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Unsteady convection heat transfer for a porous square cylinder varying cylinder-to-channel height ratio

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ABSTRACT

The unsteady laminar flow and forced convection heat transfer have been numerically investigated across the porous square cylinder with the heated cylinder bottom at the axis in the channel changing cylinder-to-channel height ratio of 10%, 30%, and 50%. The other parameters include Reynolds number ($50 \sim 250$), Darcy number ($10^{-6} \sim 10^{-2}$), and porosity ($0.4 \sim 0.8$). The pressure drops are also examined for the flow past the porous square cylinder in the channels for all cases. The results indicate that the heat transfer for the square porous cylinder is enhanced as cylinder-to-channel height ratio increases; in particular, the enhancement is more obvious for a higher Darcy number and porosity.

1. Introduction

The confined flow configuration at various channel heights is a natural one for heating fluids in many engineering applications. Most of the previous heat transfer studies on channel-confined flow at various channel heights across a square cylinder were done for the forced convection case [1–4]. Sharma and Eswaran [5] showed how the channel-confinement and buoyancy influenced the 2D laminar flow and heat transfer across a square cylinder. Furthermore, forced convection heat transfer in a channel with a porous medium is of considerably technological interest. This is due to the wide range of applications such as LED backlight module cooling system, LED streetlamp cooling equipment, electronic component cooling system, heat exchangers, drying processes, heat pipes, and so on [6–9]. Consequently, there is a need to develop a fundamental understanding of heat transfer phenomena past a square porous cylinder for a channel-confined flow at various channel heights.

Many studies have discussed the characteristics of heat transfer for porous media with various conditions including the Darcy number, porosity, Reynolds number, flow conditions, shape and bodies conditions [10–13]. Huang et al. [14] investigated enhancement of steady-state heat transfer from multiple heated blocks mounted on one wall of a channel by porous covers. Hadim [15] studied steady-state forced convection in a channel with fully and partially porous material, which contained porous layers above the heat sources and was non porous elsewhere. He found that the heat transfer was almost the same as if the channel was totally porous, which was an interesting case since the pressure drop was about 50% lower. They showed that the significant heat transfer augmentation could be achieved through the use of multiple emplaced porous blocks. Wu and Wang [16] investigated the unsteady flow and convection heat transfer for a heated square porous cylinder in a channel. They found that the average local Nusselt number increases as Reynolds number increased; in particular, the increase was more obvious at a higher Darcy number. Oult-Amer et al. [17] analyzed steady-state laminar forced convection cooling of heat generating blocks mounted on a wall in a parallel plate channel. Their results indicated that a significant increase in the mean Nusselt number (up to 50%) was predicted and the maximum temperatures within the heated blocks were compared with the pure fluid case. Jiang et al. [18] solved the problem of steady-state forced convection heat transfer of water and air in plate channels filled with sintered bronze porous media. The convection heat transfer was more intense in the sintered porous plate channels than in non-sintered porous plate channels

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