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# Numerical Investigation of Different Configurations of Pin Fin Heat Sinks with and without PCM †

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**Abstract:** The miniaturization of electronic components leads to poor heat dissipation, performance, and reliability of the devices. To optimize heat transfer from electrical components, pin fins are the best choice due to their high thermal conductivity. Different configurations of square and triangular pin fins for heat transfer characteristics were numerically investigated in this study. Three-dimensional numerical simulations were carried out for two different configurations with heat fluxes of 0.82 kW/m$^2$ subjected to the base of the heat sink. The heat transfer coefficients among the numerical simulation study and experimentation results provided a good correlation. To evaluate the overall performance, it was indicated from both numerical and experimental results that the maximum square pin fin configuration reduced the base temperature by up to 17.7% and 19%, respectively. In comparison to other configurations, the square pin fin performed better because of its increased surface area.

**Keywords:** numerical simulation; electronic devices; pin fin heat sink; heat transfer coefficient



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## 1. Introduction

Recent advancements in electronics have led to an exponential rise in the temperature and heat transfer rates, which are affected due to their smaller sizes [1]. The main purpose of heat sinks is to cool electrical equipment. Pin- and plate-finned heat sinks are the two key forms that increase thermal performance. [2]. There are wide range of heat sink design geometries, although the most common pin fin designs are square, triangular, circular, and elliptic shapes. The performance of heat sink is significantly impacted by increasing the number and thickness of fins [3]. Phase change materials alter their phases by absorbing a huge amount of heat during melting, and releasing it during solidification [4]. Numerous studies have been already performed on PCM conductivity, and to overcome this problem, researchers tend to add fin geometries, composites metal, and ultrafine particles in addition to PCM [5].

This study focuses on the numerical model investigation of various arrangements of (square and triangular) pin fin heat sinks with and without PCM. Numerical simulations using COMSOL Multiphysics 5.5 with various parameters were studied on finned heat sinks. Variables such as heat transfer rate, base temperature reduction, and the maximum temperature of all configurations were analyzed.

## 2. Numerical Methodology and Materials

In this study, a fin model for thermal performance characteristics is presented. The model was generated in AutoCAD software and imported into COMSOL Multiphysics 5.5. Aluminum grade 2024 was selected for both configurations. Two arrangements of pin fin configurations (square and triangular) were studied in this research (Figure 1). The base plate of the pin fin configurations had a surface area of 114 × 114 mm$^2$, and the thickness of the base plate was 4 mm. There were 72 fins in total, which were extruded up to 25 mm above the base plate (Table 1).

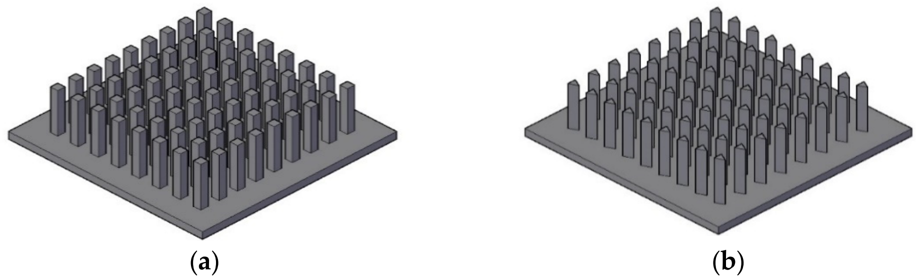


**Figure 1.** Pin fin heat sinks: (**a**) square; (**b**) triangular.

**Table 1.** Heat sink geometric properties.

| Parameters | Dimensions (mm) |
|---|---|
| Fin Height | 25 |
| Fin Dimensions | 4 × 4 |
| Number of Fins | 72 |
| Heat Sink Length | 114 |
| Heat Sink Width | 114 |

## 3. Experimental Setup

A comparison between heating and cooling of heat sink was conducted by employing different arrangements of pin fin heat sinks, i.e., square and triangular, with and without PCM. A power level of 10 W was used for this experiment and the heat sink discharged in the same way it charged, with the sidewalls and base insulated to enable heat flow in only one direction—from top to bottom—for thermal analysis. The experimental setup and exploded view of the heat sink assembly for this study are shown in Figures 2 and 3. Subsequently, the temperature contours of heat sink at different intervals of time are presented in Figure 4.

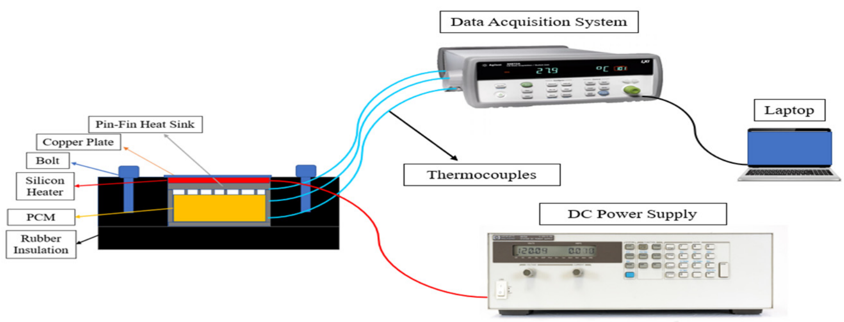


**Figure 2.** Experimental setup.

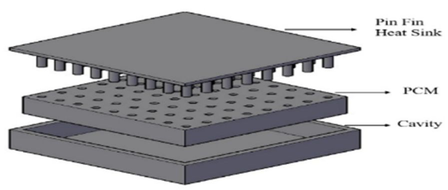


**Figure 3.** Exploded view of the assembly.

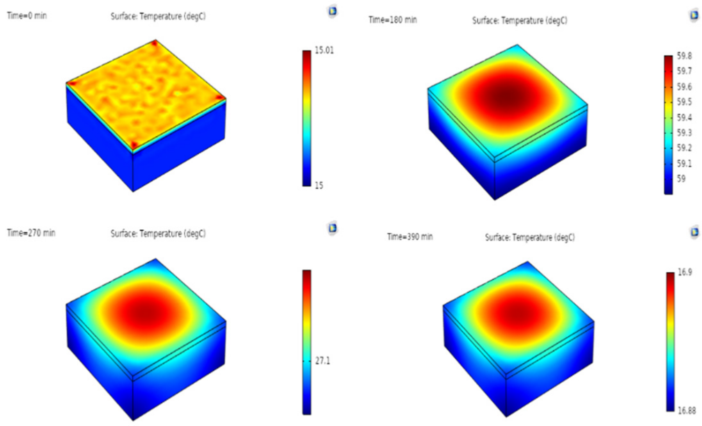


**Figure 4.** Temperature contours of a heat sink assembly at different intervals.

## 4. Results and Discussion

This study consisted of two phases: fins without PCM, and fins with PCM. The first set of simulations, performed for fins without PCM, and the second set of simulations, performed for fins with PCM, for both configurations, are shown in Figure 5.

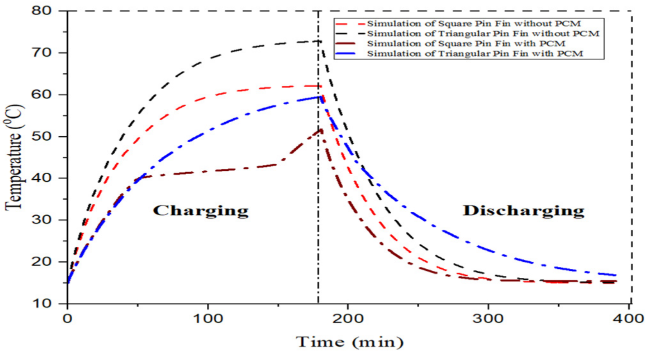


**Figure 5.** Simulation of square and triangular pin fins with and without PCM.

The reductions in base temperature are clearly seen by the in addition of PCM. Both configurations yielded the best results and maximum reduction in the base temperature of 17.7% with the square configuration, whereas the triangular configuration reduced the base temperature by up to 17.1%.

An experimental comparison of both configurations, with and without PCM, is shown in Figure 6. The maximum temperature reductions by square and triangular pin fins are 19% and 16%, respectively.

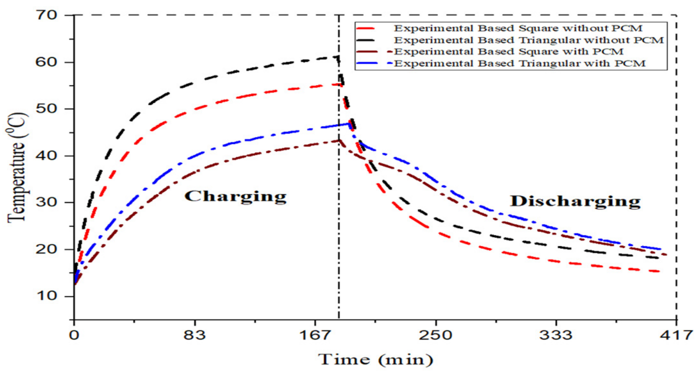


**Figure 6.** Experimental results of square and triangular pin fins.

*Validation*

Simulation results were compared with experimental data to validate the model shown in Figure 7. The observed error range was 2% for the pin fin with PCM and 3% for the pin fin without PCM, which was calculated using the formula: [Percentage error = Numerical Value—Experimental Value/Numerical Value], which was negligible. Overall, the numerical results showed the best results with the experimental data, indicating that the model was logical.

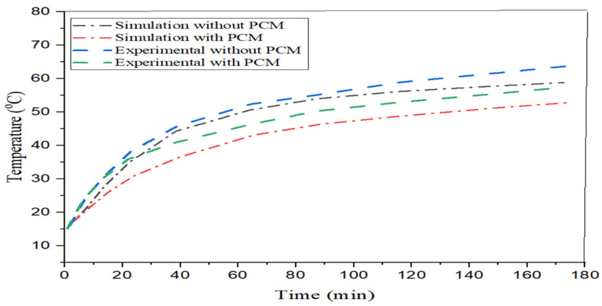


**Figure 7.** Validation of simulation results with experimental data.

## 5. Conclusions

This study focused on the reduction in base temperature in electronic applications. Numerical analyses of square and triangular pin fins provided the same results as the experimental data. The results concluded that adding PCM into the square configuration reduced the temperature by up to 17.7% as compared with a pin fin without PCM. The maximum peak temperature of the square pin fin without PCM was 62.1 °C, whereas the maximum peak temperature with PCM in the same configuration was 51.2 °C. The experimental results of the square configuration showed a maximum base temperature reduction of up to 19%. The present numerical simulation results of COMSOL Multiphysics were validated with an experimental model with the same pattern. Overall, the square configuration demonstrated better results for temperature reduction, due to the difference in surface area.

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