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The Influence of Geometry Variation and Heat Sink Angle on its Thermal Performance

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Introduction

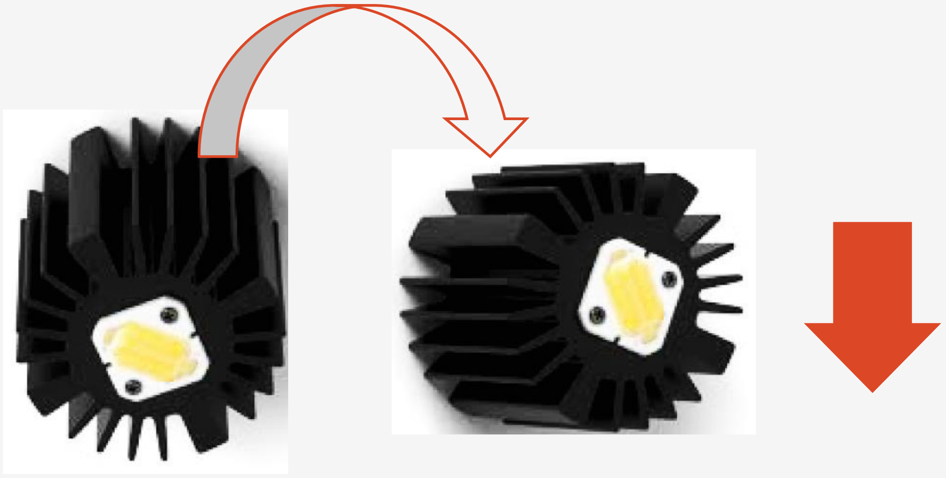
- Heat sinks are an effective heat dissipation mechanism known for increasing the performance and reliability of electronics.
- The geometry can be altered based on its application. Application can include; lighting and electronic systems.
- Heat sinks can be separated into 2 categories, passive and active.

LED Heat Sink

Motivation

Heat sink optimization:

- Fin geometry
- Fin thickness
- Fin length
- Fin gap
- Material



Heat sink orientation

Literature Review

Yu et al. (2014)

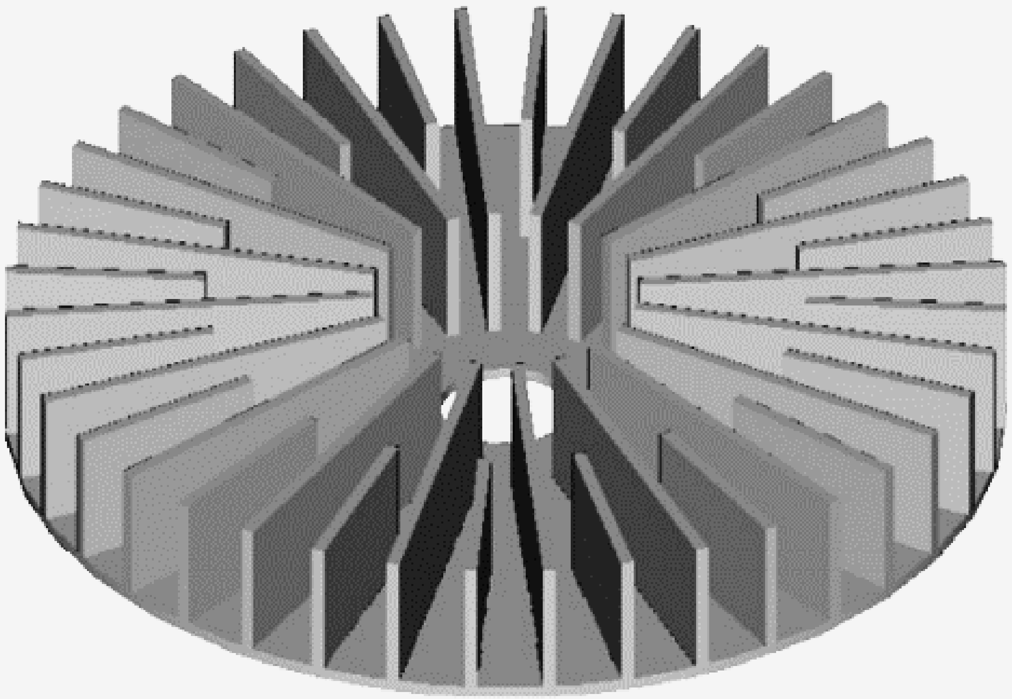
The addition of a shorter middle fin between the large main fins allows the thermal boundary layer to develop more quickly, increasing thermal performance.

Singh and Varshney (2017)

Perforations amplify the heat transfer coefficient, larger diameter perforations have greater effects.

Jang et al. (2014)

The cooling performance of a pin–fin radial heat sink with a **fin-height profile** showed an improvement of more than 45%.



LM Type Heat Sink

JAMES COOK UNIVERSITY AUSTRALIA

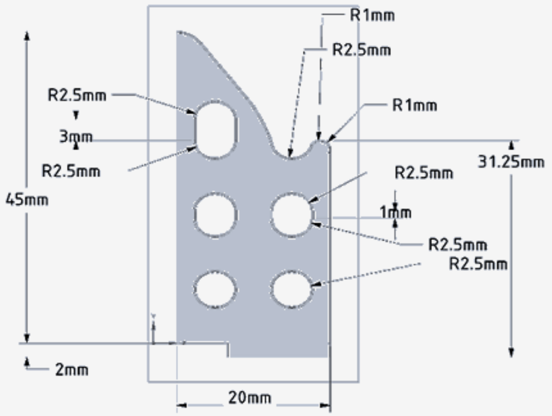
Amiga ENGINEERING EST. 1988

Objectives

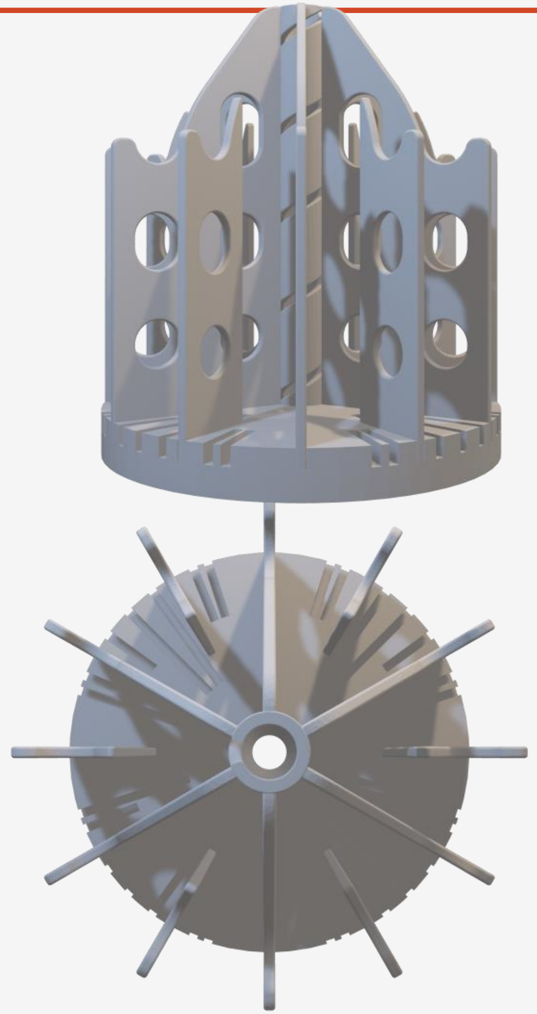
- **Design complex heat sink**
- **3D print heat sink using SLM**
- **Examine Thermal Properties under natural convection**
- **Identify the effects of orientation and number of fins on heat transfer**

Geometry

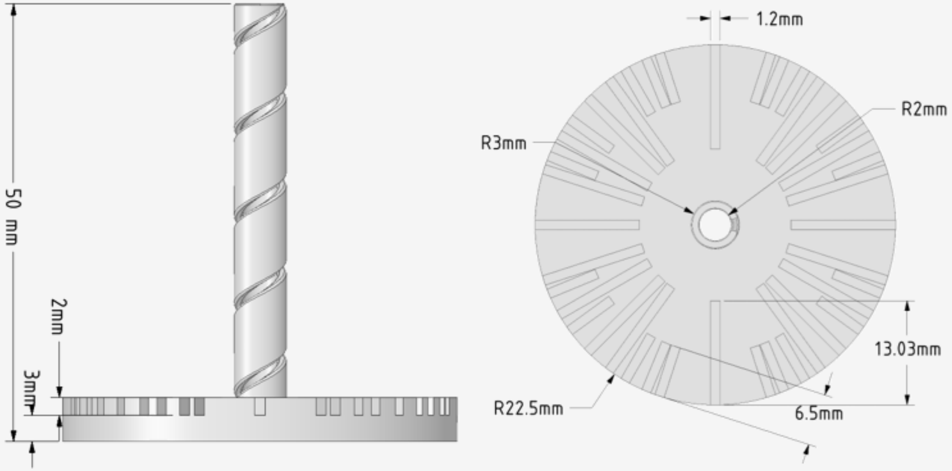
- Consultation with Amiga engineering has led to the final design of the heat sink.
- Design optimized based on the findings from extensive literature review.
- Innovative design, adjustable number of fins to suit the required application.



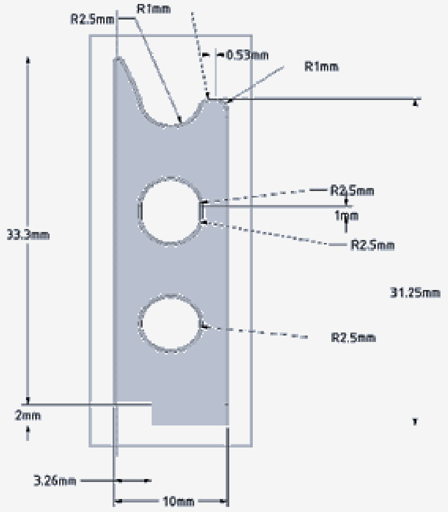
Long Fin



6 LF Heat Sink

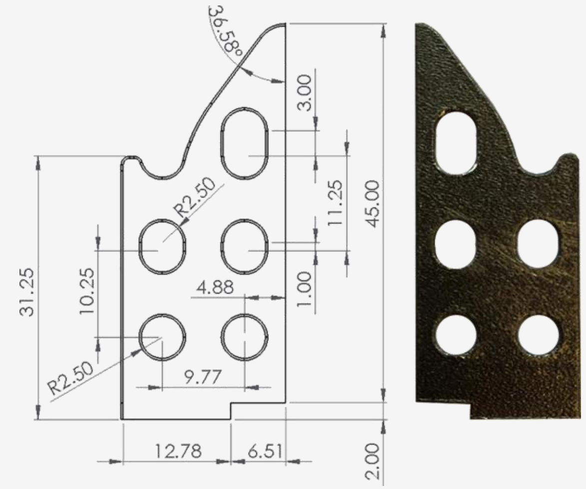


Heat Sink Base

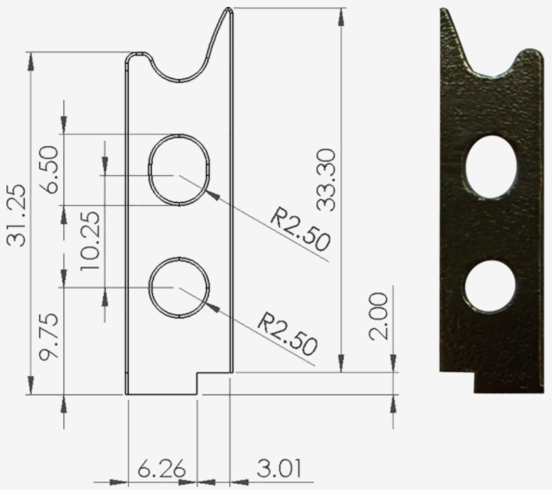


Short Fin

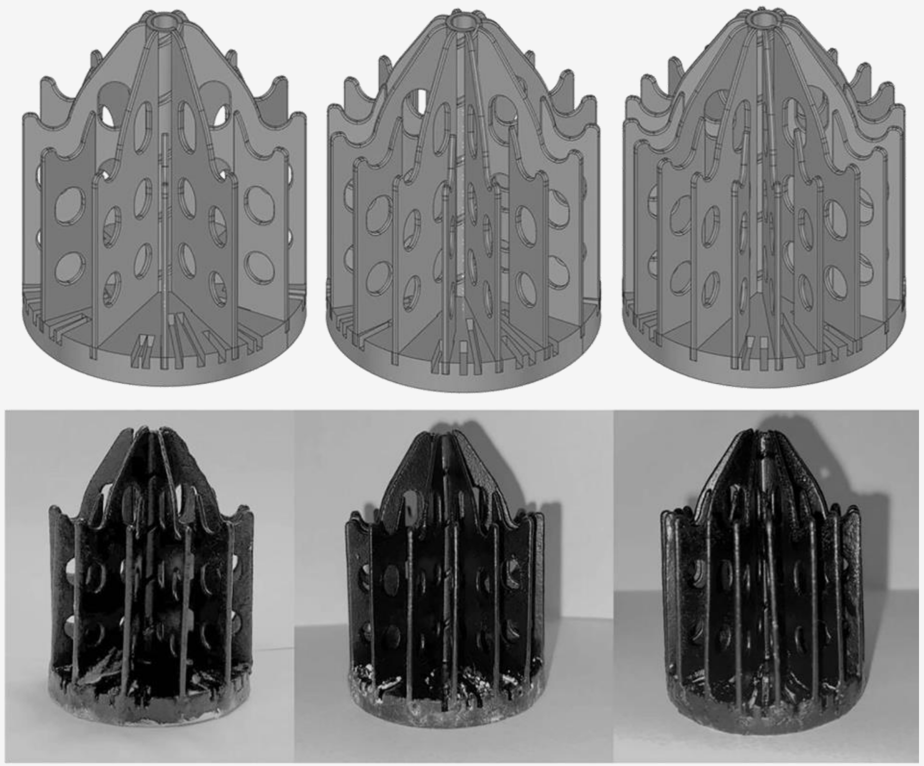
3D Printing



Long Fin



Short Fin



(a) (b) (c)

6LF 8LF 10LF

SLM 280 HL

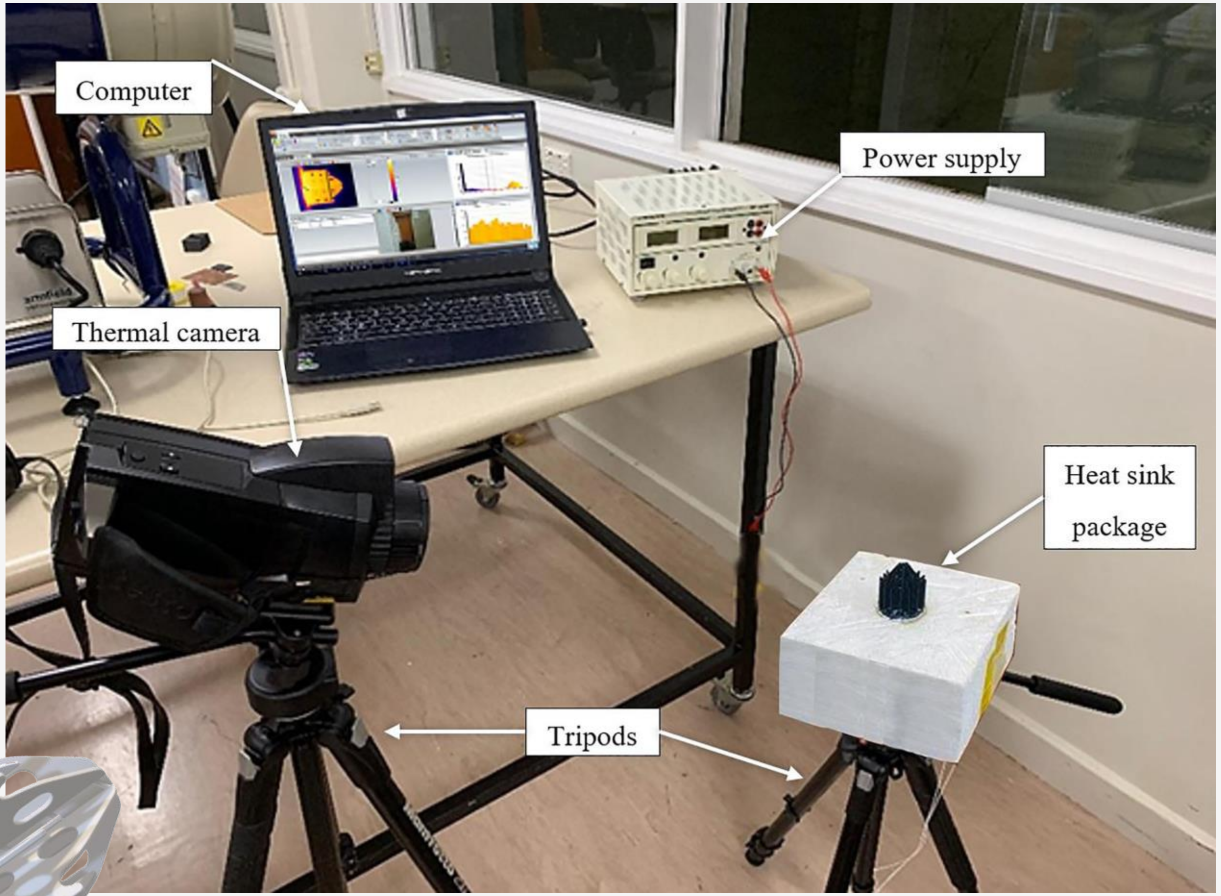
Experimental Setup

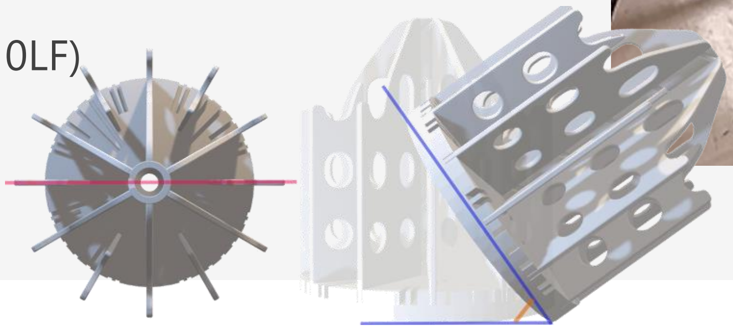
Thermal imaging camera was utilised to observe the thermal profiles of the heat sink.

A tripod, along with a level were used to measure and alter the orientation angle of the heat sink.

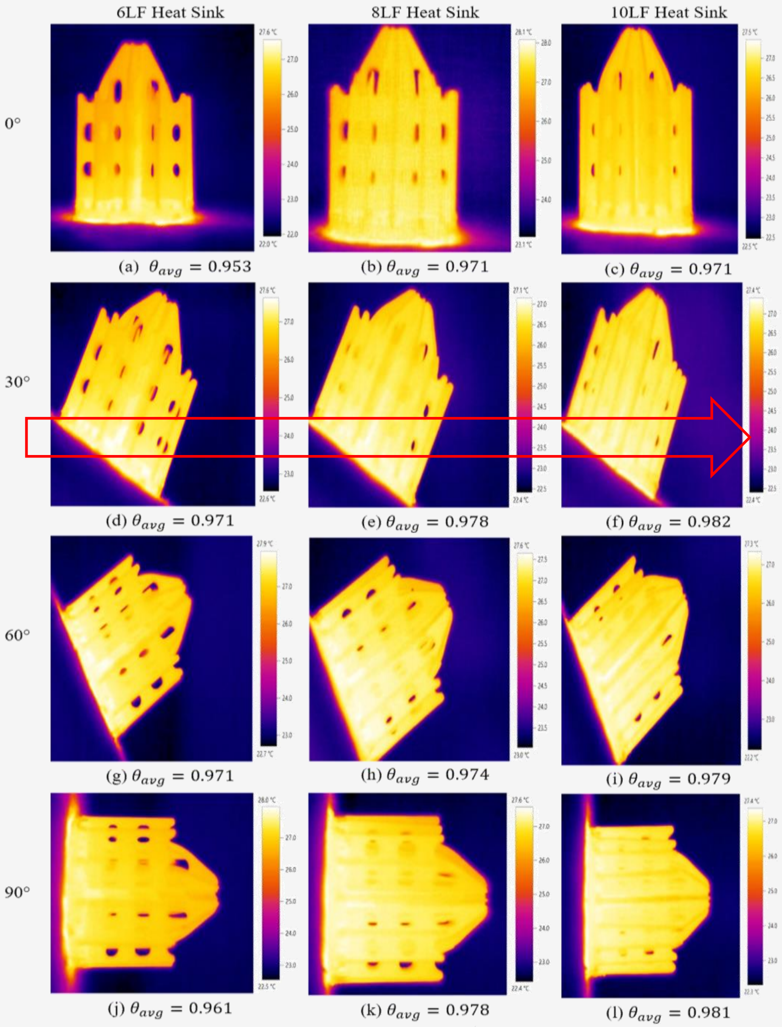
Overall,

- 10 orientations (0-90 degrees)
- 3 different heat fluxes (0.75 W, 1.5 W, 2 W)
- 3 heat sink (6LF, 8LF, 10LF)

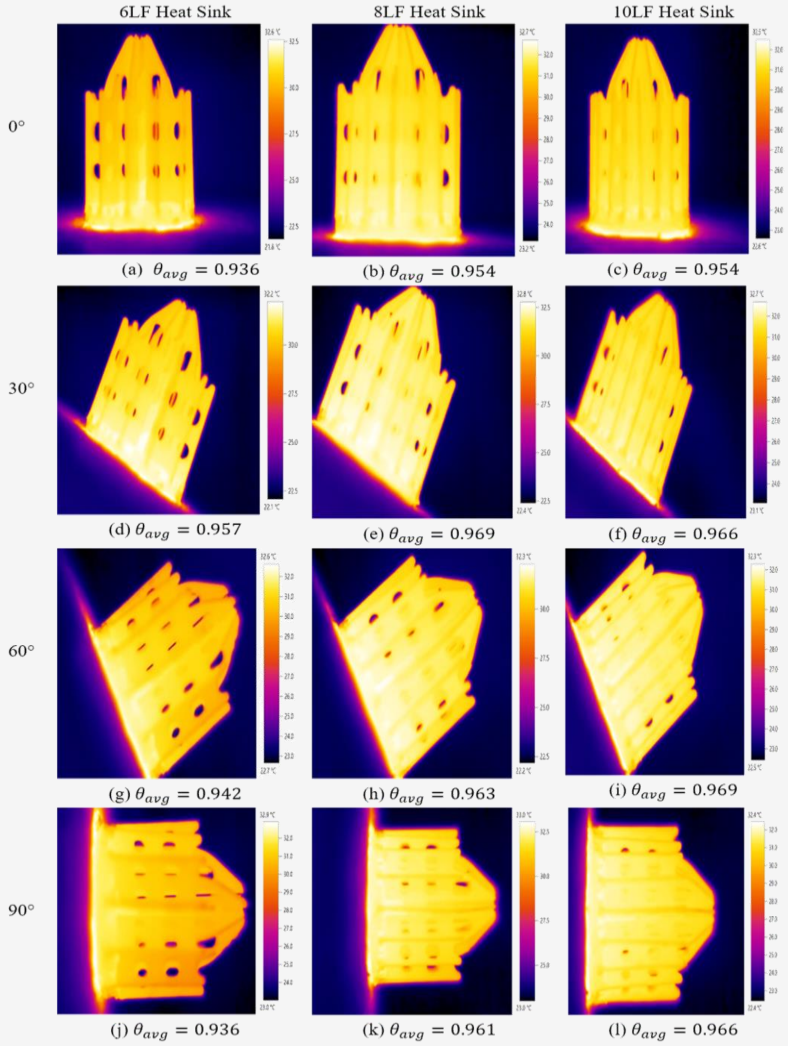




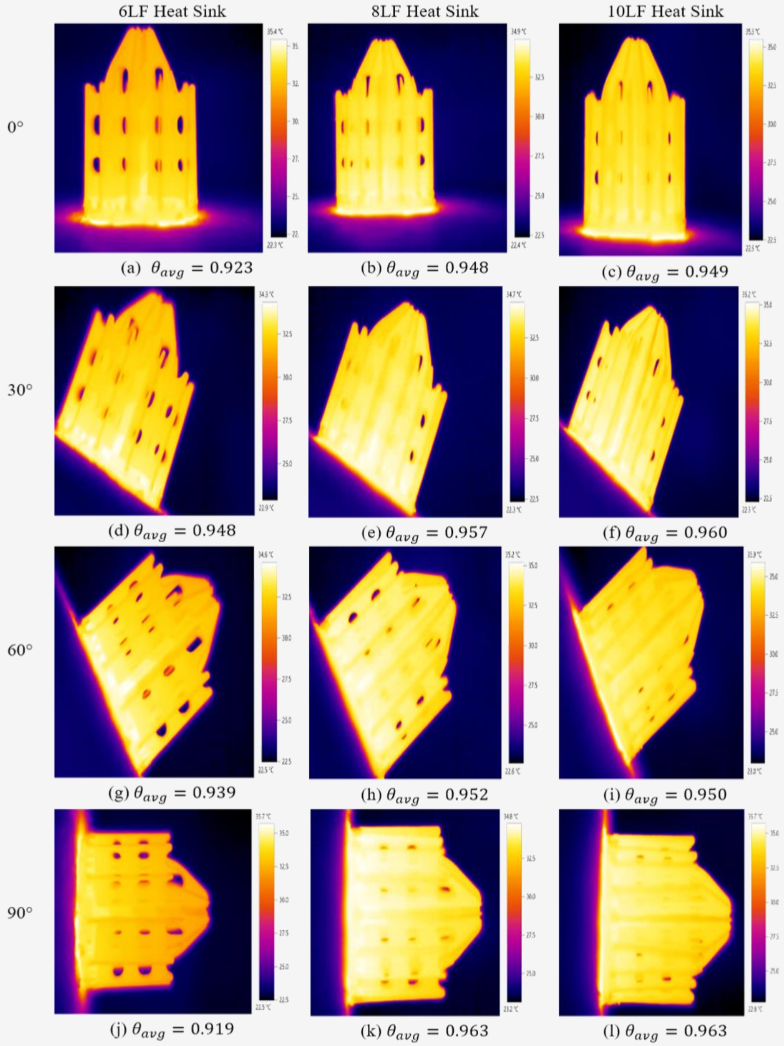
Experimental Results – Average Temperature



0.75 W Input

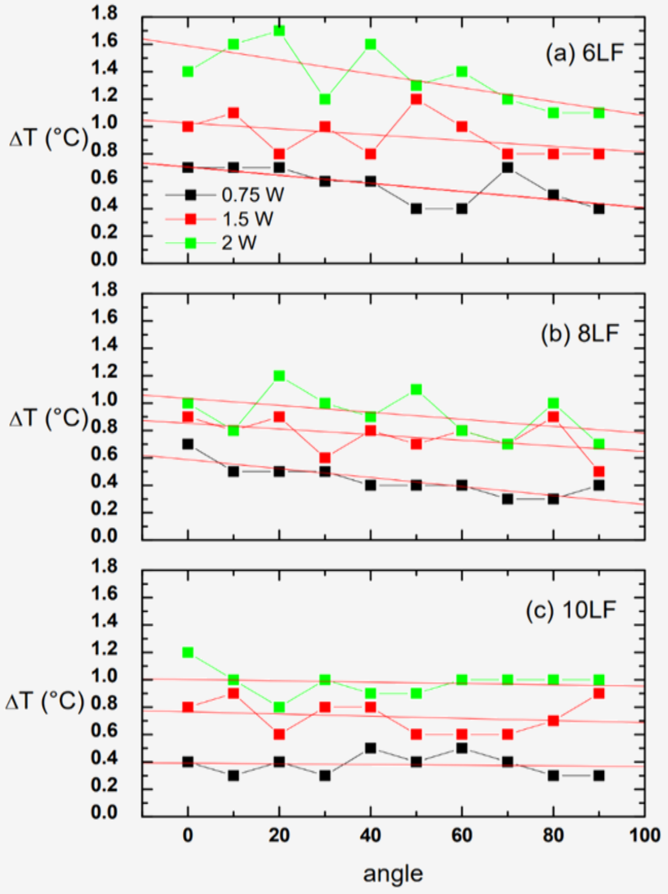


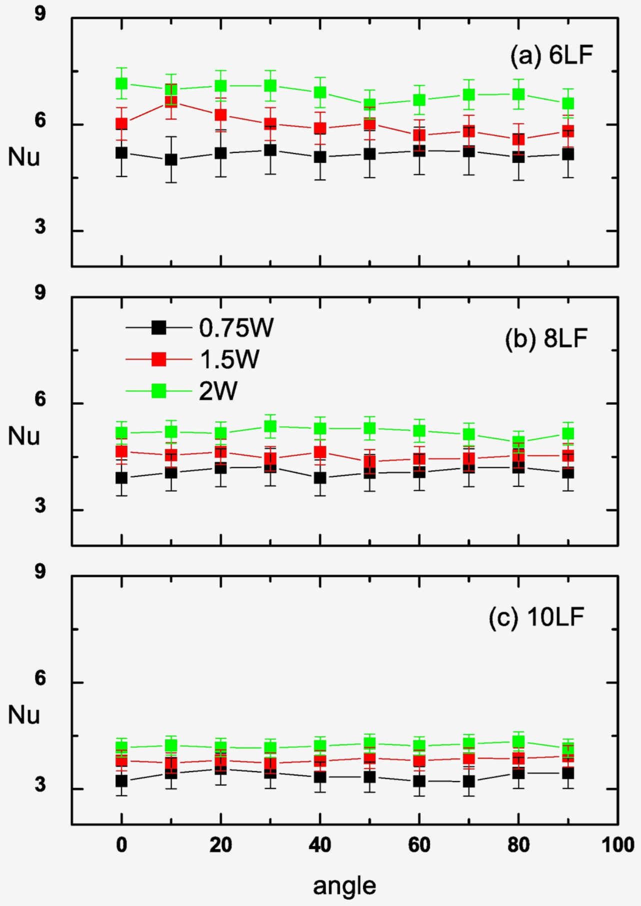
1.5 W Input

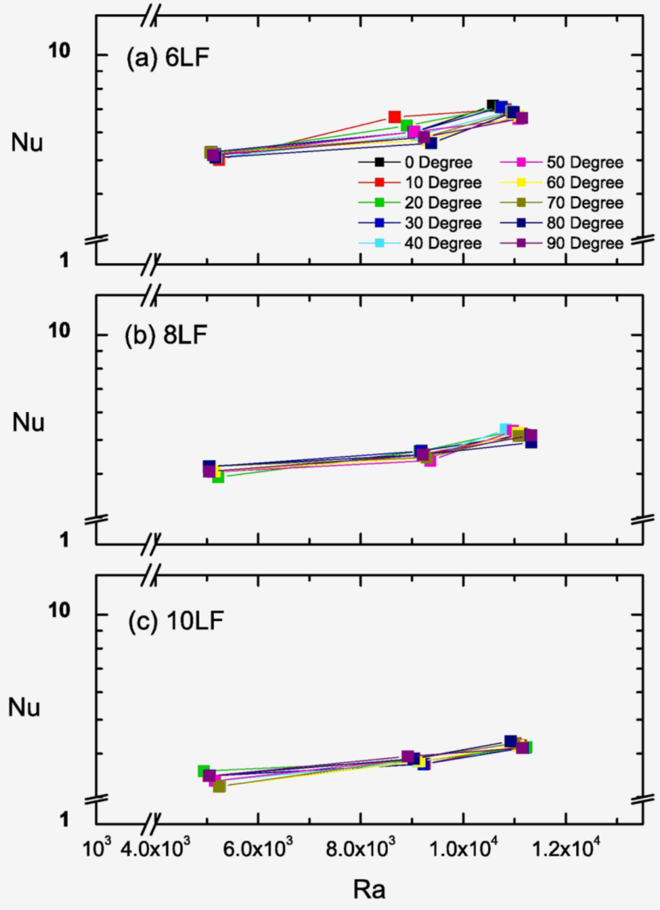


2 W Input

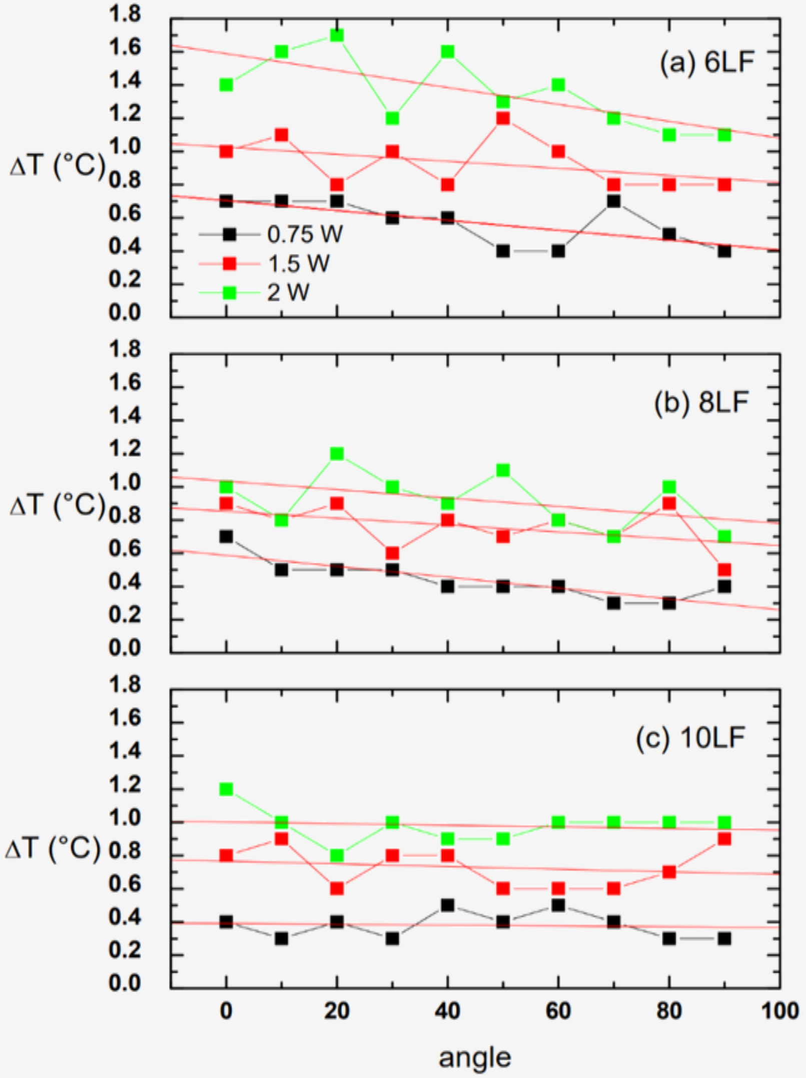
Experimental Results

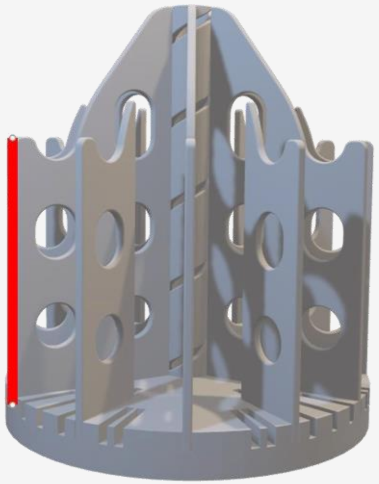






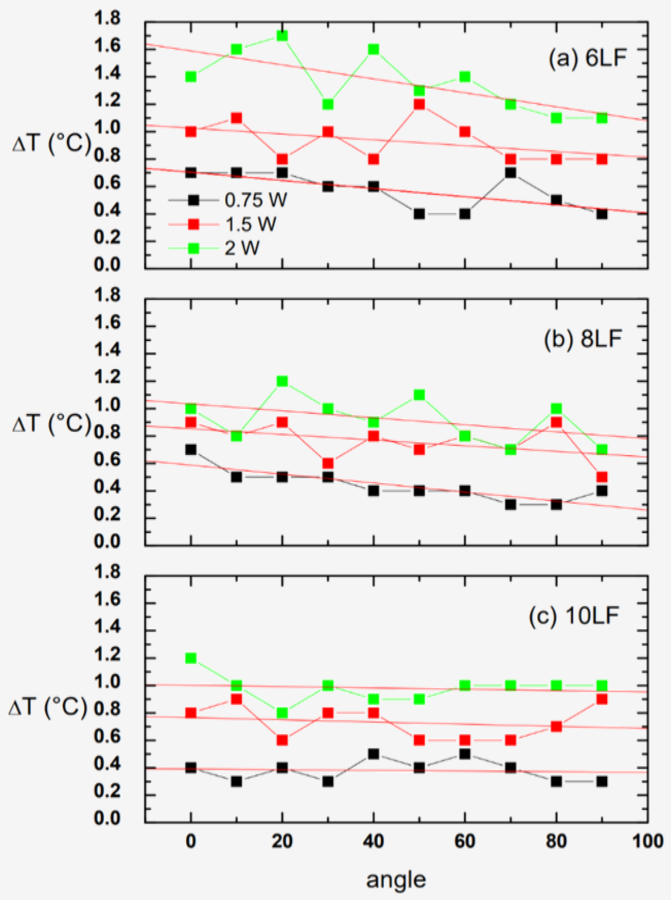
Experimental Results – Change in Temperature

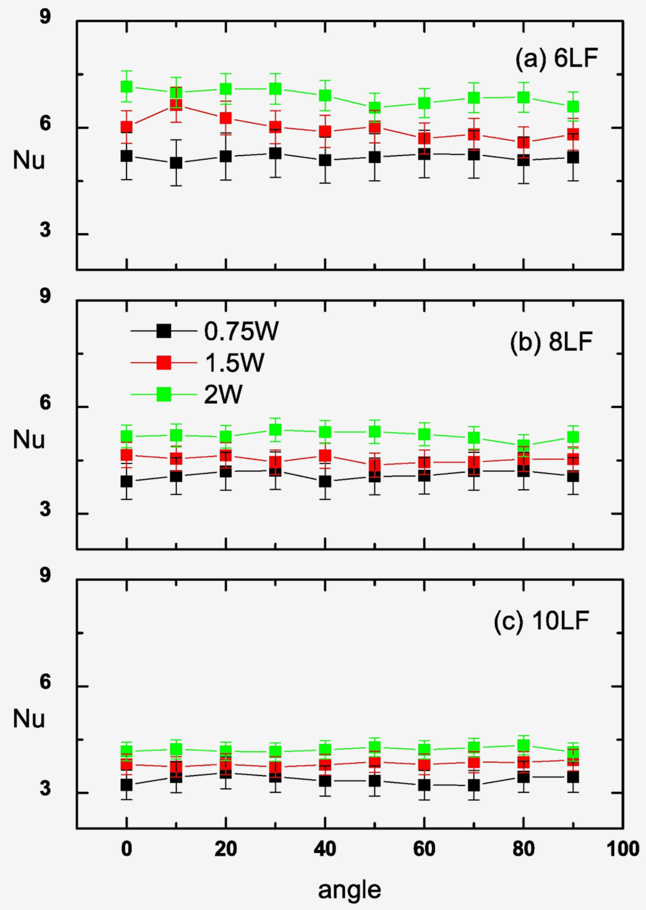


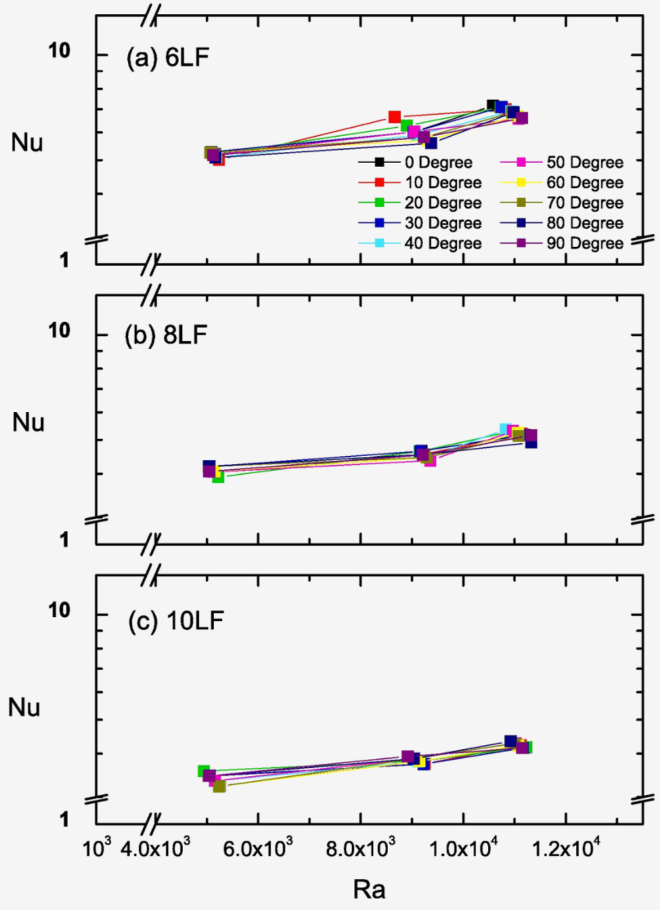


- The effect of orientation was lessened as the fin density of the heat sink increased.
- The effects of orientation can be noticed more clearly for the 2 W heat input cases.
- Change in temperature was generally the lowest for the 10 LF heat sink.

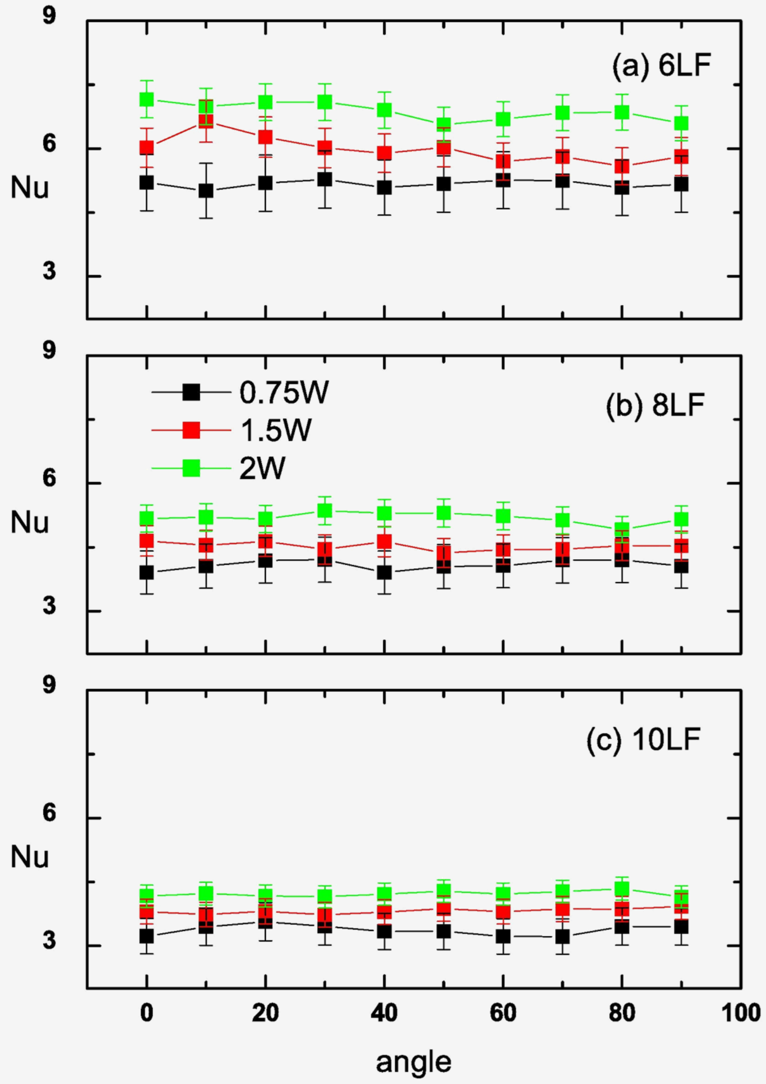
Experimental Results





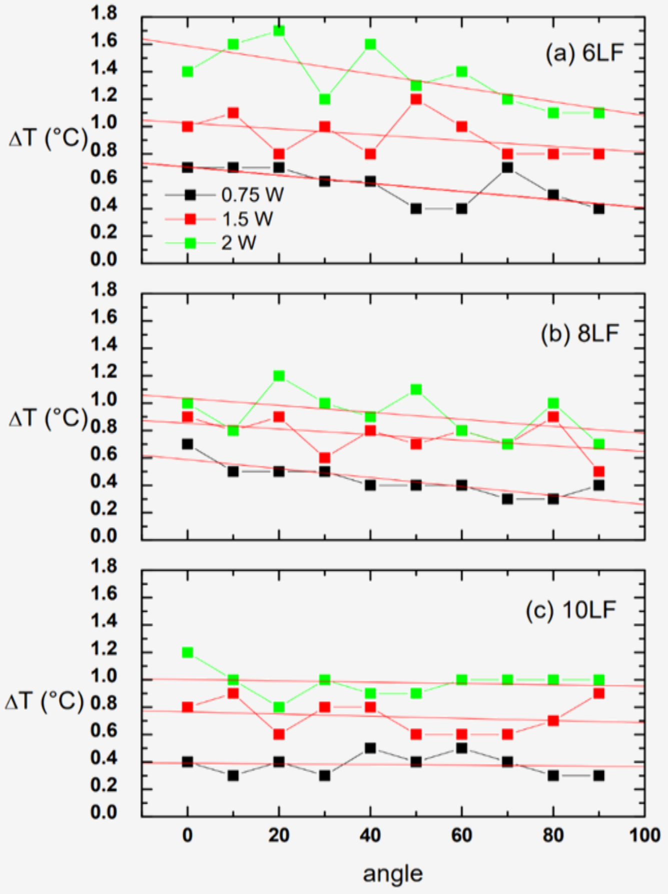


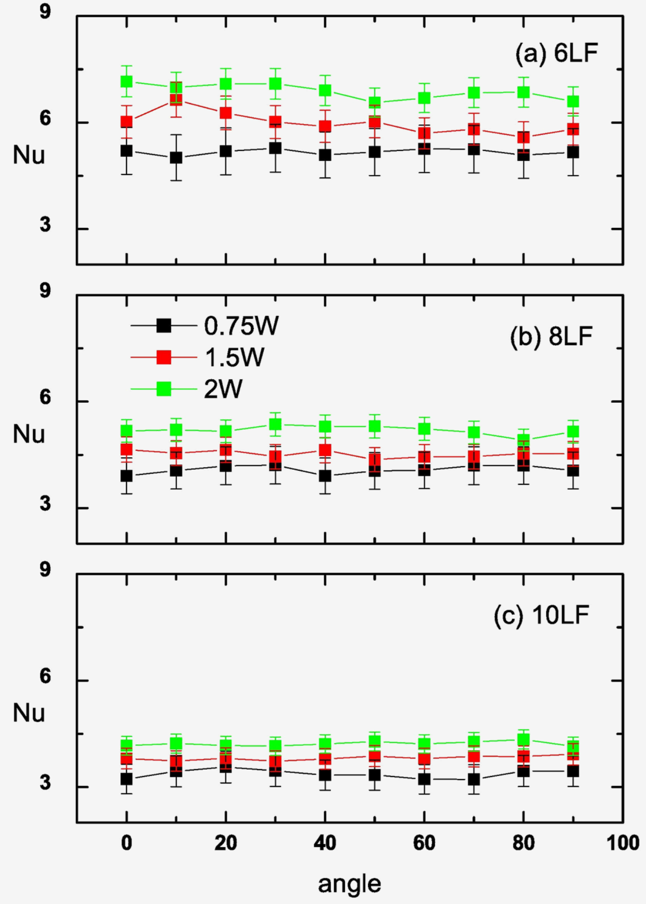
Experimental Results – Nusselt Number

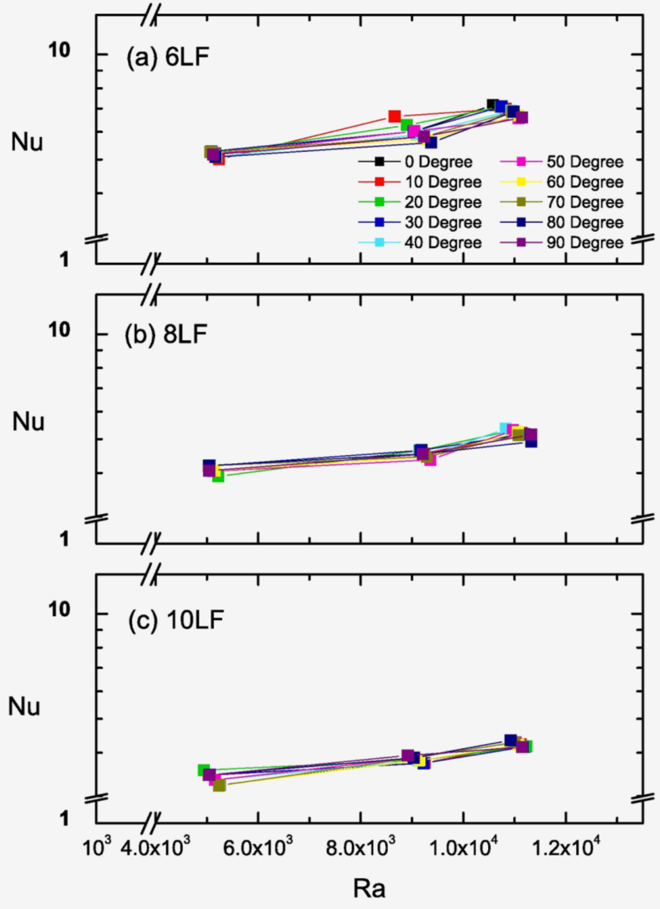


- Nusselt number was calculated based on the average temperature of the base of the heat sink and the temperature of the surroundings.
- 6 LF heat sink had the highest Nusselt number for each heat input tested. Along with this, it also produced the highest fluctuations.
- Orientation angle has a limited effect on the Nusselt number for the ranges tested.

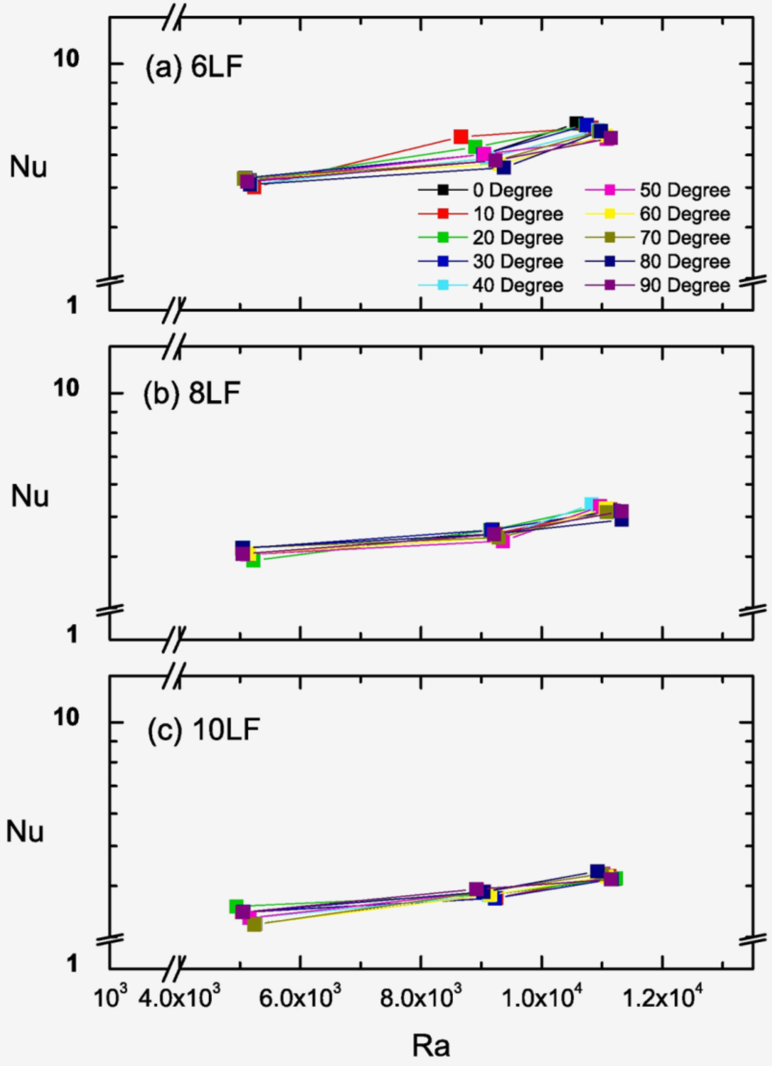
Experimental Results







Experimental Results – Nu vs Ra



- Nusselt number and Rayleigh number have a power relationship as expected.
- The change in Nusselt number based on the Rayleigh number is more significant for the 6 LF case.
- Further visualise the limited effects of orientation on Nusselt Number.

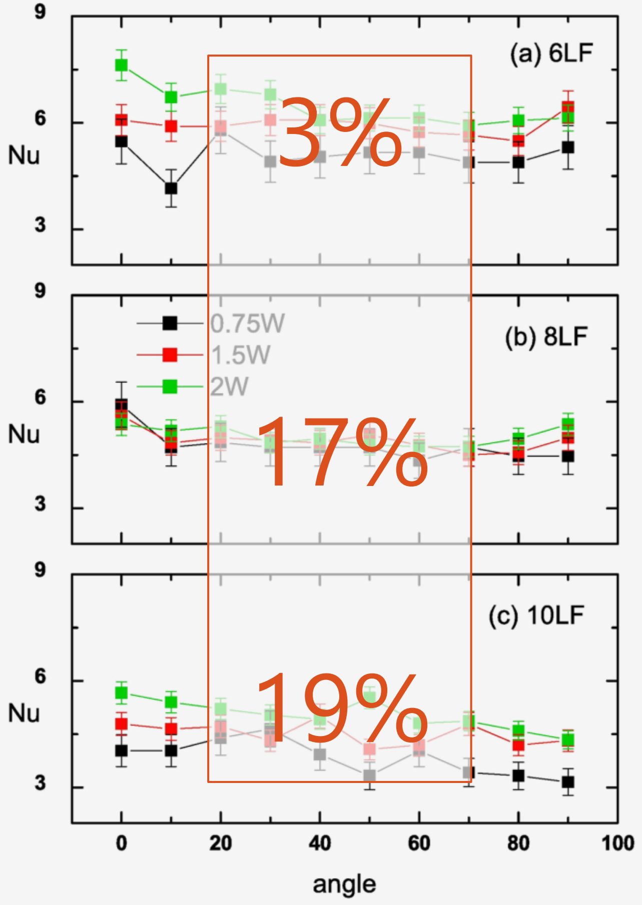
$$Nu = aRa^b$$

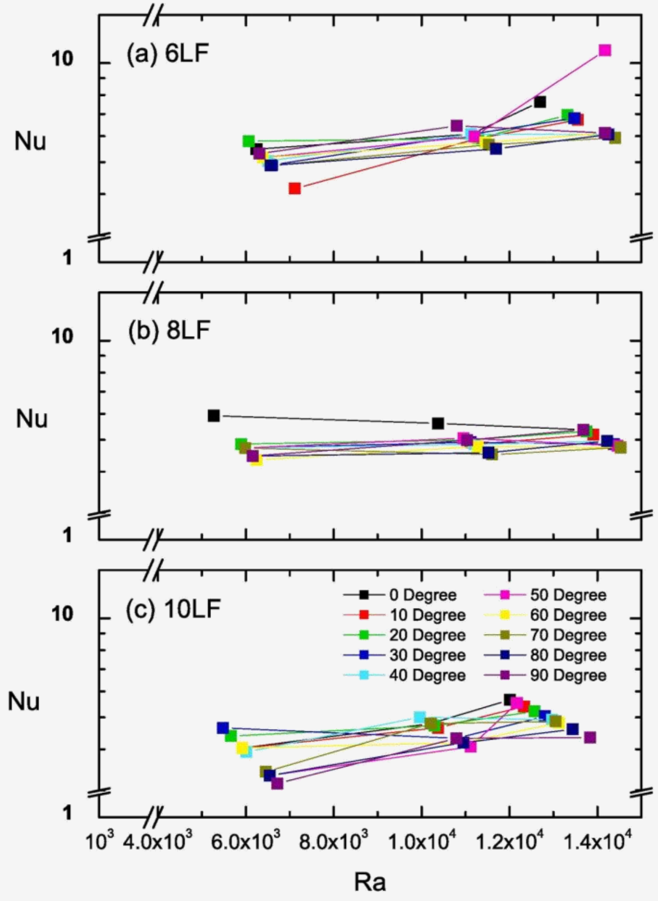
The overall correlations for the 6 LF, 8 LF and 10 LF heat sinks are $0.2748\ Ra^{0.3425}$, $0.3425\ Ra^{0.2747}$ and $0.3317\ Ra^{0.2708}$ respectively.

this correlation is very close to the correlation presented by Rahman, Bhowmik and Talukdar ($Nu \sim Ra^{0.38}$).

Rahman, M. M., H. Bhowmik, and S. Talukdar. "Design and Optimization of a Radial Flow Heat Sink under Free Convection at Steady State Condition." *Int. J. of Thermal & Environmental Engineering* 13.2 (2016): 75-80.

Experimental Results






(a)

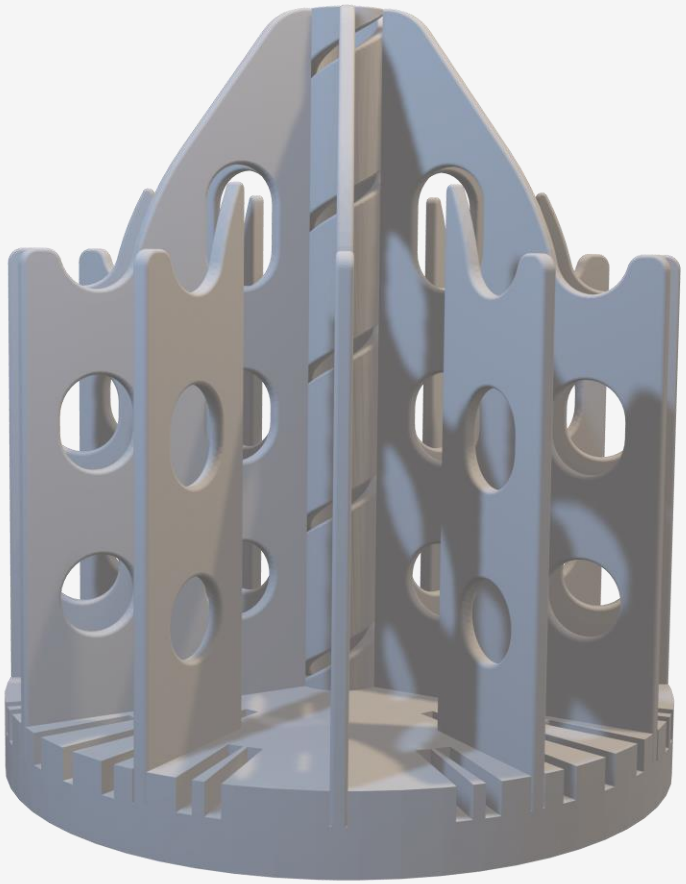

(b)


(c)

Conclusion

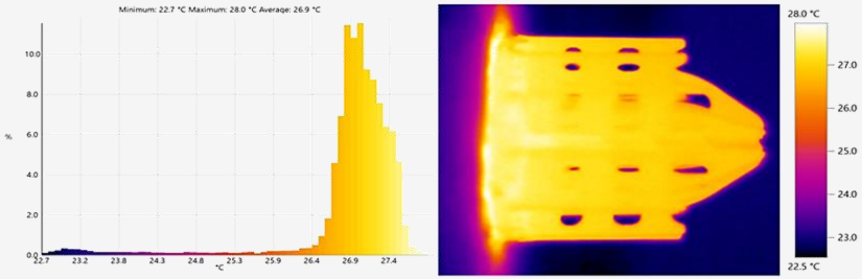
An experimental study was conducted on natural convection in additive manufactured radial heat sinks (6LF, 8LF and 10LF) exposed to a range of heat fluxes (471.57 , 943.14 and 1257.52) and orientation angles (0°–90°).

- The 6LF heat sink displayed the highest heat dissipation abilities among the geometries studied.
- The average temperature for the 8LF and 10LF cases was much higher than the 6LF case. This was caused by the conduction mechanism dominating the heat transfer in the higher density cases.
- The orientation had a minimal effect on the performance of the heat sinks and the effect was limited by the adaptations made to the fins and the central pillar of the heat sink to promote upward convective flow.
- The correlation between the Nusselt number and the Rayleigh number has been obtained for different heat sinks with short fins at various orientation angles.
- Removing short fins improved heat transfer rate for all heat sinks. The heat sink with the lowest fin density (. 6LF) showed the smallest improvement.
- Removing short fins and decreasing fin density intensified the effect of heat sink orientation.

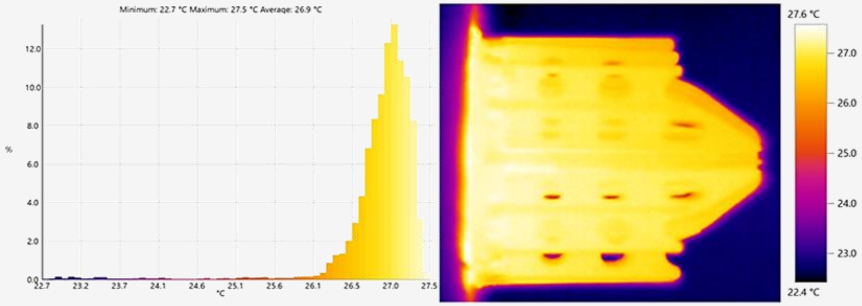


Question?

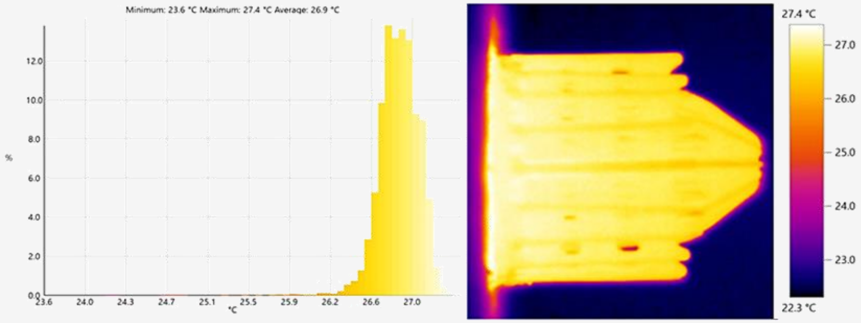
Experimental Results – Average Temperature



(a) 6 LF Heat Sink



(b) 8 LF Heat Sink



(c) 10 LF Heat Sink

- To draw comparisons between tests, it was necessary to generate a dimensionless average temperature for each case. This was done by taking a histogram of the heat sink in the IRSoft software and comparing the average temperature to the maximum temperature in the form;

$$\theta_{avg} = \frac{T_{avg}}{T_{max}}$$