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On the Thermal Characterisation of Composite Wick Embedded Heat Pipes

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Extended Abstract

With relentless growth in electronics and telecommunication technologies, modern systems are pushing towards miniaturisation, high performance and compact integration. As a result, heat fluxes produced by components such as electric vehicle batteries, 5G telecommunication modules, central processing units (CPUs), and graphics processing units (GPUs) have surged substantially. This escalation in thermal load demands for efficient and reliable thermal management solutions [1-3]. Among the various passive cooling technologies, heat pipes (HPs) have been widely utilized as highly efficient and reliable two phase heat transfer devices (TPHTD), offering effective thermal regulation in such electronic devices [4, 5]. A critical factor influencing the performance of HPs is the embedded wick structure, which governs the fluid transport mechanism within the device. The wick's primary role is to generate sufficient capillary pressure to return the working fluid from the condenser to the evaporator section, thereby sustaining the phase change cycle essential for heat transfer. Additionally, it provides the necessary surface area to facilitate efficient liquid-vapor phase transition. The capillary performance of the wick is primarily governed by two key parameters: permeability (K) and capillary pressure ($\Delta P_{cap.}$). Ideally, a wick should exhibit high permeability to minimize liquid flow resistance and a high capillary pressure to efficiently drive fluid circulation [6, 7]. However, these properties are fundamentally contradictory in nature; for instance, large pores offer high permeability but low capillary pressure, while the finer pores enable high capillary action with high flow resistance. This limitation presents a significant challenge for a single wick structure to possess both characteristics.

To address this trade-off, the present study proposes a composite wick design consisting of two layers of screen meshes with varying pore sizes. Herein, we fabricated wick structures by combining a coarse mesh and a fine mesh, with the aim of enhancing capillary performance without compromising permeability. In the wick configuration, the coarse mesh is inserted in direct contact with the entire HP wall, facilitating reduced flow resistance and enhanced permeability. The fine mesh is then layered atop the coarse mesh, covering the evaporator-side half of the HP only, to increase capillary pressure in the critical liquid-vapor interface region. The objective of this work is to experimentally investigate the thermal performance of various composite wick combinations by maintaining the coarse mesh layer constant and meticulously varying the fine mesh layer. The influence of mesh layering and axial location of the finer mesh on the HP's thermal resistance and maximum heat transport capacity (Q_{max}) will be explored in the study. The findings are expected to contribute valuable insights into optimizing wick structures for modern heat pipe applications in current and next-generation electronic and telecommunication modules.

Keywords: Composite wick; Capillary performance; Thermal management; Two phase heat transfer; Heat pipe; Electronic cooling

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