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Multiscale Considerations on Porous Media Heat Transfer

Heat transfer in porous media is ubiquitous in many industrial applications, such as heat exchangers, heat pipes, heat storage system, and porous coatings for thermal radiation. Thus, it is of great importance to understand in depth the heat transfer in porous media. This, however, is still a huge challenge, mainly attributed to the following fact. First, heat transfer in porous media is a process involving multi scales. The pores in porous media can be multi scales, ranging from nano to milli meters; and the heat transfer in each pore of porous media controls the continuum- (macro) scale heat transfer in porous media. Second, heat transfer in porous media include multiple interactions, e.g., the interaction at the interfaces between fluids and solid matrix of porous media in single phase convection, interaction at the interface between fluids of different phases in phage change heat transfer, and heat transfer between solid matrix in thermal radiation. Thus, a multi scale exploration, from interface- to pore- and continuum-scale, is needed so as to disclose in detail the mechanisms of heat transfer in porous media. In this talk, we will introduce our recent multi-scale studies on the sing-phase convection, phase change heat transfer, and thermal radiation in porous media. As for the single-phase convection, the thermal non-equilibrium effects in forced and natural convection in porous media are clarified from the pore- and continuum-scale perspectives; and the permeability for natural convection is discussed. As for the gas-liquid and liquid-solid phase change heat transfer in porous media, the movement of phase interfaces in the nano- and micro-pores of porous media is disclosed, and its effects on the continuum-scale heat transfer is revealed. As for the thermal radiation heat transfer in porous media, a multiscale framework is established, which can account for the dependent scattering effects at microscale and the coherent effects of multiple scattering at mesoscale; based on this framework, an accurate prediction of macroscale radiative properties of various densely packed porous media is achieved. Furthermore, the role of far-field and near-field interferences in the wave aspects of thermal radiation transfer is quantitatively revealed.

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