EXPERIMENTAL ANALYSIS OF EFFECT OF BASE WITH DIFFERENT INNER GEOMETRIES FILLED NANO-PCM FOR THE THERMAL PERFORMANCE OF THE PLATE FIN HEAT SINK

by

Lakshmanan PERIYANNAN[a*], Saravanan PERIYASAMY[a], and Mohan RAMAN[b]

[a]Department of Mechanical Engineering, Mahendra Engineering College, Mallasamudram, Namakkal, Tamil Nadu, India
[b]Department of Mechanical Engineering, Sona College of Technology, Salem, Tamil Nadu, India

Original scientific paper
https://doi.org/10.2298/TSCI201005243L

Experimental research demonstrates the performance of electronic devices on plate fin heat sinks in order to guarantee that operating temperatures are kept as low as possible for reliability. Paraffin wax (PCM) is a substance that is used to store energy and the aluminum plate fin cavity base is chosen as a thermal conductivity enhancer. The effects of PCM material (phase shift material), cavity form base (rectangular, triangular, concave, and convex) with PCM, Reynolds number (Re = 4000-20000) on heat transfer effectiveness of plate fin heat sinks were experimentally explored in this research. The thermal performance of concave base plate fin heat sink with PCM is increased up to 7.8% compared to other cavity base heat sinks.

Keywords*: heat sinks, paraffin wax, thermal conductivity enhancer, phase shift material, cavity form base, thermal performance*

Introduction

Electronic and microelectronic devices have witnessed a significant rise in power density as a result of recent advances in electronics technology. Improving the rate of heat transfer for such devices is critical for long-term stable operation in a highly competitive electronic equipment industry. Effective cooling of these devices is important and numerous cooling methods have been developed. Cooling techniques such as thermoelectric coolers [1], heat pipes [2], and jet impingements are available [3]. In addition to improving cooling techniques, heat sinks based on PCM research have recently been studied. For the duration of the PCM melting process, it takes in a considerable quantity of thermal energy at a steady temperature, which improves the cooling effect. Elshafei [4] evaluated the heat transfer efficiency of a heat sink (plate fin) using velocity, fin density, and clearance among tip and shroud parameters, as well as their effects on bypass flow, pressure drop ratio, and heat transfer performance. The average heat transfer coefficient and heat transfer rate are reduced while the clearance between the tip and the shroud is increased [5]. Wang *et al.* [6] discussed about Cu threads of heat sinks for enhancing heat transfer and illustrated the massive probable for improvements

*Corresponding author, e-mail: periyannanl@gmail.com

in heat conduction of PCM. Wu *et al*. [7] employed PCM boards with an immense heat storage ability and increased thermal conductivity for electronic thermal regulation. Using pin-fins (circular) and *n*-eicosane as PCM, Ali and Arshad [8] studied passive cooling system. Various configurations and thicknesses of pin-fin (circular) heat sinks made of aluminium packed with variable volumetric PCM fractions. The heat transfer efficiency of various shape of heat sink which includes different PCM was also experimentally explored by Arshad *et al*. [9]. The volumetric fraction and thickness of the fin also evaluated. Enhancement ratios showed that for a 2 mm thick pin-fin heat sink, *n*-eicosane had the most thermal output, while paraffin wax had the best thermal output for a heat sink with a 3 mm pin diameter. Ali *et al*. [10] presented similar results. The PCM-based heat sinks were tested numerically and experimentally with distinct internal fin configurations by Hosseinizadeh *et al*. [11]. It has been discovered that increasing the fin numbers and fin height result in a significant boost in thermal efficiency. It has also been observed that there is only an insignificant advance in thermal performance by rising the thickness of fin. Kandasamy *et al*. [12] studied the utilization of PCM-based heat sinks in the unsteady heat regulation of plastic quad flat package electrical devices. They discovered that the improve in thermal efficiency and melting rate until the full melting of the PCM, paraffin wax, at higher power levels. The various geometries of heat sink with different base plate materials, uniform fin width heat sinks with PCM and double base plate heat sink [13, 14]. The outcome of the base plate on the heat transfer efficiency of heat sinks also investigated. The experimental outcome are higher compared to the CFD findings. Rajesh and Balaji [15] tested unfinned and finned heat sinks with a consistent heat load, and the results reveal that utilising PCM heat sink fins can greatly improve the portable electronic device's operational efficiency. A heat sink with a hollow base was built and an experimental investigation was conducted to improve heat transfer. The influence of PCM material and varied base plate cavities on the performance of plate fin heat sinks explored in this work.

Experimental set-up and procedure

The standard tentative system used is shown in fig. 1 in this research review. The entire platform consists of four fundamental elements: DC power supply, PCM filled heat sink assembly, and data logger and laptop. To replicate a processor, an experimental set-up is set up with a 25 × 25 mm electric heater as a heat source. With the use of an anabolic substance, an electric fire is connected to the heat sink's bottom surface. The wake field thermal compound is used to ensure that the heat sink and the heater have appropriate plane contact. The necessary drilling was performed in the insulation to allow thermocouple wires and power wire cables to minimize interference. The heat sink rejects the heat that is amplified by the location of the blower in the air. The change in temperature is reliably measured using the

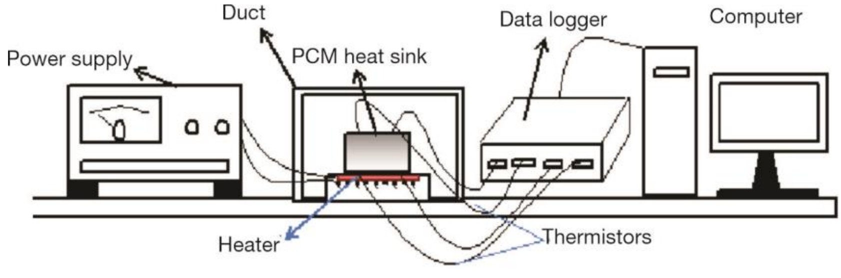

Figure 1. A illustration of the experimental set-up

data acquisition unit. The temperature values are reported in the form of a spreadsheet on the machine via a LAN cable. The temperature changes are reported using ten *K*-type thermocouples. These thermocouples regulated with a maximum error of ±0.1 °C referred from prior study. This experiment calculates the heat sink base temperatures that are employed to compare heat sink efficiency. Four A_1 to A_4 thermocouples are situated at a distance of 25 mm on all sides of the heat sink. To test outside wall temperatures on all sides, further four thermocouples are located. The mean value of these two values is used to interpret the outcomes. In this research, different cavity bases with PCM heat sinks were used, as illustrated in fig. 2.

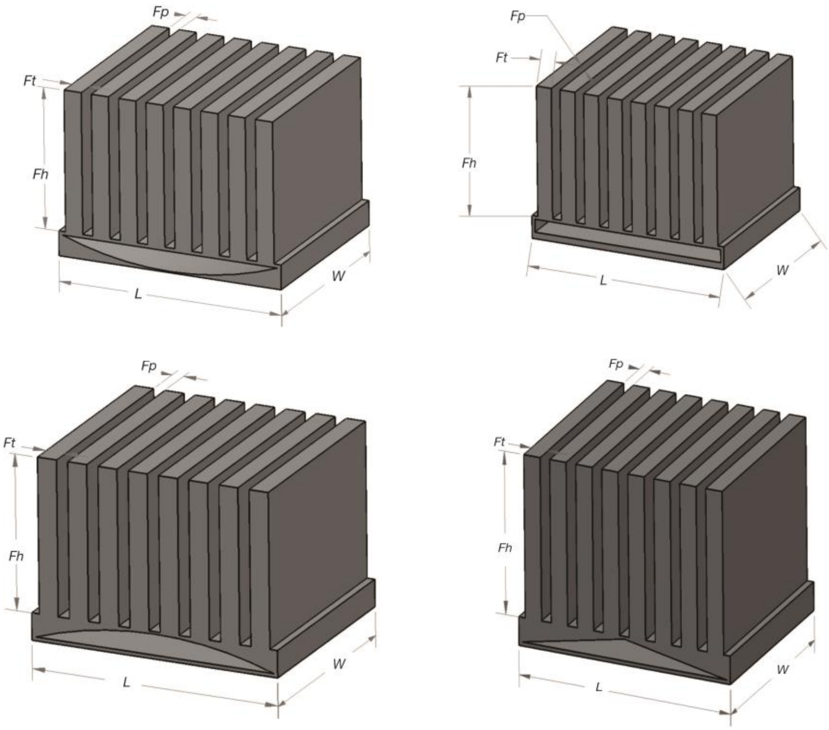

Figure 2. Cavity base plate fin heat sink

Results and discussion

Figure 3 depicts the impact of various cavity designs on the heat sink's thermal resistance, both with and without PCM. As seen in figure, the thermal resistance of the heat sink reduces as the Reynolds number increases. The drop in thermal resistance is continuously reducing as Reynolds number rises from 15000 to 25000. The thermal efficiency of the cavity with PCM dependent heat sinks is clearly increased when compared to the thermal efficiency of the cavity without PCM heat sinks. The thermal performance of the concave cavity heat sink with PCM is better than that of other PCM cavity heat sinks, but it is lower than that of other PCM cavity heat sinks. Beyond Re = 15000, the heat sink's thermal performance is observed to be reduced in all cases. Figure 3 shows that the thermal performance of a convex cavity base heat sink with PCM is superior than that of other situations. In contrast to other situations, the concave cavity base heat sink with PCM output is decreased since there is no

PCM contact with the peak of the heat sink base. The PCM is filled at the concave core to prevent heat transfer from being boosted. The thermal performance of convex cavity heat sinks is improved as a result from 5.6% to 9.7% when compared to other heat sinks.

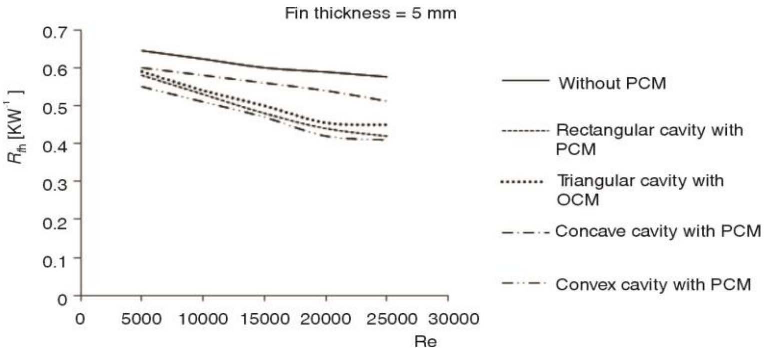

Figure 3. Thermal resistance of cavity base plate fin heat sink (fin thickness = 5 mm)

Figure 4 depicts the impact of various cavity designs with and without PCM on the thermal resistance of a heat sink with a fin thickness of 4 mm. The thermal performance of cavity base with PCM heat sinks is improved when compared to heat sinks without PCM base, as seen in this diagram. Beyond Re = 8000 is to be seen for decreasing fin thickness or

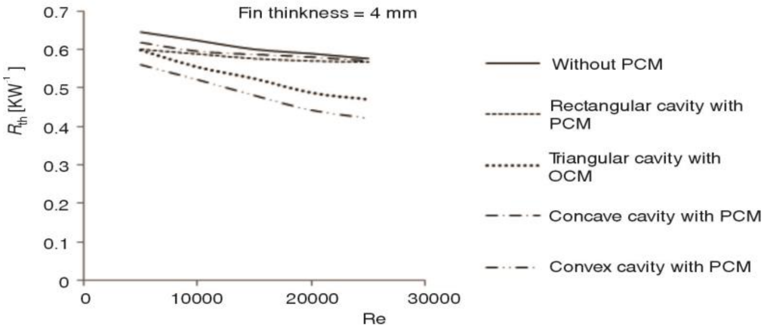

Figure 4. Thermal resistance of cavity base plate fin heat sink (fin thickness = 4 mm)

increasing the number of fins in concave cavity and triangular cavity base with PCM heat sink performance is closer to heat sink without PCM base. At Re = 4000 the thermal performance of rectangular cavity base with PCM is identical with and triangular cavity base with PCM heat sink is shown in figure and its performance is increased upto 8.6% for Reynolds number range of 8000 to 20000. The thermal performance of convex cavity base with PCM heat sink is better than other cases. Figure 5 depicts the impact of various cavity designs, both with and without PCM, on the thermal resistance of a heat sink with a fin thickness of 3 mm. The thermal resistance of a concave cavity with a PCM base heat sink is not reduced when compared to a plate fin heat sink without a PCM base heat sink, as shown in fig. 5. The thermal performance of rectangular cavity with PCM heat sink is identical with concave cavity with PCM base heat sink. At Re = 4000 the thermal resistance of triangular cavity with PCM base heat sink is closer with rectangular cavity with PCM heat sink and also it is observed that beyond Re = 12000 the thermal resistance is increased. The decrease in thermal resistance occurs gradually as Reynolds number rises from 15000 to 25000. Convex cavity with PCM heat sink performance is always better than other cases even decreasing the fin thickness.

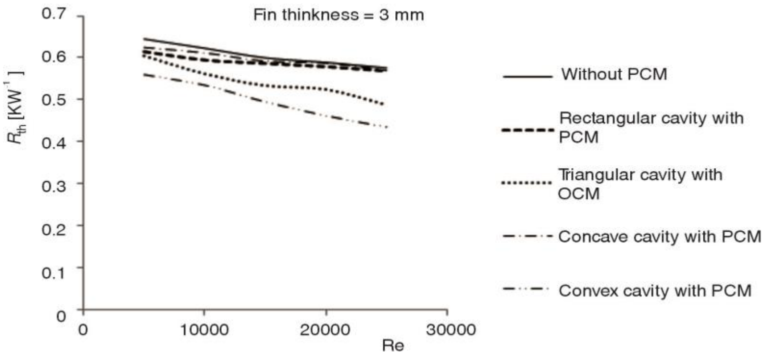

Figure 5. Thermal resistance of cavity base plate fin heat sink (fin thickness = 3 mm)

Conclusion

The electronic devices cooling can be considerably superior by adopting heat sinks that are dependent on PCM. Experimental evaluations of the influence of a hollow base with PCM on the thermal efficiency of heat sinks were discussed. The PCM incorporation lowers the heat sink's heating rate and peak temperatures, while simultaneously lowering the cooling rate. The heat sink of the concave cavity base structure has enhanced thermal efficiency, resulting in a lower heat sink centre temperature. The thermal performance of a concave cavity heat sink with a PCM that is closer to that of a triangular cavity heat sink is investigated.

References

[1] Ali, H. M., Briggs, A., An Investigation of Condensate Retention on Pin-fin Tubes, *Applied Thermal Engineering, 63* (2014), 2, pp. 503-510
[2] Ali, H. M., *et al*., Heat Transfer Enhancement of Car Radiator Using Aqua Based Magnesium Oxide Nanofluids, *Thermal Science, 19* (2015), 6, pp. 2039-2048
[3] Chung, Y. M., Luo, K. H., Unsteady Heat Transfer Analysis of an Impinging Jet, *Journal of Heat Transfer, 124* (2002), 6, pp. 1039-1048
[4] Elshafei, E. A. M., Effect of Flow Bypass on the Performance of a Shrouded Longitudinal Fin Array, *Applied Thermal Engineering, 27* (2007), 13, pp. 2233-2242
[5] Sakthivel, P., *et al*., Experimental Study About Thermal Resistance of Windows with Air Gap Between Two Glasses Used in Single Houses, *Thermal Sciences, 20* (2020), 1B, pp. 515-518
[6] Wang, H., *et al*., Experimental Investigation on The Thermal Performance of a Heat Sink Filled with Porous Metal Fiber Sintered Felt/Paraffin Composite Phase Change Material, *Journal of Applied Energy*, *176* (2016), Aug., pp. 221-232
[7] Wu, W., *et al*., Preparation and Thermal Conductivity Enhancement of Composite Phase Change Materials for Electronic Thermal Management, *Energy Conversion and Management*, *101* (2015), Sept., pp. 278-284
[8] Ali, H. M., Arshad, A., Experimental investigation of n-eicosane based circular pin-fin heat sinks for passive cooling of electronic devices, *International journal of Heat Mass Transfer*, 112 (2017), pp. 649-661
[9] Arshad, A., *et al*., An Experimental Study of Enhanced Heat Sinks for Thermal Management Using N-Eicosane as Phase Change Material, *Applied Thermal Engineering*, *132* (2018), Sept., pp. 52-66
[10] Ali, H. M., *et al*., Thermal Management of Electronics Devices with PCMs Filled Pin-Fin Heat Sinks, *International Journal of Heat Mass Transfer*, *117* (2018), Feb., pp. 1199-1204

[11] Hosseinizadeh, S. F., *et al*., Experimental and Numerical Studies on Performance of PCM-Based Heat Sink with Different Configurations of Internal Fins, *Applied Thermal Engineering*, *28* (2011), 17-18, pp. 3827-3838
[12] Kandasamy, R., *et al*., Transient Cooling of Electronics Using Phase Change Material (PCM)-Based Heat Sinks, *Applied Thermal Engineering*, *28* (2008), 8-9, pp 1047-1057
[13] Dhandayuthabani, M., *et al*., Investigation of Latent Heat Storage System Using Graphite Micro-Particle Enhancement, *Journal of Thermal Analysis and Calorimetry*, *139* (2020), 3, pp. 2181-2186
[14] Sudhagar, S, *et al*., Performance Analysis of Fin Tube Evaporator Using Various Refrigerants, *Thermal Sciences*, *20* (2020), 1B, pp. 609-612
[15] Rajesh, B., Balaji, C., Experimental Investigations on Phase Change Material Based Finned Heat Sinks for Electronic Equipment Cooling, *International Journal of Heat and Mass Transfer, 55* (2012), 5-6, pp. 1642-1649

Paper submitted: October 5, 2020
Paper revised: June 21, 2021
Paper accepted: July 16, 2021