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Numerical simulation of the thermal hydraulic performance of a plate pin fin heat sink

Wuhan Yuan [a], Jiyun Zhao [b], C.P. Tso [c], Tianhua Wu [a], Wei Liu [a], Tingzhen Ming [a,*]

[a] School of Energy and Power Engineering, Huazhong University of Science and Technology, No. 1037 Luoyu Road, Wuhan 430074, China
[b] EXQUISITUS, Centre for E-City, School of Electrical and Electronic Engineering, Nanyang Technological University, 639798 Singapore, Singapore
[c] Division of Thermal and Fluids Engineering, School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore

HIGHLIGHTS

► Pin height and air velocity significantly influence thermal performance of PPFHS.
► Less influence by in-line or staggered array.
► Less influence by neighbor pin flow-directional center distance.
► Design with >6.5 m/s air can cool to <358 K, for desktop PC CPU with 2.20 W/cm^2 flux.

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ABSTRACT

The computational fluid dynamic software FLUENT is used in assessing the electronics cooling potential of a plate pin fin heat sink (PPFHS), including the conjugate effect. The simulation results are validated with reported experimental data. The simulation shows that pin height and air velocity have significant influences on the thermal hydraulic performances of PPFHS while the influences of in-line/staggered array and neighbor pin flow-directional center distance (NPFDCD) of the PPFHS are less notable. In applying the present design to the cooling of a desktop PC CPU at a heat flux of 2.20 W/cm^2, the temperature can be kept at less than 358 K with an air velocity over 6.5 m/s.

1. Introduction

With the rapid advances in micro electromechanical systems (MEMS), the size of electronic components shrinks and the thermal power increases dramatically, resulting in high working temperatures that can greatly reduce the reliability of the components and shorten their service lives. Hence thermal management of electronic chips has been advancing in tandem, in order to control the working temperature to within acceptable limits by devising more effective ways to remove the waste heat. Devices such as heat pipes [1,2] and jet impingement cooling [3,4], have been studied. And although air has been a common coolant, liquid and flow boiling have also been considered [5,6].

Tuckerman and Peace in 1981 proposed the micro-channel heat sink (MCHS) cooling concept. They fabricated rectangle micro-channel heat sinks in silicon wafers, and using water as coolant, the MCHS was proved suitable for cooling such devices as high-performance microprocessors, laser diode arrays, radars and high-energy-laser mirrors [7,8]. The success motivated others to design better heat sinks, as attested by the following survey.

Chiang et al. [9] presented a systematic experimental design based on the response surface methodology to identify the effects of design parameters of the PFHS on the thermal performance, and explored various design parameters, such as the height and diameter of pin fin and the width of pitch between fins in the experiment. Cao and Chen [10] studied optimal design on MCHS for high power laser mirror, and suggested ways to improve on some physical parameters. Chen et al. [11] compared the performances of triangular, rectangular and trapezoidal MCHSs, while Leon et al. [12] conducted a numerical investigation on the heat sink with aerodynamic shaped cooling fins. Mohammed et al. [13,14] carried out numerical simulations to compare the zigzag, curvy, and step MCHSs and concluded that the zigzag design has the best thermal performance. For the wavy MCHS the temperature was always

* Corresponding author. Tel.: +86 27 87542618x608, fax: +86 27 87540724.
E-mail address: tzming@mail.hust.edu.cn (T. Ming).

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