Transport Phenonema in Fires
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. The overall aim of the Series is to bring to the attention of the international community recent advances in heat transfer 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.

To progress developments within the field both basic and applied research is needed. Advances in numerical solution methods of partial differential equations, 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 and other selected topics.
Transport Phenomena in Fires

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Preface

Transport phenomena such as buoyant flow, momentum, convective heat and mass transfer as well as chemical reactions between combustible species and oxygen from the surrounding air play important roles in fire modeling and simulations. In addition, soot formation, soot and gas radiation, turbulent mixing are important to the mechanism of flame heat transfer that governs fire heat release rates. The mechanisms of ignition, flame spread, steady burning flame extinction and smoke transport all need to be considered in fire modeling. In addition, temperature-dependent properties are important factors for consideration. For uncontrolled fires, their evolution in time is of great concern.

One aim of this book is to present the state-of-the-art modeling and numerical simulations of the important transport phenomena in fires. Another aim is to present how computational methodologies can be used in analysis and design of fire protection and fire safety. Computational fluid dynamics, turbulence modeling, combustion, soot formation, thermal radiation modeling will be demonstrated and applied to pool fires, flame spread, wildfires, and compartment fires.

The first chapter presents an overview of mathematical modeling and numerical simulations in fires. It also serves as an introduction to the following chapters where specific topics are addressed in more detail. References are given to the other chapters in the book that deal with specialized topics. Specifically, it will focus on transport processes that play an important role in the fire modeling such as turbulent combustion; turbulent reacting flows, chemical kinetics, convection, radiation, pyrolysis of solid fuel and numerical simulations of turbulent reacting flows using large eddy simulation and eddy dissipation concepts. The discretization of the governing equations by control volume approach will be discussed followed by solutions of ordinary differential equations by a linear multi-step method. Multi grid iterative schemes will be introduced for solution of the algebraic equations followed by a section on parallel computing. Results will be presented for upward flame spread over vertical surfaces and turbulent combustion in pool fires using large eddy simulation and a parallel CFD fire simulation code developed by the authors.

The second chapter explores transport phenomena that affect heat transfer in large (i.e. fully turbulent) fires. In this chapter the authors present the current state of knowledge as well as areas in need of additional research to enable deep understanding and quantitative prediction of hazards posed by these fires.

Chapter 3 presents heat transfer to objects in pool fires. A review is presented of modeling approaches for estimating heat flux from fires and flames. This chapter describes recent research methods for addressing observed pool fire, including the multi-scale effects of soot formation and flame structure. Finally, for accurate predictions of heat flux to objects in large-scale transportation fuel fires, the importance of error quantification and propagation in the validation and verification
framework is addressed.

Heat and mass transfer effects to be considered when modeling the effects of fire on structures are discussed in chapter 4. This chapter highlights the factors to be considered when doing the thermal analysis of a structure and will provide areas where future work is needed.

Chapter 5 describes buoyant turbulent fire plumes in uniform still and cross-flow environments. Consideration of these flows is motivated by numerous practical applications to the unconfined flows resulting from starting and steady releases of buoyant gases and liquids from unwanted fires, from industrial exhaust stacks, from explosions and from process upsets.

Chapter 6 gives an overview of pyrolysis modeling, thermal decomposition, and transport processes in combustible solids. It also discusses decomposition kinetics and thermodynamics in the solid phase due to their importance in the burning of solids. Conduction, radiation, convection, and momentum transfer within combustible solids are reviewed. Values of various material properties and pyrolysis coefficients needed for modeling are given for different materials.

Radiative heat transfer in fire modeling is discussed in chapters 7 and 8. Chapter 7 presents an account of modern spectral methods for prediction of radiative heat transfer rates within combustion media consisting of strongly nongray combustion gases as well as mildly nongray soot particles. It also discusses the interactions between turbulence and radiation. Chapter 8 presents an overview of thermal radiation models for different combustion processes. The pertinent constitutive equations and associated radiative property models are discussed.

Combustion subgrid scale modeling for large eddy simulation of fires is discussed in chapter 9. The objective of this chapter is to examine state-of-the-art subgrid scale combustion models for application to fire environments. The relative merits of these models for application to fire simulation are discussed with illustrative examples.

The last three chapters focus on Computational Fluid Dynamics (CFD) modeling of fire simulations. Specifically, chapter 10 presents CFD fire simulation and its recent development within the framework of Reynolds Averaged Navier-Stokes (RANS), Large Eddy Simulation (LES) and Direct Numerical Simulation (DNS). Chapter 11 demonstrates the implementation and application of Fire Dynamics Simulator (FDS) developed by National Institute of Standards and Technology (NIST). Finally, chapter 12 is aimed at CFD-based modeling of combustion and suppression in compartment fires using FDS.

All of the chapters follow a unified outline and presentation to aid accessibility and the book provides invaluable information for both graduate researchers and R & D engineers in industry and consultancy.

We are grateful to the authors and reviewers for their contributions. We also appreciate the cooperation and patience provided by the staff of WIT Press and for their encouragement and assistance in producing this volume. We also like to thank the Wenner-Gren Center Foundation in Sweden for financial support.

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