Computational Fluid Dynamics and Heat Transfer

International Series on Developments in Heat Transfer

Objectives

The Developments in Heat Transfer book Series publishes state-of-the-art books and provides valuable contributions to the literature in the field of heat transfer, thermal and energy engineering. The overall aim of the Series is to bring to the attention of the international community recent advances in thermal sciences by authors in academic research and the engineering industry.

Research and development in heat transfer is of significant importance to many branches of technology, not least in energy technology. Developments include new, efficient heat exchangers, novel heat transfer equipment as well as the introduction of systems of heat exchangers in industrial processes. Application areas include heat recovery in the chemical and process industries, and buildings and dwelling houses where heat transfer plays a major role. Heat exchange combined with heat storage is also a methodology for improving the energy efficiency in industry, while cooling in gas turbine systems and combustion engines is another important area of heat transfer research. Emerging technologies like fuel cells and batteries also involve significant heat transfer issues.

To progress developments within the field both basic and applied research is needed. Advances in numerical solution methods of partial differential equations, turbulence modelling, high-speed, efficient and cheap computers, advanced experimental methods using LDV (laser-doppler-velocimetry), PIV (particle-image-velocimetry) and image processing of thermal pictures of liquid crystals, have all led to dramatic advances during recent years in the solution and investigation of complex problems within the field.

The aims of the Series are achieved by contributions to the volumes from invited authors only. This is backed by an internationally recognised Editorial Board for the Series who represent much of the active research worldwide. Volumes planned for the series include the following topics: Compact Heat Exchangers, Engineering Heat Transfer Phenomena, Fins and Fin Systems, Condensation, Materials Processing, Gas Turbine Cooling, Electronics Cooling, Combustion-Related Heat Transfer, Heat Transfer in Gas-Solid Flows, Thermal Radiation, the Boundary Element Method in Heat Transfer, Phase Change Problems, Heat Transfer in Micro-Devices, Plate-and-Frame Heat Exchangers, Turbulent Convective Heat Transfer in Ducts, Enhancement of Heat Transfer, Transport Phenomena in Fires, Fuel Cells and Batteries as well as Thermal Issues in Future Vehicles and other selected topics.

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EMERGING TOPICS

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Contents

Preface

The main focus of this book is to introduce computational methods for fluid flow and heat transfer to scientists, engineers, educators, and graduate students who are engaged in developing and/or using computer codes. The topic ranges from basic methods such as a finite difference, finite volume, finite element, large-eddy simulation (LES), and direct numerical simulation (DNS) to advanced, and smoothed particle hydrodynamics (SPH). The objective is to present the current state-of-the-art for simulating fluid flow and heat transfer phenomena in engineering applications.

The first and second chapters present higher-order numerical schemes. These schemes include second-order UPWIND, QUICK, weighted-average coefficient ensuring boundedness (WACEB), and non-upwind interconnected multigrid overlapping (NIMO) finite-differencing and finite-volume methods. Chapter 3 gives overview of the finite-difference and finite-volume methods covering subsonic to supersonic flow computations, numerical stability analysis, eigenvalue-stiffness problem, features of two- and three-dimensional computational schemes, and flux-vector splitting technique. The chapter shows a few case studies for gas turbine blade design and centrifugal compressor flow computations.

The fourth and fifth chapters give overview of the finite-element method and its applications to heat and fluid flow problems. An introduction to weighted residual approximation and finite-element method for heat and fluid flow equations are presented along with the characteristic-based split algorithm in Chapter 4. Chapter 5 discusses two important concepts. One is the equal-order mixed-GLS (Galerkin Least Squares) stabilized formulation, which is a generalization of SUPG (streamline-upwind/Petrov–Galerkin) and PSPG (pressure stabilizing/Petrov–Galerkin) method. The second is the numerical strategies for the solution of large systems of equations arising from the finite-element discretization of the above formulations. To solve the nonlinear fluid flow/heat transfer problem, particular emphasis is placed on segregated scheme (SIMPLE like in finite-volume method) in nonlinear level and iterative methods in linear level.

Chapters 6 through eight give numerical methods to solve turbulent flows. Chapter 6 overviews most important methods including RANS approach, LES, and DNS and describes the numerical and theoretical background comprehensively to enable the use of these methods in complex geometries. Chapter 7 demonstrates the advantages of large-eddy simulation (LES) for computations of the flow and heat transfer in ribbed ducts through a gas turbine blade. Direct numerical simulation (DNS) is introduced in Chapter 8. In this chapter recent studies on DNS and turbulence models from the standpoint of computational fluid dynamics (CFD) and computational heat transfer (CHT) are reviewed and the trends in recent DNS research and its role in turbulence modeling are discussed in detail. Chapter 9 discusses the analytical wall-function of turbulence for complex surface flows. This chapter introduces the recently emerged analytical wall-function (AWF) methods for surface boundary conditions of turbulent flows.

Some advanced simulation modeling technologies are given in chapters 10 and 11. In Chapter 10 the current state-of-the-art and recent advances of a novel numerical method – the smoothed particle hydrodynamics (SPH) is reviewed through case studies with particular emphasis on fluid flow and heat transport. To provide sufficient background and to assess its engineering/scientific relevance, three particular case studies are used to exemplify macro- and nanoscale applications of this methodology. The first application in this chapter deals with magnetohydrodynamic (MHD) turbulence control. Chapter 11 provides the continuous and discrete phase models for simulating submicrometer aerosol transport and deposition. Lastly Chapter 12 discusses convergence acceleration of nonlinear flow solvers through use of techniques that exploit recursive properties fixed-point methods of CFD algorithms.

The authors of the chapters were all invited to contribute to this book in accordance with their expert knowledge and background. All of the chapters follow a unified outline and presentation to aid accessibility and the book provides invaluable information to researchers in computational studies.

Finally, we are grateful to the authors and reviewers for their excellent contributions to complete this book. We are thankful for the ceaseless help that was provided by the staff members of WIT Press, in particular Mr. Brian Privett and Mrs. Elizabeth Cherry, and for their encouragement in the production of this book. Finally, our appreciation goes to Dr. Carlos Brebbia who gave us strong support and encouragement to complete this project.

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