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Thermal performance enhancement of vapor chamber by coating mini-channel heat sink with porous sintering media

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ABSTRACT

This paper have been investigated on the thermal performance enhancement of air cooling vapor chamber by coating mini-channel heat sink inside with porous sintering wick sheet. The results obtained from experiments are considered and compared with without porous sintering wick sheet. The effects of power input, amount of filled working fluid into the vapor chamber and mass flow rate of air on the cooling performance and thermal resistance characteristics are considered. It can be found that the porous sintering wick sheet has significant effect on the increment of the capillary force which results in higher heat transfer rate. Therefore, the thermal performance of air cooling vapor chamber with porous sintering wick sheet inside mini-channel shows 20% maximum higher than that without porous sintering wick sheet. In addition, the increasing of power in put and cooling air mass flow rate have significantly increased thermal performance of the vapor chamber. The passive cooling device with vapor chambers is favorable technique that can enhanced thermal performance and reduce heat accumulate on the electronic component.

1. Introduction

Due to higher generated heat from the electronic devices, the electronic cooling system has become importance. Vapor chamber and heat pipe are an essential passive cooling on thermal cooling enhancement in electronics devices especially for CPU of computer. This is because its phase change heat transfer that can remove high heat transfer dissipate effectively. The vapor chamber and heat pipe have been researched by Koito et al. [1]. The numerical results are used for the design and improvement of the vapor chamber. Hsieh et al. [2,3] experimentally and numerically studied the spreading thermal resistances and the thermal performance of vapor chamber. Chen et al. [4] presented a numerical investigation of a whole set of thermal module, including a plate-fin heat sink embedded with a vapor chamber. Ming et al. [5] experimentally and numerically investigated a novel grooved vapor chamber. Li et al. [6,10] studied effect of a shield on the thermal and hydraulic characteristics of plate-fin vapor chamber heat sinks under cross flow cooling. Tsai et al. [7] investigated a two-phase closed thermosyphon vapor-chamber system for electronic cooling. Wong et al. [8,12] studied the performance of a novel vapor chamber using corrugated groove walls with working fluid of water, methanol or acetone. Wang et al. [9,11,13] analyzed the thermal performance of the vapor chamber for high-power LEDs. Ji et al. [14,16] proposed an extended vapor chamber and a copper foam using water, acetone and ethanol as working fluid. Reyes et al. [15] numerically studied on the behavior of a vertically placed vapor chamber based heat spreader intended for avionics applications. Attia and El-Assal [17] evaluated the thermal performance of vapor chamber with water and methyl alcohol at different charge ratios. Naphon et al. [18,19,24] experimentally investigated on the thermal cooling of vapor chamber for cooling computer processing unit of the personal computer, hard disk drive with water and refrigerant R-141b as working fluid. Ju et al. [20] studied the characterization of advanced evaporator wicks and thin planar vapor chambers incorporating these wicks. Tsai et al. [21] investigated the influence of inclination on the vapor chamber performance and temperature uniformity. Chen et al. [22] studied the feasibility of an aluminum alloy 6061 as the container material to fabricate the vapor chamber with the radial grooved wick and sintered aluminum powders wick. Peng et al. [23,28,30] studied a new pattern of wick is a kind of leaf vein-like fractal architecture with polygon loops which are composed of many Y-shaped bifurcations, chemical etching of wick in vapor chamber. Hassan and Harmand [25] presented three-dimensional transient model for vapor chamber with nanofluids as working fluid. Tang et al. [26] designed, built and tested a

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Nomenclature

A	heat transfer surface area [m^2]
I	current [A]
Q	total power input [W]
q	heat flux density [W m^{-2}]
R	thermal resistance [W/m^{-1} K^{-1}]
T	temperature [K]
t	time [s]
V	voltage [V]
λ	thermal conductivity [W m^{-1} K^{-1}]

Subscripts

a	air
base	vapor chamber base
condense	condenser
contact	contact surface
e	electricity
evap	evaporator
heat source	heat source
inlet	inlet
TIM	thermal interface material
tot	total

multi-artery vapor chamber. Sun and Qiu [27] experimentally studied a novel asymmetrical vapor chamber, patterned with multiscale micro/nanostructured surfaces. Chang et al. [29] examined the thermal performances of a newly devised thin loop-type vapor chamber of 0.5 mm interior height at the controlled evaporator heat fluxes and condenser thermal resistances with vertical and horizontal orientations. Mizuta et al. [31] investigated the thermal performance of flat laminate vapor chamber called Fine Grid Heat Pipe. Lu et al. [32] presented a thermal hydraulic model to analyze the performance of a VC with different sintered central columns. Patankar et al. [33] studied a transport limitations and thermal requirements encountered in mobile applications. Velardo et al. [34] numerically studied a vapor chamber heat spreaders using the concept of effective thermal conductivity. Shaeri et al. [35] proposed a novel vapor chamber to assess the feasibility of combining hydrophobic and hydrophilic wettability in the evaporator to optimize thermal performance. Overall, the performance of the proposed vapor chamber was lower than that of the baseline vapor chamber. The most productive products have been continuously performed by Ali et al. [36–41]. They have been studied on the heat transfer and flow characteristics of mini-channel heat sinks with various geometry. In addition, they have been continuously performed on the thermal performance of the phase change material embedded with pin fin heat sinks with different configurations for the passive cooling of electronic devices (Ali et al. [42–46]).

According to authors' knowledge, there are many papers presented numerical and experimental study on the heat transfer performance of vapor chamber using air as a coolant and some papers had been reported the effect of the wick structures. However, only few work reported on the heat transfer characteristics of air cooling vapor chamber with and without porous sintering wick sheet in mini-channel heat sink. Therefore, the objective of this paper is to investigate the thermal performance enhancement of air cooling vapor chamber by coating mini-channel heat sink inside with porous sintering wick sheet.

2. Experimental apparatus and test procedure

2.1. Experimental apparatus

The schematic illustration of the experimental study is shown in Fig. 1. The main equipment of the test loop facility is consisted of a wind- tunnel, air cooling vapor chamber system, test section, and a data acquisition system. The wind tunnel is used to generate air flow in the range of 0.006–0.015 kg/s flowing through the test section with a specific mass flow rate and temperature. The pressure drop across the test section, and the orifice of the wind tunnel are measured by differential pressure transducer with accuracy and uncertainty of 0.02%, ±0.02 respectively. In the experiment, the CPU is replaced by 3 cartridge heaters each of 60 W inside a copper block to generate heat to the copper block as the heat source by using AC power supply. In order to minimize thermal resistance between the electrical-vapor chamber and vapor chamber-heat sink unit, a thin film of high thermal conductivity is applied at their junction interface. The working fluid (de-

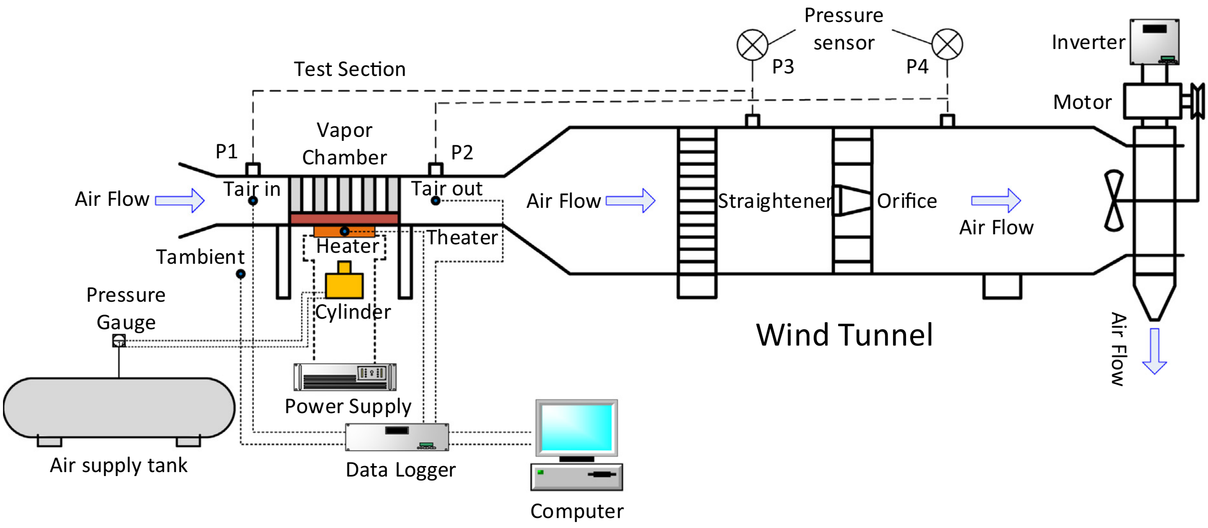

Fig. 1. Schematic illustration diagram of the air cooling vapor chamber.