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Investigation of the thermal performance of a novel flat heat pipe sink with multiple heat sources

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ABSTRACT

A novel flat heat pipe sink with multi-heat sources (a heat sink configured with four flat heat pipes) has been developed and fabricated in this work. Compared with conventional heat sink, the novelty of this passive heat transfer device is capable of realizing high heat transport performance. Experimental investigation was systematically conducted to test and evaluate the thermal performance of the novel flat heat pipe sink. Thermal resistance, maximum heat transport capacity and heat dissipation capacity of the novel flat heat pipe sink are among the main operating parameters that are qualitatively studied and analyzed. The experimental results showed that overall thermal resistance of the heat sink was reduced with increasing the multi-heat sources. The minimum thermal resistance of 0.103 °C/W appeared in the case of three heat sources, air flow rate of 4.5 m/s and inclination angle of 90°. Similar to the thermal resistance, increasing number of heat sources resulted in an increase of the maximum heat transport capacity. Meanwhile the maximum heat transport capacity and heat dissipation capacity of the heat sink were significantly improved. Furthermore, when operating temperature was controlled at 65 °C, the novel heat sink could still transport heat flux of nearly 400 W, which showed its high heat flux transportation in heat dissipation of compact electronic devices.

1. Instruction

Electronic devices are being developed with ever increasing power density [1]. High heat flux electronics not only has negative influence on the efficiency of machine, but also even causes damage to the machine itself. The high heat fluxes require better cooling technologies to prevent overheating. Consequently, strengthening cooling device efficiency or fabricating new high efficient cooling device for removing high heat flux do great significance in the improvement of heat transport technology [2].

Nowadays, the mainstream heat dissipation methods of electronic devices are: air cooling, liquid cooling, semiconductor refrigeration device and heat-pipe sink. Heat pipe has many advantages than other conventional heat sink, which can utilize the latent heat of boiling and condensation with small temperature differences to remove higher heat fluxes [3]. Although there are many kinds of heat pipes with different configurations, such as two-phase closed thermosyphon [4–6], capillary-driven heat pipe [7–9], loop heat Pipe [10], capillary pumped loop (CPL) heat pipe [11], and pulsating heat pipe [12]. It has been clearly demonstrated that the flat-shaped heat pipes [13–18] have an advantage in terms of heat removal capability and geometrical adaptation for many applications especially in electronic cooling.

Many of the recently reported investigations pertain to the analysis of heat pipes used as heat sinks and thermal spreaders for electronic cooling applications; some of the research has focused on the analysis of large heat pipes [19,20]. However, domestic and foreign research work mentioned above mainly focuses on mechanism and thermal performance of a single flat heat pipe with one heat source. In the case of high heat fluxes, such kind of a flat heat pipe sink may occupy large space. Therefore, it is obvious that the development of radiator trends to miniaturization and integration in order to save more space.

In this work, a novel flat heat pipe sink with multiple heat sources was developed and fabricated to meet the tough thermal requirements in high heat fluxes. The novel heat sink was embedded with four flat heat pipes of high thermal performance. Each flat heat pipe has three evaporators, and several condensing zones. Experimental investigations were conducted to determine thermal performance of the novel flat heat pipe sink with multiple heat sources under anti-gravity situation.

2. Experimental investigation

2.1. A novel flat heat pipe sink

The prototype of the flat heat pipe sink is shown in Fig. 1, which was

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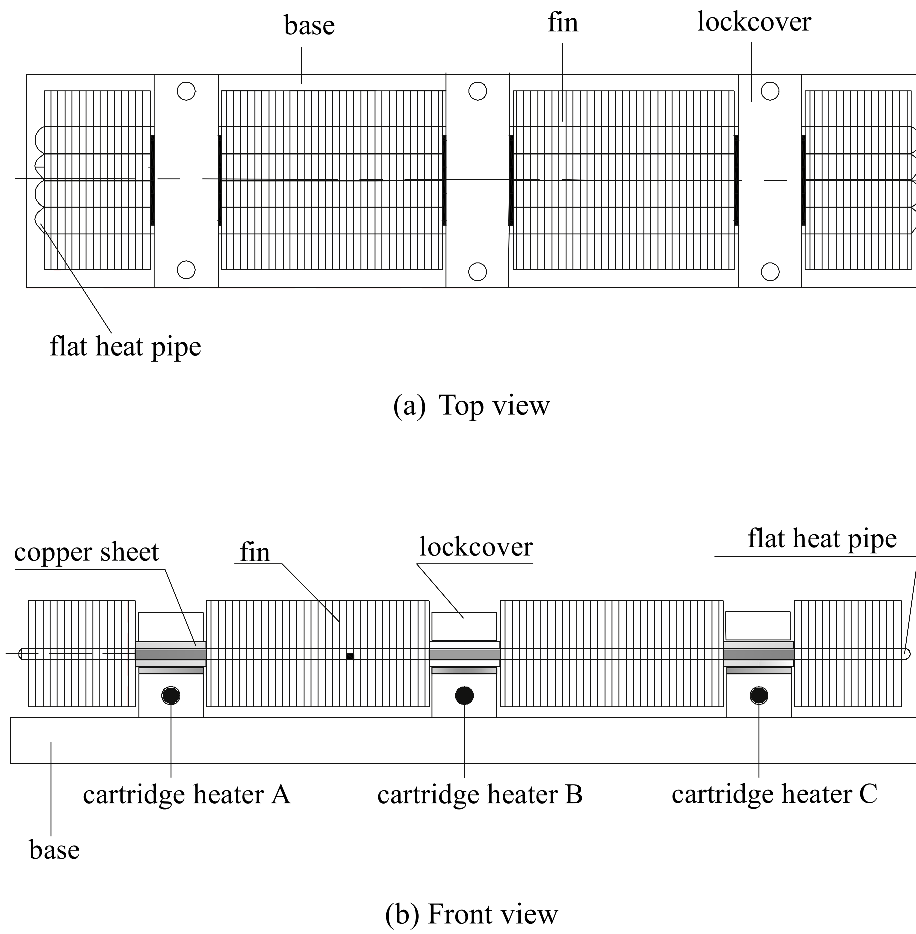

Fig. 1. Configurations of the novel flat heat pipe sink.

Table 1
Detailed dimension and material of the novel flat heat pipe sink.

Component	Dimension	Material
Heat sink	255 × 50 × 35 mm	Copper
	Wall thickness = 0.5 mm	
Heating area	30 × 20 mm	
Fin	Thickness = 0.4 mm	Aluminum
	Pitch = 2.4 mm	
	Middle fin stacks = 27 pc	
	Side fin stacks have = 13 pc	
Flat heat pipe	255 × 7.5 × 4.0 mm	Copper
	Wick thickness = 0.8 mm	Sintered copper
	Particle diameter = 1.65×10^{-4}	Copper

fabricated in an envelope of 255.0 × 50.0 × 35.0 mm. Four sintered copper flat heat pipes arranged in parallel in the center of the heat sink. Each of the sintered copper flat heat pipes has the same envelope of 255.0 × 7.5 × 4.0 mm. Water was employed as the working fluid. The detailed dimension and material of the novel flat heat pipe sink with multi-heat sources are listed in Table 1.

The working principle of the novel heat pipe was illustrated in Fig. 2. Dreg by the action of capillary force, the working liquid constantly refluxed through the sintered layer to heating surface, quickly and continuously evaporated to vapor. The vapor filling with the whole vapor chamber transferred the large heat fluxes to condenser through the tube wall. The wall delivered the heat to fins outside, meanwhile air flow took the heat away from the fins outside.

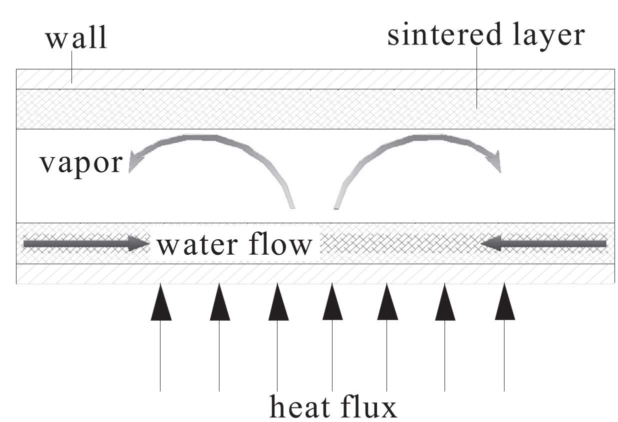

Fig. 2. Schematic of working principle the flat heat pipe.

2.2. *Experimental setup*

The experimental setup shown in Fig. 3 is used for testing the performance of the novel flat heat pipe sink. The experimental system included two DC fans (for producing air flow with rated voltage of 1.6 Ampere), air channel (for keeping air temperature and velocity of the wind), a test unit, three cartridge heaters, a data acquisition system (FLUKE 2680A), two DC power suppliers (one for fans and the other for cartridge heaters), a PC (for monitoring, logging and processing the experimental data). The novel heat sink were heated by virtual heat