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Thermal characteristics in asymmetrically heated channels fully filled with brass beads

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This study experimentally investigated the heat transfer characteristics in the asymmetrically heated rectangular channels fully filled with porous materials. Air was used as the coolant. The porous materials were packed by brass beads with average diameters (d) of 2, 4 and 6 mm. The channel width (W) was fixed to be 60 mm. Variable parameters were the relative length of packed channel ($L/d = 5$–60), the relative height of packed channel ($H/d = 1.67$–15), and the Reynolds number ($Re_D = 755$–7921 and $Re_{dp} = 38$–2703). The results indicated that the bead diameter (d), rather than the hydraulic diameter (D_h), may be a proper parameter to generalize the data for heat transfer in a packed channel. The particle Nusselt number ($\overline{Nu}_{dp}$) increased with decreasing L/d, while the H/d was not sensitive to $\overline{Nu}_{dp}$. Finally, the correlations of average and local particle Nusselt numbers ($\overline{Nu}_{dp}$ and $Nu_{dp,x}$) for various L/d, H/d and Re_{dp} were provided.

1. Introduction

Under modern technological advancements, various precision electronic devices are designed with thin-profile, compact size and multiple functions. However, the produced heat of unit volume rises significantly when electronic components are becoming smaller, yielding immediate negative influence on the operating efficiency, stability and service life. The electronic components may be damaged due to high temperature in the case of failure of proper cooling. Thus, it is urgently required to resolve the problem of thermal dispersion in modern electronic devices. A well-proven economic and efficient heat dispersion technology is that using porous heat sinks coupling with forced convection. Besides, the porous media have been applied widely in electronic cooling, thermal energy storage system, packed bed reactors, packed-bed regenerators, fixed-bed nuclear propulsion systems and many other areas. Therefore, researchers have focused their attentions to the studies of fluid flow and heat transfer in porous media for decades, including flow drag, nature convection, forced convection, effective conductivity, solid-to-fluid heat transfer coefficient, etc.

Previous researches on fluid flow and heat transfer in porous media were mainly devoted to spherical-beads packed beds. Our work aims at the heat transfer enhancement by packing metallic beads into the internal cooling channel. Some previous relevant works were selected and surveyed as follows. Koh and Colony [1] indicated that the cooling efficiency of porous materials could not be brought into full play in the case of free convection. However, if the coolant is pressurized and then driven into the porous materials, the porous cooling system has much better heat transfer performance. Cheng and Hsu [2] analyzed the forced convection of porous annular channel at the fully-developed region, and took into consideration the variable porosity and stagnant thermal conductivity. Non-Darcy effects considered in the theoretical model includes boundary effect, inertial effect and channeling effect. They inferred that ignoring the effect of near-wall variable porosity on the effective thermal conductivity resulted in the difference of numerical prediction. Vafai et al. [3] investigated experimentally the heat transfer in a channel filled with the spherical-beads packed bed and simulated it numerically. They examined the channel effect by considering the variable porosity in the numerical model. Renken and Poulikakos [4] also explored experimentally the forced convective heat transfer of packed-sphere channel and also simulated it numerically. Chou et al. [5] found that the Nusselt number in fully-developed region of the porous channel was mainly affected by the channeling effect in the case of small Peclet number, but gradually governed by transverse thermal dispersion effect as increasing the Peclet number. In addition, the transverse thermal dispersion effect at the thermal entrance region was weak. In the case of larger Peclet number, the ratio of channel's hydraulic diameter to bead diameter (D_h/d) has significant influence on heat transfer also owing to the transverse thermal dispersion effect. Winterberg and Tsotsas [6] studied the thermal and flow mathematical model of packed-sphere channel, and sorted out many

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