EFFECTS OF VELOCITY SLIP ON PERMEABILITY, EFFECTIVE THERMAL CONDUCTIVITY AND INTERSTITIAL HEAT TRANSFER COEFFICIENT IN MICRO-POROUS MEDIA

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ABSTRACT

Forced convection in packed-beds of various arrangements and wire screens is investigated numerically by simulating gas flows in porous matrices with micro-sized pores. We study the influence of hydrodynamic slip phenomena that appear when the characteristic dimension of micro pores is characterized by Knudsen numbers ranging from Kn = 0.01 to Kn = 0.1. The approach is based on the numerical solution of the conservation equations of incompressible fluid mechanics, followed by a post-processing to identify the macroscopic properties.

Two techniques for determining the macroscopic properties are used. The first is based on the method of asymptotic expansions, also known as homogenization method, founded on the concept of separation of scales [1]. The second technique is based on the method of averaging at the level of a representative elementary volume [2].

The governing equations are solved by using a finite-element, commercialized software (Comsol multiphysics). Spatial convergence studies were carried out and the solutions were compared with results (without slippage effect) reported in the archival literature. Various geometries are considered (plane to 3D geometries of cubes or spheres), but these comparisons are limited to isothermal flows.

The effect of the interfacial velocity-slip on the permeability in micro porous media is then considered. The resulting formalism of the periodic homogenization structures is used for the simulations of isothermal gas flows in various geometries of one structural unit. Owing to the range of Reynolds numbers relevant to incompressible gas flows through micro-porous media, the permeabilities are determined by calculating the spatial averages of velocity fields, solutions of the Stokes equations. The values obtained by imposing no slip conditions are compared with first order slip conditions. We discuss the relative increase in permeability due to the slip effect according to the geometry of the pores.

We present then solutions for anisothermal flows and we study the slip effect on the effective conductivity in 2D micro-porous media. The Navier-Stokes and energy equations are solved by imposing symmetry conditions in one or two directions, while the whole extent of the flow is computed in its main direction, from the inlet to the outlet sections of channels. The heat transfer problem is thus that of conjugate conduction-convection in channels with finite thickness walls made of non-touching solid blocks. The intrinsic mean velocity and temperature fields are calculated from these

local solutions [3]. We consider cases where the local thermal equilibrium condition can be considered as satisfied and other corresponding to a non-local thermal equilibrium (NLTE) [4]. We determine the dispersion conductivity based on the Péclet number and show the influence of velocity slip on longitudinal and transverse components for various porosities and slip lengths. In NLTE cases, interfacial heat transfer coefficients are also calculated.

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