Master's Thesis Engineering Technology

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Simulation-based study of heatsink optimization using the chimney effect for enhanced natural convection

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INTRODUCTION

- **Thermal management** is a critical subject in power electronics, since overheating causes reduced system efficiency or system failure. **Increasing switching frequency** and **surface reduction** magnifies the importance.
- Natural convection heatsinks are needed in mid-to-high power electronic applications, where **reliability and low acoustic noise** is required (e.g. off-grid power systems, backup power systems, etc.).

PROBLEM STATEMENT

- **Slow airflow speeds** in and around natural convection heatsink.
- Traditional designs fail to utilize natural convection's potential.

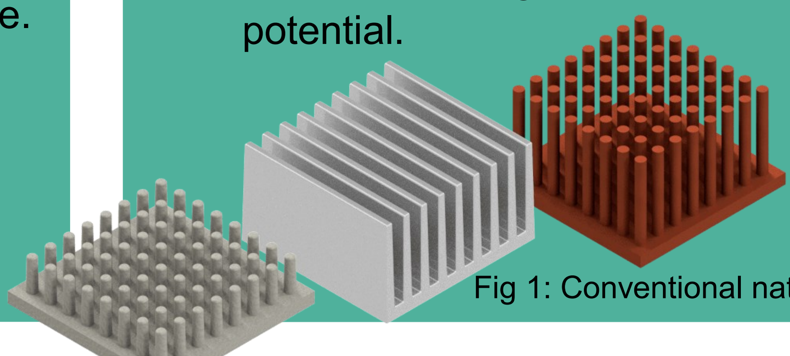


Fig 1: Conventional natural convection heatsinks [1]

CHIMNEY EFFECT

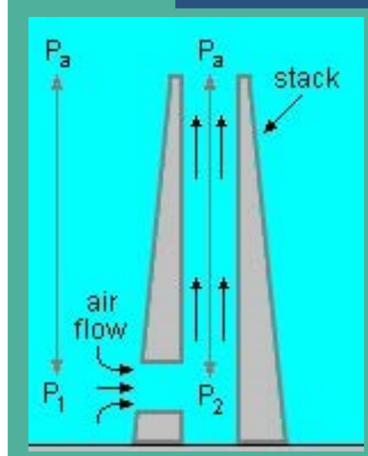


Fig 2: Chimney effect [2]

A vertical flow of fluid or gas, caused by **buoyancy forces**.

Relatively hot gas inside the chimney has lower density and rises. It creates low pressure and draws in **cooler, and higher pressure air from the bottom opening**.

Chimney effect equation: $Q = CA\sqrt{2gh\frac{T_i - T_o}{T_i}}$

OBJECTIVES

Define the most important factors and dimensions to increase air velocity and reduce peak temperature in a heatsink that utilizes the chimney effect.

- Increase the average air velocity by 10%
- Reduce the peak temperature by 3%

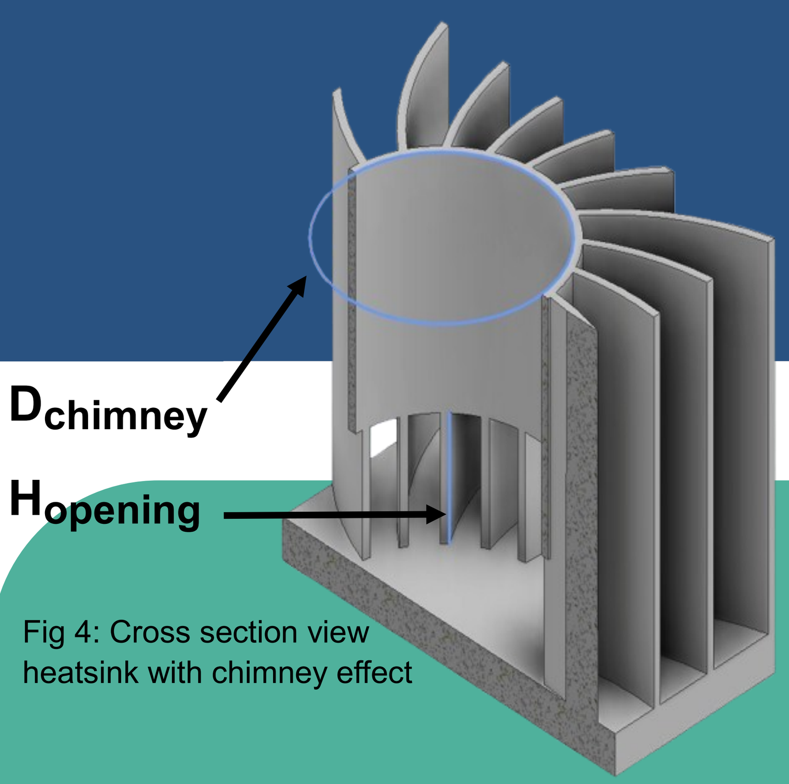
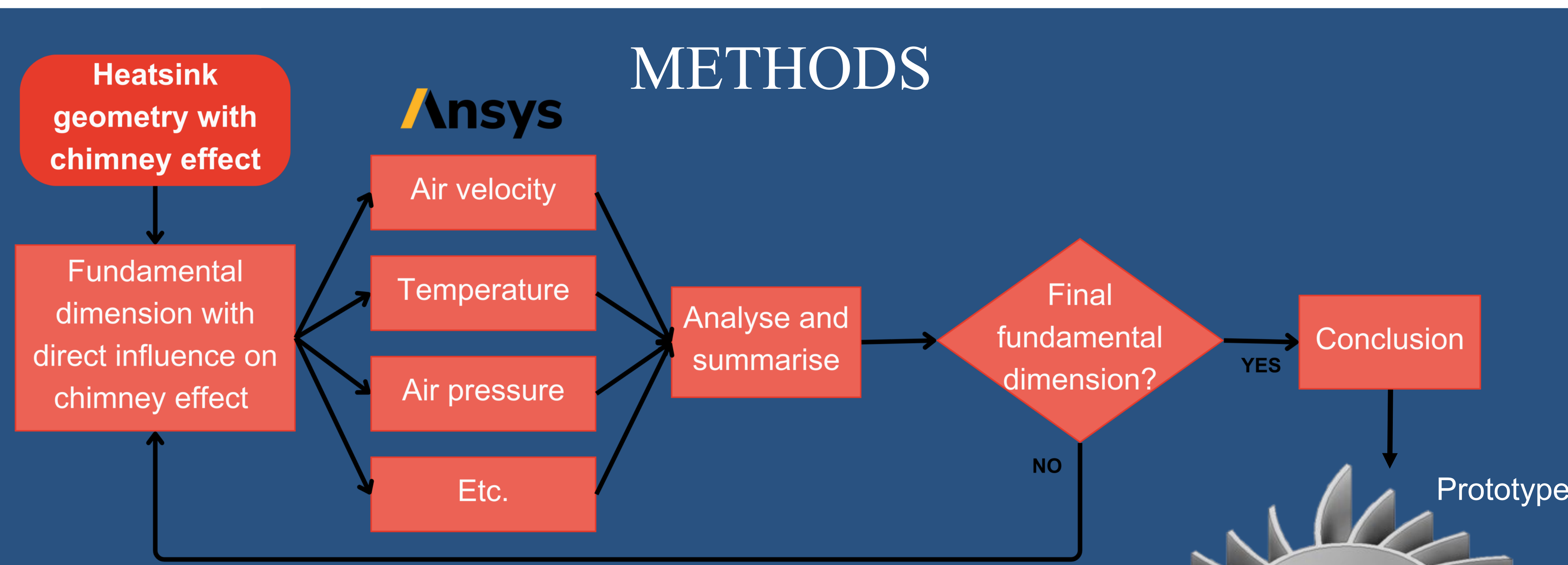


Fig 4: Cross section view heatsink with chimney effect

METHODS



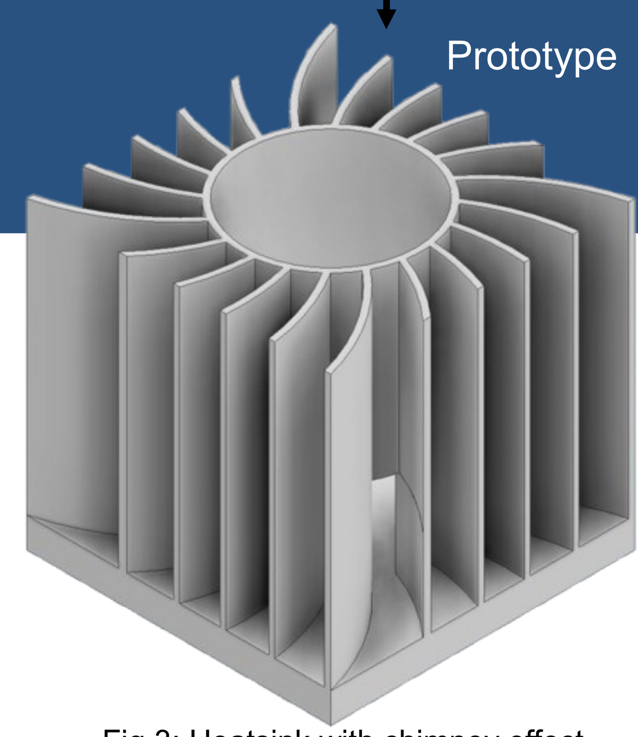


Fig 3: Heatsink with chimney effect

RESULTS

Chimney diameter ($D_{chimney}$)

Height of the bottom opening ($H_{opening}$)

Fig. 5 shows that both dimensions are insignificant towards the heatsink's efficiency, and cause less than 2% increase in peak temperature for the middle 31% of these parameters.

Only towards extreme low and high values of the dimensions, the efficiency drops significantly.

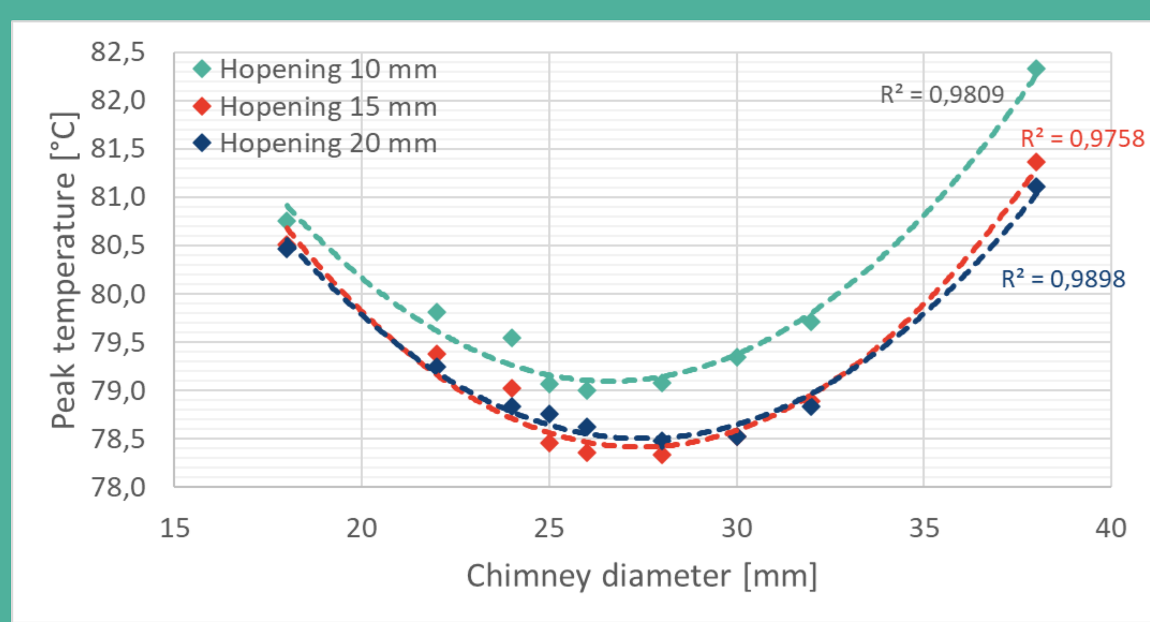


Fig 5: Peak temperature in function of chimney diameter and height of bottom opening

More surface area in chimney

Fig. 6 shows a correlation between the increase in surface area in the chimney and the increase in peak temperature.

Fig. 7 shows that more surface area creates higher air resistance in the chimney, and this causes a reduced air velocity across the base plate.

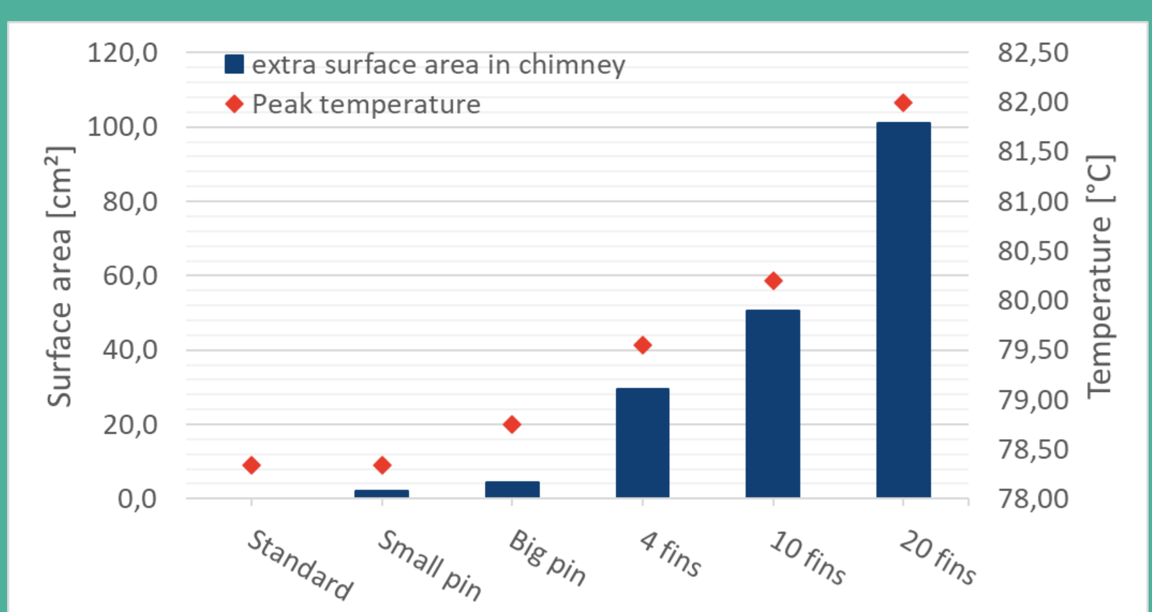


Fig 6: Surface area and peak temperature comparison for 6 designs

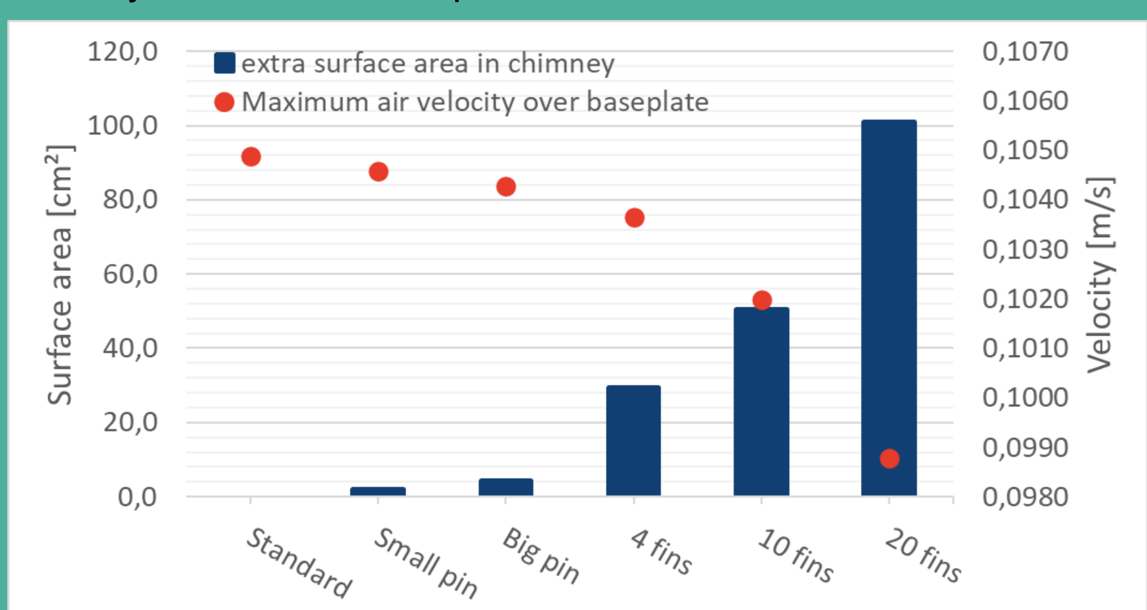


Fig 7: Surface area and air velocity comparison for 6 designs

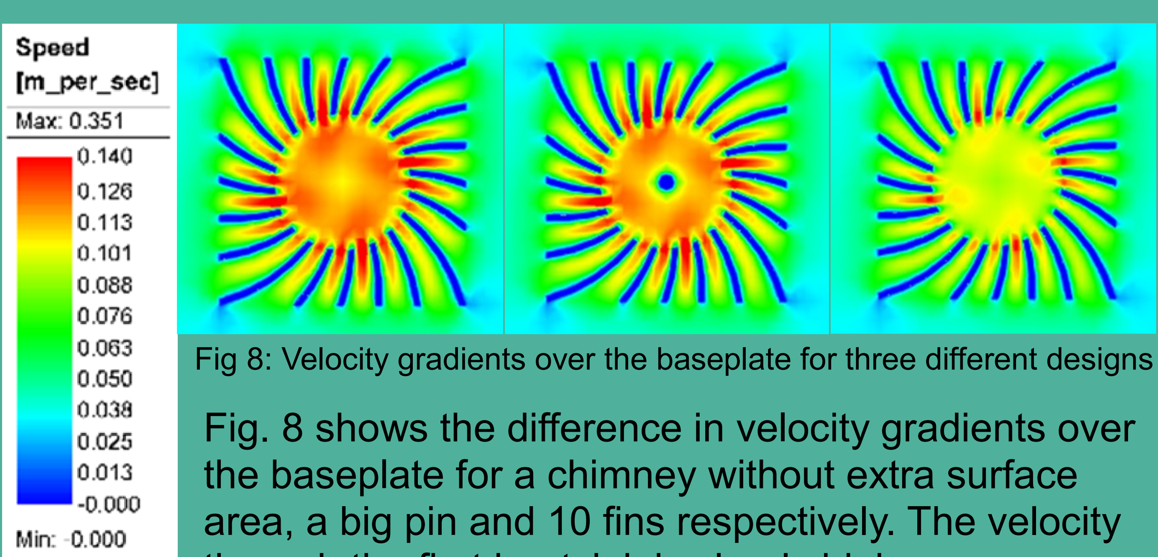


Fig 8: Velocity gradients over the baseplate for three different designs

Fig. 8 shows the difference in velocity gradients over the baseplate for a chimney without extra surface area, a big pin and 10 fins respectively. The velocity through the first heatsink is clearly higher.

Average air velocity increased by 15%
Peak temperature decreased by 0.6%

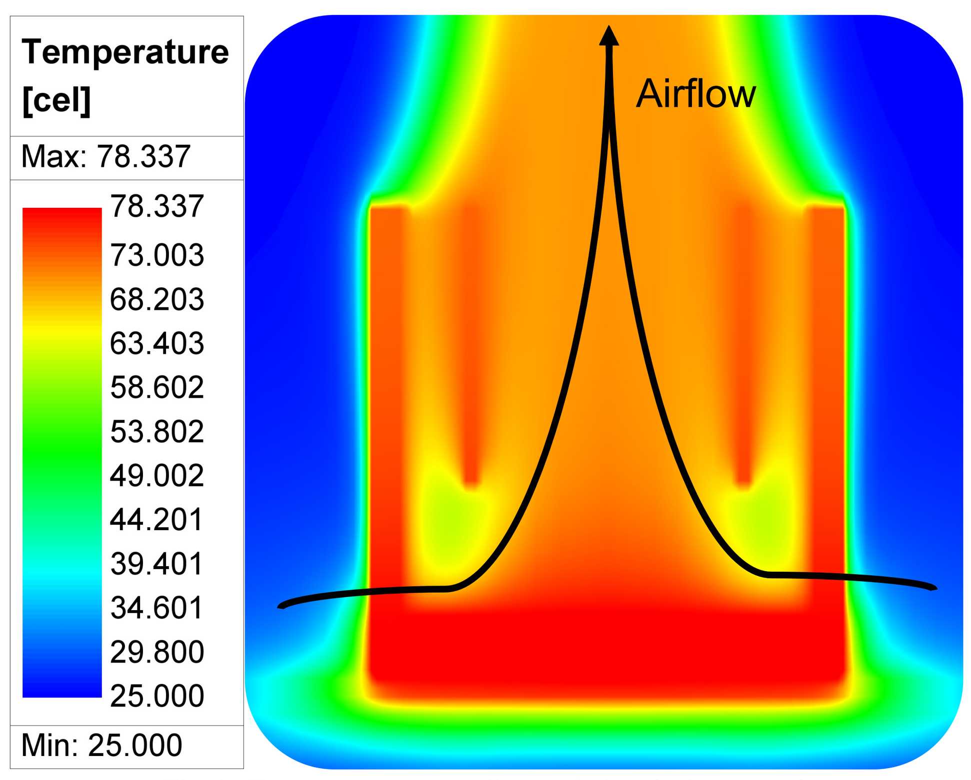


Fig 9: Temperature gradient of simulation result

CONCLUSION

1. Air velocity across the base plate is the most critical factor in reducing the peak temperature.
2. No extra surface area in chimney to obtain strongest air velocity across the baseplate.

Further research:

- Thermal testing and validation.
- Apply this finding to other studied geometries with chimney effect.
- Taller chimney for stronger chimney effect.

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[1] Diabatix, Sarah da Silva Andrade, August 25, 2023. [online]. Available: https://www.diabatix.com/blog/pin-fin-heat-sink-applications-enhancing-thermal-management-for-optimal-performance. [Accessed: 2024-12-12]

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