# The effects of thermal cycling tests on the charging and discharging of a PCM based heat sink

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**ABSTRACT**

Electronic appliances produce a great deal of heat during operation. It is essential to control the temperature of these devices in order for them to function reliably and safely. During the phase change process, phase change materials absorb heat to maintain a relatively constant temperature. In this subject of experimental studies, it is studied how thermal cycle tests affect energy storage system charging and discharging behavior. The performance of heat sinks and phase change materials (PCM) with and without pin fins was compared. For this experiment, RT-42 was used as a phase change material, while Aluminum 2024-T851 was used for the pin fin and heat sink. Various parameters like temperature, fins, and power were considered. Twenty thermal cycle tests were conducted on PCM-based heat sinks with or without fins and it was found that fins improved thermal performance. An analysis of twenty thermal cycle tests performed on PCM-based without pin fin heat sinks at 10 W revealed a maximum temperature difference of 1.08 °C. Thermal cycle tests conducted on PCM, and triangular pin fin-based heat sink found that the maximum temperature difference between tests was 0.57 °C at 10 W. This indicates that the effect of thermal cycling tests on charging and discharging is relatively minor with PCM based storage devices without fins and is almost non-existent with PCM based energy storage system with fins.

**Keywords**: Thermal cycle tests, charging and discharging, thermal management, phase change material

## 1. INTRODUCTION:

With the advancement of the electronic industry, excessive temperature generation reduces the overall performance and reliability of electrical appliances, PV panels, and batteries [1], [2]. Thermal optimization using phase change materials-based systems has been refined to prevent premature equipment malfunction and maintain equipment reliability [3], [4]. PCMs with high latent heat storage capability, excellent thermal stability, and adequate melting/freezing temperatures have sparked an interest in thermal control applications such as thermal management electronic devices [5], [6], thermoelectric generators [7], [8], photovoltaic panels [9], [10], [11], and buildings air conditioning [12], [13]. As PCM's low thermal conductivity makes it challenging to utilize, especially at higher temperatures, researchers are aiming to improve its thermal conductivity, thermal stability, and thermal energy storage capability by integrating thermal conductivity enhancers such as plate and pin fins [14], [15], porous metal foams [16], and nanoparticles [1], [17].

Sharma et al. [18] evaluating urea was conducted. thermal cycle tests showed a change in latent heat of fusion and melting point of -21% and -23.6 °c, respectively. It was observed that urea did not melt after 50 cycles. and -21%, respectively.

## 2. EXPERIMENTAL SETUP

An experimental setup is illustrated in Figure 1 with labels for all components used in the experiment. The volume fraction of PCMs is defined as the "ratio of PCM's volume to the overall sink volume" and is presented by "$\psi PCM$". Which can be find as:

$$\psi_{PCM} = [\frac{Vpcm}{Vs - Vf}¿ \qquad (1)$$

Using the formula above, the volume fraction of the PCM can be determined, with the volume fraction of PCM being 0.9.

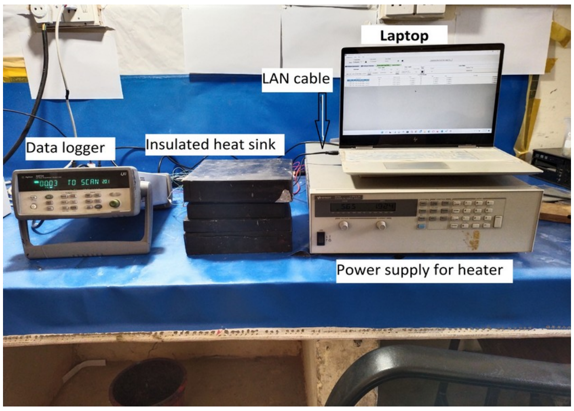


**Figure 1: Actual view of experimental setup**

### 1.1 Thermocouple Position

Thermocouples are placed at various heights throughout the cavity. The experiment's heating process is uniform, which implies that the temperature within the cavity must be the same at any given height. Maintain the thermocouple in-line configuration, it indicates that although the thermocouples are all in a line, they are all at different heights. Because of this, we maintain the identical X and Z axes for all thermocouples. And Schematic of the thermocouple position is shown in Fig. 2 which mentioned that the thermocouple 1 is fixed under the heater for the reading of its temperature and is considered as an origin, the thermocouple 2 is fixed under the Aluminum plate of 4 mm so the location of $T_2$ according to the axis is (0, 4, 0). The third thermocouple was fixed in the middle (15 mm) of the cavity so the location of $T_3$ was (0, 15, 0). The fourth and the last thermocouple was fixed in the base (30 mm) of the cavity so the location of $T_4$ was (0, 30, 0).

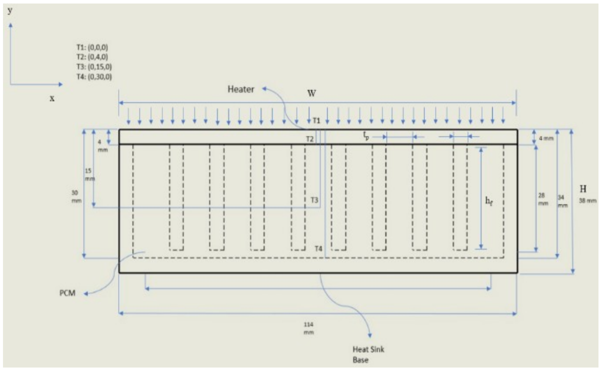


**Figure 2: Thermocouple Positioning in Heat Sink at Different Hights**

## 3. RESULTS AND DISCUSSION

### 3.1 Heat sink experimental validation

Experimental findings from a PCM heat sink with no fins and a PCM heat sink with pin fins are used to validate the existing model. Figure 2 illustrates the comparison of experimental instances' average heat sink temperatures. The outcomes of the studies demonstrated good agreement and demonstrated that the current experimental paradigm can be applied to more investigations.

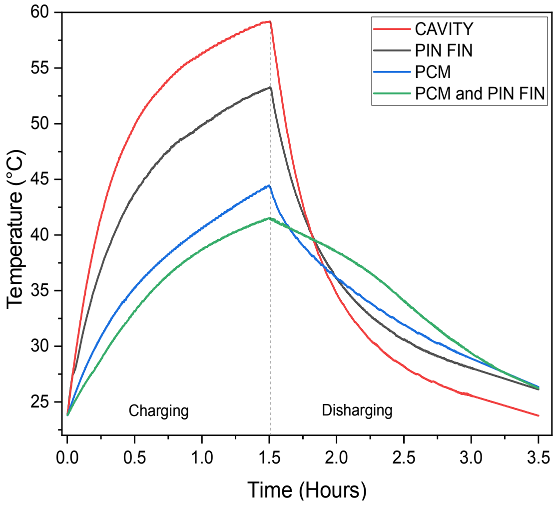


**Figure 3: Experimental Validation for heat sink**

### 3.2 Effect of Thermal Cyclic Tests on the PCM based energy storage system

For various thermal cycle tests, Figure 4 shows the temperature profiles for a PCM-based heat sink. For 20 thermal cycle testing, it can be seen that very little temperature change for the thermal cycle tests was indicated in the graphs. To analyse the findings and to make comparisons, four thermal cycles from these are selected as the fifth, tenth, fifteenth, and twentieth.

#### *3.2.1 Effect of Thermal Cycling Tests*

Figure 5 depicts the maximum temperature for Thermal Cycle Test 20 of 44.821 °C and the minimum temperature for Thermal Cycle Test 1 of 43.73 °C, which is a difference of 1.08 °C after 1.5 hours of charging. And after 3 hours 45 minutes of discharge, the temperature of all thermocouples returns to room temperature.

From the foregoing description, it may be inferred that the heat sink's PCM-based thermal cycling tests had only a minimal impact.

Thermal cycle 05, cycle 10, cycle 15, and cycle 20 charging and discharging are depicted in Figure 4. It demonstrates unequivocally that the charging and discharging trends are the same across all cycles.

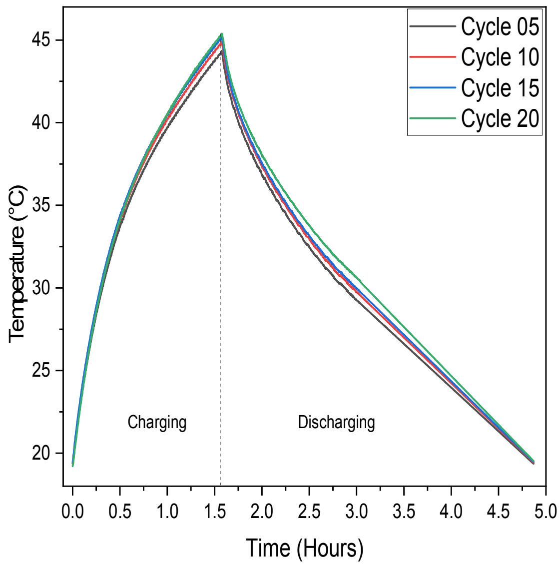


**Figure 4: Thermal cycle trend analysis of PCM based energy storage system**

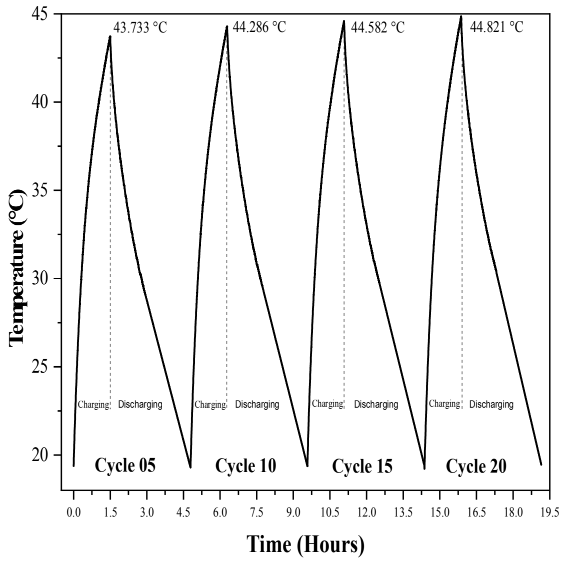


**Figure 5: Effect of Thermal Cycling test on Energy Storage system**

**Table 1:** Effect of Thermal Cycle Tests of PCM based Heat Sink

| **Maximum Temperature of Thermal Cycle Tests** | | | |
|---|---|---|---|
| Cycle 05 | Cycle 10 | Cycle 15 | Cycle 20 |
| 43.733 °C | 44.286 °C | 44.582 °C | 44.821 °C |
| **Effect of Thermal Cycle Tests** | | | |
| $Cycle_{10}$ - $Cycle_5$ | | 0.553 °C | |

| | |
|---|---|
| $Cycle_{15}$ - $Cycle_5$ | 0.849 °C |
| $Cycle_{20}$ - $Cycle_5$ | 1.08 °C |
| $Cycle_{15}$ - $Cycle_{10}$ | 0.296 °C |
| $Cycle_{20}$ - $Cycle_{10}$ | 0.535 °C |
| $Cycle_{20}$ - $Cycle_{15}$ | 0.239 °C |
| *Maximum Temperature Difference = 1.08 °C* | |

### 3.3 Effect of Thermal Cyclic Tests on PCM based triangular pin-fin configuration

Because pin fins are now often used for thermal management, in that experiment, we were analysed the impact of thermal cycling tests on the PCM-based pin fins heat sink. According to H. M. Ali et al. [19] with or without PCM, triangular pin-fins are determined to be the most efficient pin-fin arrangement for heat transfer. In order to research the impact of thermal cycling testing, Twenty thermal cycling tests were carried out on a triangular pin fin heat sink based on PCM. To analyse the findings and to make comparisons, four thermal cycles from these are selected as the fifth, tenth, fifteenth, and twentieth.

#### *3.3.1 Effect of Thermal Cycling Tests*

Figure 7 shows the temperature profiles over time for the charging and discharging for four thermal cycle tests. The data from these tests differ just slightly when comparing the highest temperature, and the thermal cycles themselves also exhibit the same trend. The system's restriction is the charging time of 1.5 hours and the discharging time of 6 hours needed to achieve room temperature for each thermal cycle.

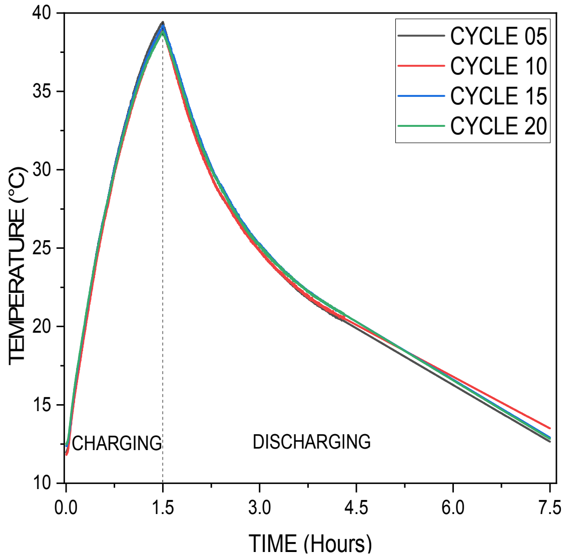


**Figure 6: Thermal cycle trend analysis of PCM based energy storage system**

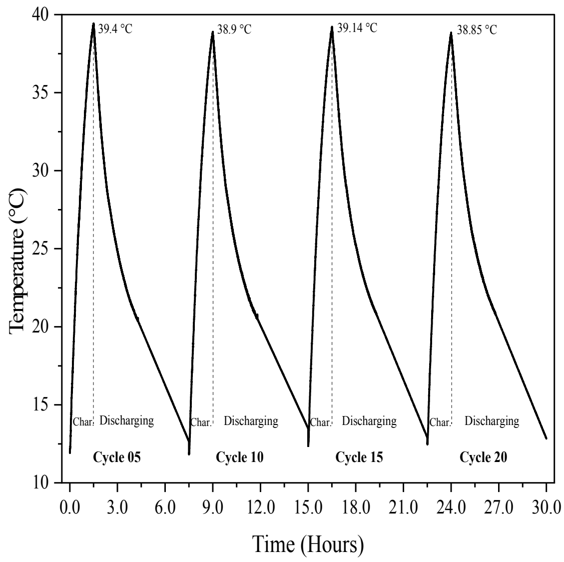


**Figure 7: Effect of Thermal Cycling test on Energy Storage system**

**Table 2:** Effect of Thermal Cycle Tests of PCM and fin based Heat Sink

| **Maximum Temperature of Thermal Cycle Tests** | | | |
|---|---|---|---|
| Cycle 05 | Cycle 10 | Cycle 15 | Cycle 20 |
| 39.4 °C | 38.9 °C | 39.14 °C | 38.85 °C |
| **Effect of Thermal Cycle Tests** | | | |
| $Cycle_5$ - $Cycle_{10}$ | 0.54 °C | | |
| $Cycle_5$ - $Cycle_{15}$ | 0.29 °C | | |
| $Cycle_5$ - $Cycle_{20}$ | 0.58 °C | | |
| $Cycle_{15}$ - $Cycle_{10}$ | 0.25 °C | | |
| $Cycle_{10}$ - $Cycle_{20}$ | 0.04 °C | | |
| $Cycle_{10}$ - $Cycle_{20}$ | 0.29 °C | | |
| *Maximum Temperature Difference = 0.58* | | | |

| $^{\circ}C$ |
|---|

## 4. CONCLUSION

In this work, the impact of thermal cycling tests on PCM-based heat sinks and PCM-based heat sinks with pin-fin arrangements for thermal management of electronic devices is being investigated. The PCM used is Paraffin wax (RT-42) with melting point 38-43 $^{\circ}$C and volume fraction of 0.9. The results are taken for all parameters at 10 W to find the effect of thermal cycling tests. For PCM based heat sink there is charging of 1.5 hours and discharging of 3 hours and 45 minutes time to reach the room temperature. Similarly, for PCM and pin fin-based heat sink there is charging of 1.5 hours and discharging of 6 hours' time to reach the room temperature. It can be deliberated as:

- After investigation of thermal cycles test, we were found that maximum temperature difference was 1.08 $^{\circ}$C. So, its conclude that effect of thermal cycle tests on PCM based energy storage systems was minor.
- After investigation thermal cycles test, it was found that there is maximum temperature difference was 0.5 $^{\circ}$C. So, its conclude that effect of thermal cycle tests on the PCM based triangular pin fins energy storage systems was negligible.

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