



Contents lists available at ScienceDirect

International Journal of Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/ijhmt

Thermal design and operational limits of two-phase micro-channel heat sinks

Sung-Min Kim^{a,*}, Issam Mudawar^{b,*}

^a School of Mechanical Engineering, Sungkyunkwan University, 300 Cheoncheon-dong, Suwon 400-746, Republic of Korea

^b Purdue University Boiling and Two-Phase Flow Laboratory (PU-BTFFL), Mechanical Engineering Building, 585 Purdue Mall, West Lafayette, IN 47907-2088, USA

ARTICLE INFO

Article history:

Received 13 August 2016

Received in revised form 5 October 2016

Accepted 6 October 2016

Available online xxxxx

Keywords:

Thermal design

Heat sink

Micro-channel

Dryout incipience

Premature critical heat flux

Two-phase critical flow

ABSTRACT

While the vast majority of published studies on two-phase micro-channel heat sinks have been focused on determination of pressure drop and heat transfer coefficient, very few studies have addressed the operational limits of these devices. This study provided a comprehensive methodology for thermal design of micro-channel heat sinks with saturated inlet conditions. This includes predictive methods for pressure drop and heat transfer coefficient using universal correlations that rely on large databases amassed from numerous sources, and which encompass many working fluids, and very broad ranges of hydraulic diameter, mass velocity, inlet pressure, and inlet quality. This is followed by predictive tools for thermal limits associated with dryout incipience and premature critical heat flux, as well as two-phase critical flow limit. The three limits are combined to define an envelope for acceptable heat sink performance. Using these tools, a parametric study is performed to determine the variation of maximum heat flux with total volumetric flow rate for different combinations of the channel's geometrical parameters for three working fluids, HFE-7100, R134a, and water. Then, the values of maximum heat flux are used to assess corresponding variations of pressure drop and maximum bottom wall temperature of the heat sink. It is shown that maximum heat flux is dominated by different limits for different flow rate ranges, and may be increased significantly, while decreasing bottom wall temperature, by using a large number of small channels. Furthermore, using deeper micro-channels is shown to increase maximum heat flux and decrease pressure drop, while producing a relatively weak adverse effect on bottom wall temperature.

© 2016 Published by Elsevier Ltd.

1. Introduction

1.1. High-flux two-phase thermal management

As heat dissipation from electronic and power devices began to escalate beyond the capabilities of air cooling technologies and, later, single-phase liquid cooling technologies, thermal management system designers shifted their attention to phase-change cooling technologies, which capitalize on full cooling potential of the working fluid, both sensible and latent [1].

Phase change cooling can be implemented in a variety of configurations, the simplest of which is pool boiling thermosyphons [2–6]. These systems offer several advantages, including simplicity of design, low cost, and, most importantly, passive circulation of

the working fluid with the aid of buoyancy. But low circulation speeds place upper limits on cooling performance of thermosyphons that are below the operating heat flux in many cutting-edge electronics applications.

These limits have spurred numerous research efforts aimed at achieving superior cooling performance by capitalizing on high coolant speed achieved with pumped liquid loops. Currently, attention is being placed on three primary competing pumped two-phase cooling schemes: jet-impingement, spray, and micro-channel [7]. Each of these schemes provides intrinsic cooling merits while also posing performance challenges and limits.

Jet impingement provides enormous cooling heat fluxes, but greatly increases coolant flow rate requirements as well as produces appreciable temperature gradients across the heated wall away from the impingement zone [8–10]. To mitigate large temperature gradients, multiple jets have been recommended [11–13] to create multiple impingement zones, but this tactic poses additional challenges, including increased coolant flow rate

* Corresponding authors.

E-mail addresses: smkim@skku.edu (S.-M. Kim), mudawar@ecn.purdue.edu (I. Mudawar).

URLs: <http://htl.skku.edu> (S.-M. Kim), <https://engineering.purdue.edu/BTFFL> (I. Mudawar).

Download English Version:

<https://daneshyari.com/en/article/4994814>

Download Persian Version:

<https://daneshyari.com/article/4994814>

[Daneshyari.com](https://daneshyari.com)