IOP Concise Physics

Lattice Boltzmann Modeling of Complex Flows for Engineering Applications

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Chapter 1

Introduction

If we take a quick glance at the world around us, we can easily observe how fluids lie at the heart of many strikingly complex natural and engineering phenomena.

Our carbon-based life would not exist without fluids and without the astonishing, and sometimes unexpected, behaviour they exhibit.

These concepts of complexity and mutation, in everything that flows, are well expressed in the following extract from Eraclitus:

> *We cannot go down twice in the same river, and you cannot tap a deadly substance in the same state, but because of the impetuosity and the speed of change it disperses and collects, comes and goes.*

In this fragment, life itself is compared to the current of a river that always flows, changing forever, without ever repeating. Fluids occur, and often dominate a broad spectrum of physical phenomena, across a wide range of (space and time) scales: from the formation of galaxies and the evolution of stellar systems to oceanic currents, from turbulent and chaotic flows in pipes and rivers to the circulation of blood in veins and arteries all the way down to nano and angstrom-scale pores and flows in ultrathin nano and sub-nano membranes for reverse osmosis desalination. In this perspective, a comprehensive and in-depth knowledge of the physics of fluids at different scales of motion is required, in order to predict the complex behaviour of large-scale geological flows, to investigate flows of biological interest and to efficiently design devices for technical use from micro to macro scales, just to name a few.

For these reasons, a full set of experimental, theoretical and numerical methodologies is needed to inspect, in full detail, the fluid dynamics phenomena emerging at different scales of motion.

The aim of this book is to show the most recent advances of lattice kinetic theory in the field of complex hydrodynamics. With its roots in kinetic theory, the main idea

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behind the Lattice Boltzmann equation is to provide minimal kinetic models encompassing the essential physics of mesoscopic processes, so that the macroscopic fluid properties obey the desired governing set of equations. The simplicity of formulation and its versatility explains the rapid expansion of the LB method to applications in complex and multiscale flows.