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Flow and heat transfer characteristics of water and ethylene glycol–water in a multi-port serpentine meso-channel heat exchanger

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ABSTRACT

Fluid flow and heat transfer characteristics in a multi-port serpentine meso-channel heat exchanger are numerically analyzed. Two liquid working fluids, namely water and an ethylene glycol–water mixture, are investigated as coolants. The results are compared with experimental data for the same geometrical and operating conditions. The numerical predictions of heat transfer rate, pressure and temperature drops in the coolants, and the core surface temperature around the serpentine bend agree very well with the experimental data. Simulation results show that the presence of a serpentine bend in the meso-channel heat exchanger enhances the heat transfer rate on average about 20% compared to a straight slab of the same length without the bend. The multi-port slab has flat heat transfer surfaces on the top and bottom faces where air flow has excellent contact and maintains a uniform temperature distribution. Also the parallel channels located inside the meso-channel slab core help to distribute the heat fairly evenly through all the channels. The serpentine meso-channel heat exchanger has a good potential application as an automotive radiator with reasonably enhanced heat transfer characteristics using an ethylene glycol–water mixture as the coolant.

1. Introduction

Heat exchangers using viscous liquid working fluids are encountered in highly specialized areas such as microelectronics cooling, aerospace, biomedical processes, robotics, and automotive applications. Achieving high heat transfer using miniaturized units has become an increasing demand from industry. Small flow passages represent the next step in heat exchanger development due to their high heat transfer, lightweight, and space minimizing potential over traditional tubes.

There is no well-established, unique hydraulic diameter that separates narrow channels from conventional scale ones. The heat exchanger studied in this paper is classified to be a meso-channel heat changer according to the Mehendale et al. [1] classification. The circular, 1 mm diameter channels are located inside the serpentine multi-port slab. Multi-port straight or serpentine flat slabs, with or without fins, are frequently encountered as the cores in many typical heat exchangers. Studies of these applied geometries are found relatively less in the literature. Some works [2–6] have reported experimental results of heat transfer and fluid flow in narrow size multi-port slabs. Although some works on micro-channel heat exchangers or heat sinks using non-circular cross-section are available [7–12], the detailed study of a complete heat exchanger comprised of narrow-diameter circular channels is still insufficient.

Research on various liquid working fluids in narrow channel heat exchangers and on viscous liquids is also limited in the literature. A viscous working fluid often experiences the laminar flow regime and a longer flow-developing length depending on the operating condition. Ethylene glycol–water solution is widely used in the heat exchanger industry as a heat transfer fluid. Study of this commercially important fluid in meso- and micro-channels is scarce, and the availability of data is rare in the open literature. Garimella et al. [2] in a single tube heat exchanger, and Jokar et al. [12] and Oliet et al. [13] in complete heat exchangers, investigated glycol–water mixture flow using non-circular cross-sections.

Traditional design techniques for conventional heat exchangers such as ε–NTU relations cannot be directly applied to small diameter channel heat exchangers because their design assumes a constant value for the convective heat transfer coefficient. The value of the heat transfer coefficient can be obtained using various correlations for individual ducts. Thermally fully developed flow may not exist over a large portion of micro- and meso-channel heat exchangers due to entrance region effects; therefore the heat

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