ME – PhD Thesis Defence

Numerical simulations of deforming capsules and cells in a flow

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ABSTRACT

Understanding the evolution of deforming capsules and cells in various flow configurations can assist in better diagnosis of diseases like Malaria and sickle cell anemia. Flow of deformable capsules is also useful in pharmaceutical and medical industries for applications such as targeted drug delivery and artificial blood. Experimental studies of such systems could be tedious due to the small length scales involved and difficulty in replicating the material properties in a laboratory setup. Numerical simulations of capsules and cells in a flow can aid in better understanding of such systems. In this context, we have developed a highly parallel numerical framework which comprises of an incompressible Navier-Stokes solver in Cartesian coordinates using finite volume approach, a front tracking module to track and simulate deforming capsule membranes, and an immersed boundary approach to simulate complex geometries. Membrane forces are calculated using a finite element based approach on the triangulated mesh used for front tracking, and coupled to the momentum equations as source terms. After rigorously validating the solver, we perform an in-depth analyses of three different flow configurations. In the first part of the work, we study flow of capsules through constrictions. We further propose a device for sorting of deforming capsules of same size but varying stiffness. We show that by using a tapered constriction placed laterally to the incoming flow in a microchannel, high resolution sorting of capsules can be achieved in a compact setup. The application of such devices are in pharmaceutical industry as well as in point of care diagnostic devices. In flow through microchannels observed in several biological systems, capsules often interact with the walls. In the second part of the thesis, we study the dynamics of an elastic capsule impacting a solid surface. We perform simulations to study the post impact evolution of capsule filled with a fluid and show the existence of multiple flow regimes. We have also investigated the effect of the membrane constitutive model on the capsule dynamics. Finally, we study the effect of shear flow on capsules/vesicles adhering to a solid surface. Considering a short range potential between the solid and the vesicle, we study the effect of surface curvature on the vesicle binding. We also study the effect of shear flow on such adhered capsules/vesicles.

ABOUT THE SPEAKER

Kiran Satheesh completed his B.Tech in Mechanical Engineering from NIT, Calicut, following which, he was at ISRO's Liquid Propulsion Systems Centre, Trivandrum, for a brief period. Later he moved to Aerospace Department at IISc for his MSc(Engg) degree focusing on simulations of compressible Multiphase flows. Presently, he is a PhD student at Dept. of Mechanical Engineering, IISc studying the evolution of deforming capsules and cells under various flow configurations using numerical simulations.