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Forced Convection Heat Transfer Enhancement Using Porous Blocks within Channels

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Extended Abstract

During the last few years, an increasing interest has been devoted to fundamental studies of forced convection in ducts of various shapes fully or partially filled with a porous material. This interest is due to the presence of porous media in numerous engineering applications and natural processes such as filtration, groundwater flow, enhanced oil recovery, compact heat exchangers, packed bed and many others. The use of porous/fluid composite systems is an innovative method that can provide valuable solutions for improving energy efficiency of thermal systems, and can positively impact in areas ranging from preservation of energy resources to limiting global warming. Among these studies, one can quote the earliest work of Hadim (1994), Huang and Vafai (1994), Sung et al. (1995) and Chikh et al. (1995). They showed that when using partly filled ducts with porous materials there is optimal conditions for which heat transfer enhancement could be achieved. Recently Huang et al. (2010) used porous covers on heat sources to simulate electronic ships cooling. Nebbali et Bouhadef (2011) showed that under certain conditions heat transfer can be augmented with using less porous inserts.

The present work presents a numerical investigation of fluid flow and forced convection heat transfer in a parallel-plate channel partially obstructed with four porous blocks. These blocks are mounted alternatively on the top and the bottom walls of the channel in two different arrangements: the blocks are attached to the walls, referred to as config 1 and the case where a narrow gap exists between the blocks and the channel walls, denoted by config 2. Local heat sources are placed on the top wall of the channel in the location of the porous blocks. The flow is supposed to be permanent, bi-dimensional and the fluid and solid phases are in thermal equilibrium. The main concern of this study is the analysis of the effect of various parameters on the hydrodynamic and thermal fields.

The finite volume formulation was used to solve numerically the governing equations. This approach ensures conservation of mass, momentum and energy over each control volume, and, thus across the fluid/porous interface as well. A skewed grid distribution was used along both coordinate axes. In the X-direction, the mesh points were densely packed at the channel entrance and at the interfaces of the fluid/porous blocks. In the Y-direction, grid points were clustered near the top and bottom surfaces of the channel as well as in the neighborhood interfaces of fluid/porous blocks in both directions. The accuracy and the validity of the numerical model developed were verified by comparing the present results with relevant limiting cases available in the literature.

Throughout this investigation, some interesting results were revealed, showing that the thermal efficiency of the both configurations can be improved in several ways comparatively to the non porous channel. Thus, the average Nusselt number, Nu_m is not a monotonous function of the Darcy number, *Da*. In fact, the Nu_m increases when the permeability of the porous layer increases up to a critical value beyond which, Nu_m decreases until it reaches an asymptotic value, which corresponds to the non-porous case. However the pressure drop increases leading to an additional pumping power in order to overcome the resistance to the flow generated by the porous matrix. Another result shows that the narrow gap used in config2 improves the heat transfer significantly while lowering slightly the pressure drop comparatively to config1. This result is explained by the fact that the gap augments the velocity close to

the heated wall on the first and third blocks. Another result that should be emphasized is that config2 uses less quantity of porous material while showing a better thermal efficiency.

In conclusion, this study confirmed the great potential of the use of partially porous channels to improve heat transfer. However, further studies emphasizing the effect of certain parameters and the local thermal non equilibrium condition are needed to optimize the heat transfer gain and keeping the pressure drop at reasonable levels.

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