects/structures being represented on the mesh by a level-set field. A second–order accurate finite-difference formulation is implemented for the incompressible fluid flow equations. With the level-set method bypassing the difficulties involved in surface representation and the finite-difference formulation easing the treatment of grids near the interface, extension to three-dimensional problems has been straightforward.

The applications of this numerical capability include metal-matrix composite (MMC) processing and interaction of compliant intestinal wall with the transport of material in the gastro-intestinal tract through peristalsis. MMC manufacturing involves several fluid-solid interaction problems including phase change of the metallic front in the presence of convection, settling and interaction of particles/fibers in the liquid metal, and interfacial phenomena such as particle-front interactions at high temperatures. The present method allows for simulation of the solidification/particle-front interactions and particulate settling processes. A second-order accurate evolution of the solidification front has been achieved using this computational method. The interaction of the solidification front with the particles (typically ceramics) and conditions leading to pushing/engulfing of particles are being examined. The settling of solid particulates/dendritic structures in the liquid melt and their mutual interaction is also simulated. In the MMC processing application, the boundary of the solid does not deform in response to the fluid forces. The present method also has the capability of simulating *active fluid-solid interactions* by interfacing finite-element structural calculations with the fluid flow. This coupled interaction arises during the propagation of peristaltic waves in the different segments of the intestine leading to the mixing, dispersion and absorption of nutrients. The stresses in the elastic intestinal wall are calculated using a finite-element method and the kinematic information at the wall, residing on the finite-element surface mesh, is transferred to the fluid flow as an interfacial boundary condition. The flow solver communicates with the wall through an evolving level-set field. The fluid stresses at the interface, obtained by solving the flow equations are transmitted back to perform the structural computations. The complexities involved in performing these simulations will be presented also with results from the validation studies and other calculations (as mentioned above) highlighting the features of this computational tool.