LAMINAR FLOW FORCED CONVECTION HEAT TRANSFER BEHAVIOR OF PHASE CHANGE MATERIAL FLUID IN MICROCHANNELS WITH STAGGERED PINS

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ABSTRACT

Microchannels have been extensively studied for electronic cooling applications ever since they were found to be effective in removing high heat flux from small areas. Many configurations of microchannels have been studied and compared for their effectiveness in heat removal. However, there is little data available in the literature on the use of pins in microchannels.

Staggered pins in microchannels have higher heat removal characteristics because of the continuous breaking and formation of the boundary layer, but they also exhibit higher pressure drop because pins act as flow obstructions. This paper presents numerical results of two characteristic staggered pins (square and circular) in microchannels. The heat transfer performance of a single phase fluid in microchannels with staggered pins, and the corresponding pressure drop characteristics are also presented.

An effective specific heat capacity model was used to account for the phase change process of PCM fluid. Comparison of heat transfer characteristics of single phase fluid and PCM fluid are made for two pins geometries for three different Reynolds numbers. Circular pins were found to be more effective in terms of heat transfer by exhibiting higher Nusselt number. Circular pin microchannels were also found to have lower pressure drop compared to the square pin microchannels.

Keywords:
Microchannels, Phase Change Material (PCM) fluid, staggered square and circular pins, and aspect ratio.

INTRODUCTION

Microchannels have been studied for electronic cooling applications because of their capacity in removing high heat flux from small areas. Many configurations of microchannels have been studied and compared for their effectiveness in heat removal [1-8]. However, there is little data available on the use of pins in microchannels. Also, except for few publications, there are virtually no optimization studies in this area.

Recent studies of microchannels have also shown that a phase change material (PCM) fluid improves the heat removal rate while maintaining lower wall temperature. Experiments have shown that PCM fluids exhibit an enhanced heat capacity due to the phase change material’s latent heat of fusion [9-18]. Hao and Tao [18-19] did an extensive study and evaluated the performance of PCM particle flow in circular microchannels. They modeled the particle flow separately from the mean flow using source terms in momentum and energy equations. They also considered the particle-particle interactions and particle-depletion layer effects near the wall. Said [20] performed a computational fluid dynamics (CFD) analysis of PCM slurry flow in microchannels with thick walls taking into account conjugate heat transfer. Results from the previous efforts on PCM slurry flows have been promising with the main advantage being the lower wall temperature for same heat flux removal compared to conventional single phase fluids.

The current work focuses on use of PCM fluid in microchannels with staggered pins, both circular and square pins. Also, the heat transfer characteristics without the presence of pins (called as “no pins”) is studied and compared with square and circular pins configurations.