EXPERIMENTAL INVESTIGATION OF THE EFFECT OF FIN CONFIGURATION ON THE THERMAL PERFORMANCE OF VARIOUS PCM BASED HEAT SINKS

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The aim of this research is to investigate the effect of heat sink configuration on phase change material performance for cooling portable electronic devices.
Introduction

– Portable mobile electronic devices
  ▪ Continuous increase in their capabilities
  ▪ Continuous reduction in their size
– Increased heat flux densities causing
  ▪ Deterioration in performance and even failure of critical components
  ▪ User discomfort
– Phase Change Materials (PCM) has high latent heat of melting can produce:
  ▪ Controllable temperature stability,
  ▪ Good energy storage density and relatively low weight.
  ▪ This is a completely passive method of cooling, therefore PCM based systems are more compact compared to active methods of cooling.
Heat Sinks Configurations

- **Single Cavity (SC)**
- **Parallel Fins**
  - 3-Cavity
  - 6-Cavity
- **Crossed Fins**
  - 9-Cavity
  - 36-Cavity
- **SC + Honeycomb Insert**
Experimental Setup and Instrumentation

- Thermoprobe
- Data logger
- PCM-filled Heat Sink
- Desktop Computer
- Power Supply
- OMEGALUX 50x50mm Heater
- Insulation material
- PCM temperature thermocouple probes
- Air temperature thermocouple probe
- To data logger
- PCM level
- Heat sink side surface thermocouple
- Heat sink bottom surface thermocouples
- Top view
- Bottom view
# Materials Properties and Dimensions of Heat Sinks and Cavities

<table>
<thead>
<tr>
<th>Heat sinks</th>
<th>Dimensions of heat sink (L x W x H)mm</th>
<th>Number of cavities, N</th>
<th>Dimensions of Cavity (L x W x H)mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Cavity (SC)</td>
<td>50 x 50 x25</td>
<td>1</td>
<td>46 x 46 x23</td>
</tr>
<tr>
<td>SC + honeycomb</td>
<td>50 x 50 x25</td>
<td>Refer Fig. 1b</td>
<td>Refer Fig. 1b</td>
</tr>
<tr>
<td>3-Cavity</td>
<td>50 x 50 x25</td>
<td>3</td>
<td>14 x 46 x 23</td>
</tr>
<tr>
<td>6-Cavity</td>
<td>50 x 50 x25</td>
<td>6</td>
<td>6 x 46 x 23</td>
</tr>
<tr>
<td>9-Cavity</td>
<td>50 x 50 x25</td>
<td>9</td>
<td>14 x 14 x 23</td>
</tr>
<tr>
<td>36-Cavity</td>
<td>50 x 50 x25</td>
<td>36</td>
<td>6 x 6 x 23</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PCM</th>
<th>Phase Change Temperature $T_{Melt}$ (°C)</th>
<th>Density, $\rho$ (kgm$^{-3}$)</th>
<th>Specific Heat $C_p$ (Jkg$^{-1}$K$^{-1}$)</th>
<th>Thermal conductivity, $k$ (Wm$^{-1}$K$^{-1}$)</th>
<th>Melting heat, $\Delta H$ (kJkg$^{-1}$)</th>
<th>Maximum Operating Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCM-HS29P</td>
<td>29</td>
<td>1550 (liquid) 1840 (solid)</td>
<td>2260</td>
<td>0.54 (liquid) 1.09 (solid)</td>
<td>190</td>
<td>80</td>
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<tr>
<td>PCM-HS34P</td>
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<td>1850 (liquid) 1980 (solid)</td>
<td>2344.6</td>
<td>0.47 (liquid) 0.5-0.6 (solid)</td>
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<td>PCM-OM37P</td>
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<td>NA</td>
<td>NA</td>
<td>218</td>
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<td>PCM-OM46P</td>
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<td>860</td>
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<td>PCM-HS58P</td>
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<td>1290</td>
<td>NA</td>
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<td>90</td>
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<tr>
<td>Rubitherm RT-42</td>
<td>42</td>
<td>880 (solid) 760 (liquid)</td>
<td>2100</td>
<td>0.2</td>
<td>174</td>
<td></td>
</tr>
</tbody>
</table>
Single Cavity Heat Sink with and without PCM at heating load of 4W (1.6kW/m²)
Comparison of various heat sink designs with PCM – Heating Mode at 4W

Parallel fins

- Single Cavity
- 3 - Cavity
- 6 - Cavity

Crossed fins

- Single Cavity
- 9 - Cavity
- 36 - Cavity
Comparison of various heat sink designs with PCM – Heating Mode at 4W

![Graph showing temperature over time for different cavity designs](image-url)

- **Single Cavity**
- **3 - Cavity**
- **6 - Cavity**
- **9 - Cavity**
- **36 - Cavity**
Comparison of various heat sink designs with PCM – Cooling Mode

Parallel fins

Crossed fins

Temperature (°C) vs. Time (minutes) graphs for Parallel and Crossed fins designs.
Single Cavity with Honeycomb – Comparison with other heat sink designs with PCM – Heating Mode at 4W
Comparison of various heat sink designs with PCM – Cooling Mode

![Graph showing the temperature over time for different heat sink designs.](image-url)

- Single Cavity
- 9 - Cavity
- 36 - Cavity
- Honeycomb
- 3 - Cavity
- 6 - Cavity

Temperature (°C) vs. Time (minutes)
Heat capacity values of the various heat sinks designs

- 36-Cavity
- 9-Cavity
- SC+Honeycomb
- 6-Cavity
- 3-Cavity
- Single Cavity

Heat sink thermal capacity (J/K)
Heating and cooling responses for the six types of PCM at 3, 4 and 5W respectively.
Conclusions

- Inclusion of PCM can reduce the operating temperature of heat sinks for electronic devices.

- Introducing fins in the PCM heat sink can further reduce the operating temperature but associated with higher manufacturing cost.

- Incorporating a honeycomb insert instead of fining can produce similar performance but with reduced manufacturing cost.

- PCMs with lower melting points produced lower heat sink operating temperatures for longer durations than that of the paraffin wax.
Thank you!