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The effect of porous insert position on the enhanced heat transfer in partially filled channels[☆]

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ABSTRACT

In the present work, the effect of porous insert position on enhanced heat transfer in a parallel-plate channel partially filled with a fluid-saturated porous medium was studied. The fully-developed laminar flow and convective heat transfer in the channel were simulated using Lattice Boltzmann Method (LBM). The walls of the channel were subject to a uniform constant temperature. The flow field and thermal performance of the channel were investigated and compared for two configurations: first the porous insert was attached to the channel walls, and second the same amount of the porous material was positioned in the channel core. Comparing the results of the present study to the analytical solutions, a reasonable agreement was observed. The effects of various parameters like Darcy number, porous medium thickness, etc. on the conduit thermal performance were investigated in both channel configurations. It was found that the position of the porous insert has significant influence on the thermal performance of the channel.

1. Introduction

Convective heat transfer in systems including porous inserts attracts many researchers due to the wide applications of these systems in engineering processes and equipment like geothermal energy recovery, air heaters, drying processes, electronics cooling, solid matrix heat exchangers, etc.

Fluid flow and convective heat transfer in channels partially filled by porous medium have been analyzed in several investigations analytically, experimentally, and numerically. Poulikakos and Kazmierczak [1] studied fully-developed convection between two parallel plates and in a circular pipe partially filled with an adhered porous matrix to the wall, theoretically. They applied both constant heat flux and uniform constant temperature boundary conditions at walls in their case studies. Vafai and Kim [2] presented an exact solution describing the interfacial fluid mechanics in fluid porous interface. Kuznetsov [3] presented an analytical solution for the fully-developed forced convection in a composite channel bounded by two infinite fixed plates utilizing the boundary layer technique. The porous medium was placed adjacent to the upper wall of the channel. A uniform heat flux was imposed at the lower plate, while the upper plate was adiabatic. Analytical solutions for the velocity and temperature distributions, as well as Nusselt number were obtained. In a similar work, Kuznetsov [4] presented an analytical solution for the steady fully-developed fluid flow in a composite region which was partly filled with a porous medium. Different from the previous investigations, the stress jump boundary condition was used in this study. Kuznetsov [5] presented analytical studies of forced convection in partly porous configurations. Chikh et al. [6] gave an analytical solution for non-Darcian fully-developed forced convection in a gap between two concentric cylinders. The inner cylinder was exposed to a constant heat flux while the outer was thermally insulated. The porous layer was attached to the inner cylinder. Kuznetsov [7] considered the problem of fluid flow and heat transfer in Couette flow through a composite channel with insulated fixed plate and isoflux moving plate. The porous insert was attached to the fixed plate at the upper side. An analytical solution was given for the evaluation of flow velocity, temperature distribution and Nusselt number.

Kuznetsov [8] studied analytically the effect of thermal dispersion on fully-developed forced convection in a parallel-plate channel partly filled with a fluid-saturated porous medium. The walls of the channel were subject to a constant heat flux. Peripheral parts of the channel were occupied by a fluid-saturated porous medium of uniform porosity.

Al-Nimr and Alkam [9] presented numerical solutions for the problem of transient developing forced-convection flow in concentric annuli partially filled with porous substrates using finite difference method. The porous substrate was attached either to the inner cylinder, or to the outer cylinder.

Abu-Hijleh and Al-Nimr [10] studied the transient hydrodynamics behavior of the fluid flow in parallel-plate channels partially filled

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