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Effects of magnetic field on nanofluid forced convection in a partially heated microchannel

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ABSTRACT

This paper numerically examines the laminar forced convection of a water–Al_2O_3 nanofluid flowing through a horizontal microchannel. The middle section of the microchannel is heated with a constant and uniform heat flux. The middle section is also influenced by a transverse magnetic field with a uniform strength. The effects of pertinent parameters such as the Reynolds number ($0 \leq Re \leq 1000$), the solid volume fraction ($0 \leq \phi \leq 0.04$) and the Hartmann number ($0 \leq Ha \leq 100$) on the flow and temperature fields and the heat transfer performance of the microchannel are examined against numerical predictions. The results show that the microchannel performs better heat transfers at higher values of the Reynolds and Hartmann numbers. For all values of the Reynolds and Hartmann numbers considered in this study, the average Nusselt number on the middle section surface of the microchannel increases as the solid volume fraction increases. The rate of this increase is considerably more at higher values of the Reynolds number and at lower values of the Hartmann number.

1. Introduction

The recent development of automotive, aerospace and electronic technologies has been associated with a continuous reduction in the size of components and an increase in their power and heat generation. Effective cooling strategies are, therefore, required to maintain the safe and efficient operation of these components. Microchannels have been proven to have relatively higher heat dissipation capabilities than conventional heat removal devices because of their higher heat transfer surface area to fluid volume ratio [1–4]. As the hydraulic diameter of the microchannels decreases, the heat transfer coefficient increases and the microchannels demonstrate superior cooling performance. This is, however, associated with larger pressure drops. The optimal design for microchannels largely depends on their operational functionality, reliability and thermal performance. Tullius et al. [5] comprehensively reviewed the cooling performance of microchannels with various designs and different fluids. Air, water and fluoro-chemicals are the most common fluids used in microchannels. The heat transfer performance of these fluids is limited, however, due to their transport properties and/or low thermal conductivity.

In applications where a significant amount of heat needs to be removed from a very small surface, the coolant should have more effective heat transfer characteristics. Nanofluids have been proven to have high thermal conductivity and to be very stable [6]. Nanofluids consist of nanoparticles such as oxide ceramics, nitride ceramics, carbide ceramics, metals and semiconductors, which are suspended in a base fluid such as water, ethylene, glycol, engine oil or refrigerant. Most researchers argue that the addition of nanoparticles with relatively higher thermal conductivity to the base fluid results in an increase in the thermal performance of the resultant nanofluid [7–9]. Despite their high thermal conductivity, nanofluids can cause a high pressure drop, leave sedimentation of particles and clog the microchannel over time [10]. Moreover, heat transfer enhancement by means of nanofluids is still a controversial issue. Some researchers argue that the augmentation or mitigation of heat transfer reported in the published numerical studies is due to variations in the models used to predict the properties of nanofluids [11,12]. A comprehensive nanofluid simulation study should take into account the structure, shape, size, aggregation and anisotropy of the nanoparticles as well as their type, the fabrication process, particle aggregation and the deterioration of nanofluids.

The application of nanofluids in microchannels has generated considerable interest amongst researchers. Various models for the effective thermal conductivity of nanofluids have been used

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