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Lattice Boltzmann Method: A Mesoscopic Modelling Framework for Flow, Heat Transfer, Phase Change and Combustion

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Abstract

Over the past six decades, computational fluid dynamics (CFD) has evolved into a vital tool for fundamental research and design optimization, supplementing and in some cases, replacing experiments and physical prototyping. Yet, conventional CFD is based on solving the continuum, macroscopic conservation laws, which suffers from many inherent drawbacks such as a lack of physical fidelity, time-consuming mesh generation, high computational cost and difficult coding. To a large extent, these problems can be addressed by the lattice Boltzmann method (LBM), which is a mesoscopic, statistical approach based on the general kinetic theory. LBM bridges scales across microscales and macroscales, and seamlessly incorporates multiscale multiphysics features. It has a unified formulation for both continuum and dispersed phases, simple treatment for complex configurations, and superb parallel efficiency on even heterogenous computing architectures. These features make LBM a powerful modelling framework for a wide range of phenomena in both science and engineering domains. This plenary talk will cover both fundamental theories of LBM and its applications in flow, heat transfer, phase change and combustion. Examples will be given in modelling diverse phenomena such as multiphase flow, boiling, batteries, hydrogen production, carbon storage, supersonic flow and combustion.