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Modeling Approaches to Natural Convection in Porous Media



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Preface

Fluid flow and heat transfer in a porous medium are of interest in a number of engineering applications as well as in the environment. The primary purpose of this book monograph is to introduce modeling approaches for natural convection in porous media. These models are applicable to a wide variety of media, including sand, soil, randomly packed spheres or cylindrical tubes, and open cell metal foams, which have gained attention in recent years as potentially excellent candidates for meeting the high thermal dissipation demands in the electronics industry.

As an introduction to the topic of heat and mass transfer in porous media, Chap. 1 introduces the conventional defining parameters used to specify porous media and provides an overview of the governing equations and background material that set the stage for understanding modeling efforts. The local thermal equilibrium (LTE) and nonlocal thermal equilibrium (NLTE) approaches are introduced and compared.

Chapter 2 extends the theoretical presentation to consideration of the microscopic governing equations and volume-averaged macroscopic equations for flow and natural convection heat transfer. The theoretical development connects the microscopic drag and heat flux between solid and fluid phases in a porous medium through a recently developed geometry factor. Closure models are presented in a form applicable to a porous medium of arbitrary microscopic geometry.

Chapter 3 introduces numerical methods for simulation of natural convection in porous media, including the traditional finite difference based projection method and the nondimensional lattice Boltzmann method. The models are discussed in terms of the dimensionless governing parameters for natural convection. Mesh methods are presented for the finite difference and lattice Boltzmann numerical approaches.

Chapter 4 illustrates the application of the presented numerical methods to simulate the transient velocity and temperature fields and global heat transfer for in an adiabatic thin enclosure with an embedded heat sink. In this problem, the heat sink is a heat exchanger composed of multiple tubes. The example problem is an interesting application of the theory of porous medium to a practical engineering problem and illustrates the enormous power of treating a heat exchanger as a porous medium. Problem solutions are presented via porous medium model simulations by the projection method and the non-dimensional lattice Boltzmann method, and by direct

numerical simulations with non-dimensional lattice Boltzmann method. Advantages and disadvantages of each numerical approach including comparison of the physical results and the CPU time are discussed. In addition, the use of the geometry factor to represent the porous medium is illustrated.