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Multi-Scale Fluid Flows with Moving Boundaries

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Many multi-scale fluid flow problems involve moving boundaries. For these problems, although the governing laws and computational procedures for the individual domains are established, treatment of the whole physical system associated with multiple physical mechanisms, length and time scales, and unknown boundary movement and shape pose significant challenges. In this talk, we preent two clases of problems, (i) multiphase flows involving topological changes due to merger and break-up of objects, and (ii) aerodynamics of flexible, flapping Wing. For multiphase flows, from the continuum mechanics' viewpoint, the phase interface is a discontinuity and must be addressed as an integral part of the solution procedure. In this talk, the Eulerian-Lagrangian method will be emphasized, which consists of the Eulerian approach for field equations, explicit interface-tracking, Lagrangian interface modification and reconstruction algorithms, and a cell-based unstructured adaptive mesh refinement (AMR) in a distributed-memory computation framework. Problems involving high Weber number drop collision will be presented. Coalescence, stretch, and break-up of satellite droplets due to the interfacial instability, and the competing mechanisms of the primary and secondary droplet break up, along with the gas-liquid interfacial dynamics are probed. For flapping wing aerodynamics, coupled fluid flows and highly flexible wing structures requires integrated treatments of multiple types of governing equations. In particular, the effects of flexibility on the force generation and propulsive efficiency of flapping wings are significant as the wing deformation interacts with the vertical flow structures. As the Reynolds number, reduced frequency (k), and Strouhal number (St) vary, the corresponding aerodynamic forces on a wing can be examined using a scaling argument. We present recent efforts and progress in better understanding the vertical flows structures associated with flexible flapping wings and the implications on scaling laws of the aerodynamic force generation.