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RESEARCH PAPER

A novel method for characterization of liquid transport through micro-wicking arrays

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Abstract The existing methods for predicting/modeling the permeability of a wick structure involve the use of a capillary pressure model. Thus, the validity of the existing permeability models has not been verified independent of the capillary pressure. Here, for the first time, the permeability and capillary pressure of monoporous wick structures have been independently determined using a new experimental approach. In the new approach, the liquid mass flow rate against gravity is measured by testing the wick at its dryout threshold at different wicking lengths. The permeability and capillary pressure of the wick are then uniquely determined by curve fitting the wicking length-dependent mass flow data. The advantage of the developed method over Washburn's rate of rise technique is that the current method yields both capillary pressure and permeability values while the former only returns the product of the two parameters. The permeability values obtained from the experiments were used to examine the accuracy of the existing permeability models.

Keywords Wick structures · Micropillar arrays · Permeability · Capillary · Heat pipe · Two-phase heat spreader

List of symbols

A	Cross-sectional area of wick (m^2)
A_m	Area of liquid meniscus (m^2)
d	Diameter of pillar (m)
g	Acceleration due to gravity (m/s^2)
H	Height of pillar (m)
H_{eff}	Height of liquid from pillar base to meniscus (m)
h_{fg}	Latent heat of vaporization (kJ/kg)
K	Permeability (m^2)
L	Wicking length—distance between top of evaporator and top of liquid pool (m)
$\dot{m}$	Mass flow rate (kg/s)
p	Pitch (m)
P_{cap}	Capillary pressure (N/m^2)
r	Pillar radius (m)
s	Solid volume fraction
w	Edge-to-edge pillar spacing (m)
θ	Solid–liquid contact angle (radians)
μ	Dynamic viscosity (Ns/m^2)
ρ	Density (kg/m^3)
σ	Surface tension (N/m)
ϕ	Volumetric porosity

1 Introduction

Two-phase heat carriers (or spreaders), often made in the form of a pipe, are among the most widely used thermal management tools due to their reliability, passive operation, and compactness. Because of these benefits, it is desired to expand their use to high-performance applications, particularly military systems with high heat loads and moving platforms that are often subjected to high gravitational forces (i.e., high "g"). Two important factors that limit the performance of a two-phase heat carrier are the capillary pressure and the hydraulic permeability of its wick structure, which determine its maximum liquid transport capacity. Traditional wick structures include sintered metal powders, woven meshes, slotted metal sheets, and grooved walls. (Silverstein 1992; Peterson 1994; Faghri 1995). In recent years, micro- and nanoscale wick structures have been the subject of

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