Modelling of multi-phase systems with complex interfaces

Murray Rudman

Energy and Thermofluids Engineering
CSIRO Manufacturing and Infrastructure Technology
Graham Rd, Highett, Victoria 3190, Australia

Multi-phase systems, especially those comprised of liquids and another phase (gas-liquid, solid-liquid, liquid-liquid) often have bulk properties that are difficult to measure and/or model. On this basis, such systems can be termed complex fluids, whose bulk properties vary from place to place and time to time in a flow. Computational modelling of such multi-phase systems has traditionally been undertaken from the point of view of interpenetrating continua that assumes an Eulerian-Eulerian approach to solve two (or more) sets of coupled PDEs describing some sort of averaged transport in each of the phases. Less common is the treatment of the dispersed phase using a Lagrangian approach. However both of these methodologies require modelling assumptions on how the phases interact, and how bulk properties depend on the distribution and interaction of the phases. These assumptions have major implications for the accuracy of computational models based on them. Nevertheless, for very many applications, this will remain the only possible modelling approach for the foreseeable future.

An alternative approach is to attempt to model the details of each and every droplet, bubble or particle in a flow. Until recently, this has been impossible except for either simplified physical scenarios, or very specific cases where a small number of drops, bubbles or particles are present. However the situation is improving, and massively parallel computer architecture and computational algorithms have resulted in simulations of large numbers of discrete droplets/bubbles in continuous fluids to be undertaken. Although technology is still some distance from being able to consider real applications, the ability to simulate many hundreds of droplets/bubbles opens the way forward to using these techniques to shed light on the underlying physics of these systems and to help formulate constitutive models for interpenetrating continua methods.

Underlying this latter approach to multi-phase flow modelling are the numerical methods that allow simulation of multiphase systems with complex, moving interfaces. In this paper I will provide a brief overview of the range of different methods that are currently being used, although will focus on one of them, the Volume-of-Fluid (VOF) method, that is increasingly being used for this type of simulation. Some of the numerical issues around efficient solution of the equations will be discussed and I will present examples of where these methods have been used and how good (or otherwise) predictions have been. Finally, the weaknesses of the methods will also be raised, and indication of where the challenges for the future lie.