Kinetic Theory Models for Dispersed Multiphase Flows

Rodney Fox

Anson Marston Distinguished Professor, Engineering Department of Chemical and Biological Engineering, Iowa State University

Kinetic theory is a useful theoretical framework for developing CFD models for dispersed multiphase flows. For example, Lagrangian particle tracking methods can be formulated in terms of a kinetic equation written in an Eulerian framework. For most applications, direct solution of the kinetic equation is intractable due to the high dimensionality of the phase space. A key challenge is thus to reduce the dimensionality of the problem without losing the underlying physics. Lagrangian methods and Eulerian multi-fluid models are two widely used CFD tools for accomplishing this task. In theory, starting from the same kinetic equation, Lagrangian and Eulerian CFD models should yield identical results for multiphase statistics (e.g. phase volume fractions, phase velocities, etc.) but this is often not the case. More often than not, the reason for the discrepancy can be found in the closures invoked in deriving the Eulerian CFD model. Recently, we have developed a more general closure approximation based on reconstructing the distribution function in the kinetic equation from its moments using a quadrature-based methodology. In principle, this Eulerian CFD approach can treat dispersed multiphase flows as accurately as the corresponding Lagrangian approach. Using examples from granular, gas-particle, and bubbly flows, we discuss the underlying fundamentals of quadrature-based moment methods for simulating dispersed multiphase flows.

Bio Professor Fox has made numerous ground-breaking contributions to the field of multiphase and reactive flow modeling. The Fox group spearheaded many fundamental advances in the development of novel computational fluid dynamics (CFD) models to overcome specific scientific challenges faced in the chemical and petroleum industries. He pioneered the use of in situ tabulation (ISAT) for efficiently handling complex chemistry in detailed multiphase reactor models, and developed powerful quadrature-based moment methods (DQMOM, CQMOM, EQMOM) for treating distribution functions (particle size, bubble size, etc.) required for CFD models of single and multiphase reactors. The impact of Fox’s work extends far beyond chemical engineering and touches every technological area dealing with turbulent flow and chemical reactions (e.g., combustion, atmospheric science, nuclear fuel processing, etc.). His monograph, Computational Models for Turbulent Reacting Flows, published by Cambridge University Press (CUP) in 2003, offers an authoritative treatment of the field. He is currently co-authoring a new monograph under contract with CUP on computational models for polydisperse multiphase flows that will appear in 2013.