Numerical Investigation on Hydro-thermal Characteristics of Microchannel Heat Sinks with PCM Inserts for Effective Thermal Management Applications

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ABSTRACT
The increasing power density and miniaturization of modern electronic components have raised concerns regarding effective thermal management systems. The performance, efficiency, and lifespan of electronic devices greatly depend on the efficacy of their heat dissipation mechanisms. Micro-Channel Heat Sinks (MCHS) have proven to be highly effective in this regard, showcasing superior heat dissipation capabilities. In this study, a novel approach is introduced to enhance the thermal performance of MCHS through the integration of conjugate heat transfer and energy storage. Numerical investigations were conducted to assess the performance improvement of MCHS with the incorporation of Phase Change Materials (PCM). The numerical model employed in this study exhibited good agreement with existing experimental and simulation results documented in the literature. The hydrothermal characteristics of six PCM-based hybrid MCHS models were analyzed and compared with a model of a heat sink without PCM, considering various parameters such as thermal resistance, liquid fraction, Thermal Performance Factor (TPF), pressure drop, Poiseuille number, and Nusselt number. Significant performance enhancements were observed in the MCHS with the integration of PCM, including a noteworthy 12% increase in TPF and a 7.3% reduction in thermal resistance in the proposed models. The combined impact of heat flux and Reynolds number on the liquid fraction was investigated, while the influence of PCM channel shape and aspect ratio (AR) was also discussed.
Keywords: Fluid flow; Thermal management; Electronic cooling; Hybrid micro-channel heat sink; Phase change material (PCM); Liquid Fraction.