Machine Learning Based Thermal Management Design

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Overview

- With the continuing rapid development of higher efficiency integrated circuits, a need to dissipate heat arises.
- Traditional CPU cooling solutions only able to provide average loop temperatures or temperatures at specific locations in the cooling loop.

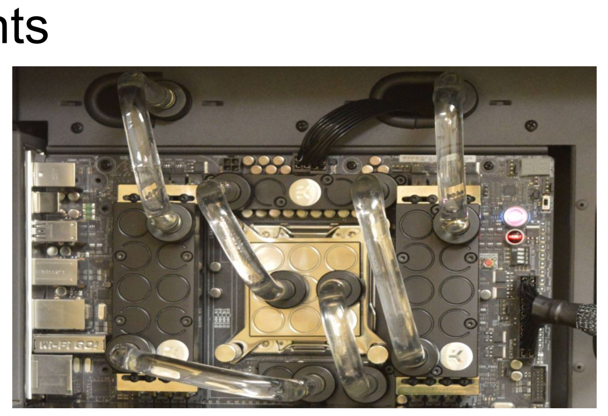
Objectives

- Design a liquid cooling block based on Google's TPU v3 which allows high bubble production during heat transfer.
- Train an AI model to detect bubbles and output bubble statistics (velocity, size, interactions, etc.)
- Integrate AI detection into the cooling block to monitor and control the temperature at any locations at any time.

Existing Solutions & Limitations

CPU Air Cooler

+ Keep the whole computer case at low temperature
- Loud & can not detect temperature at specific points

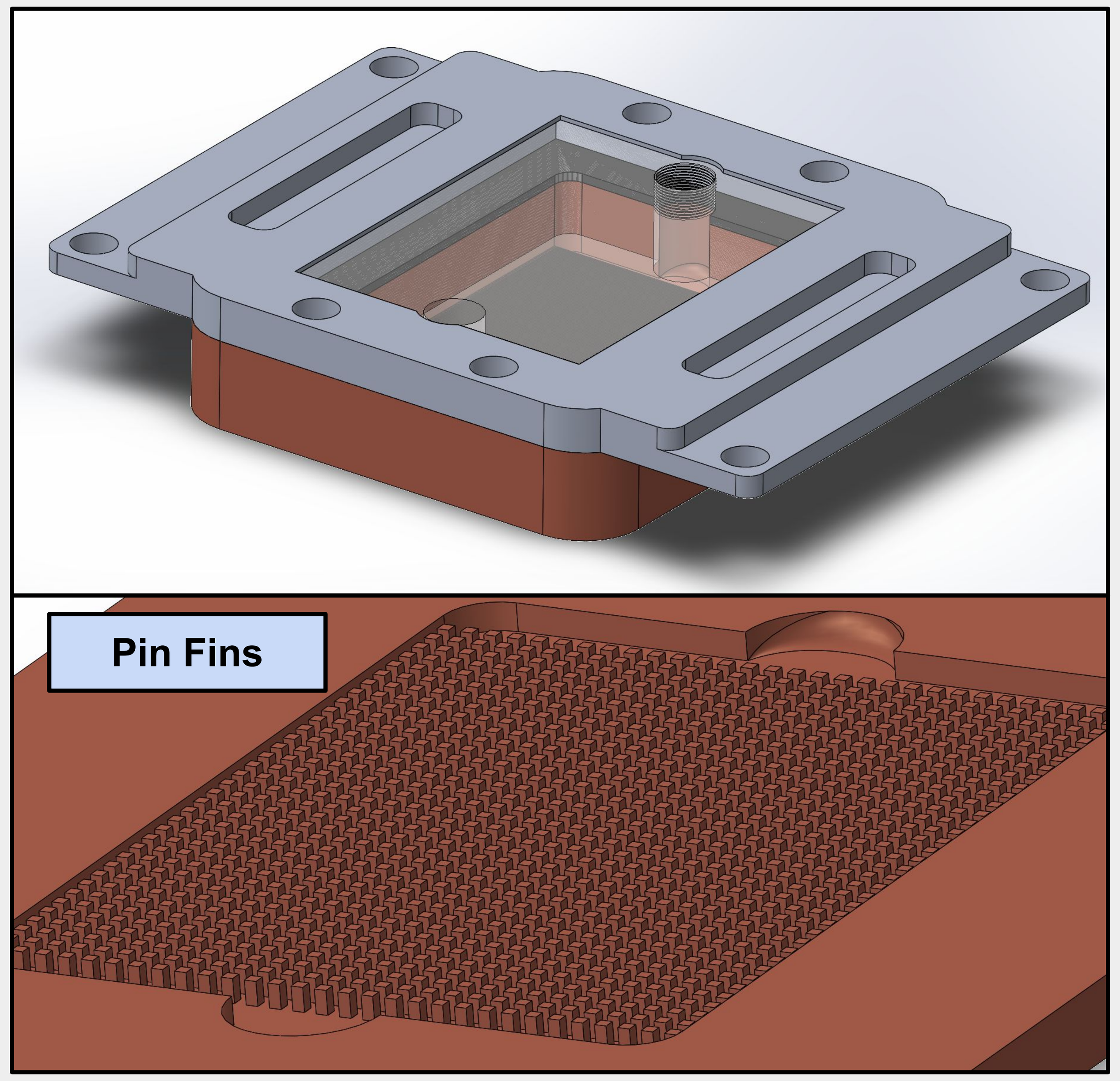


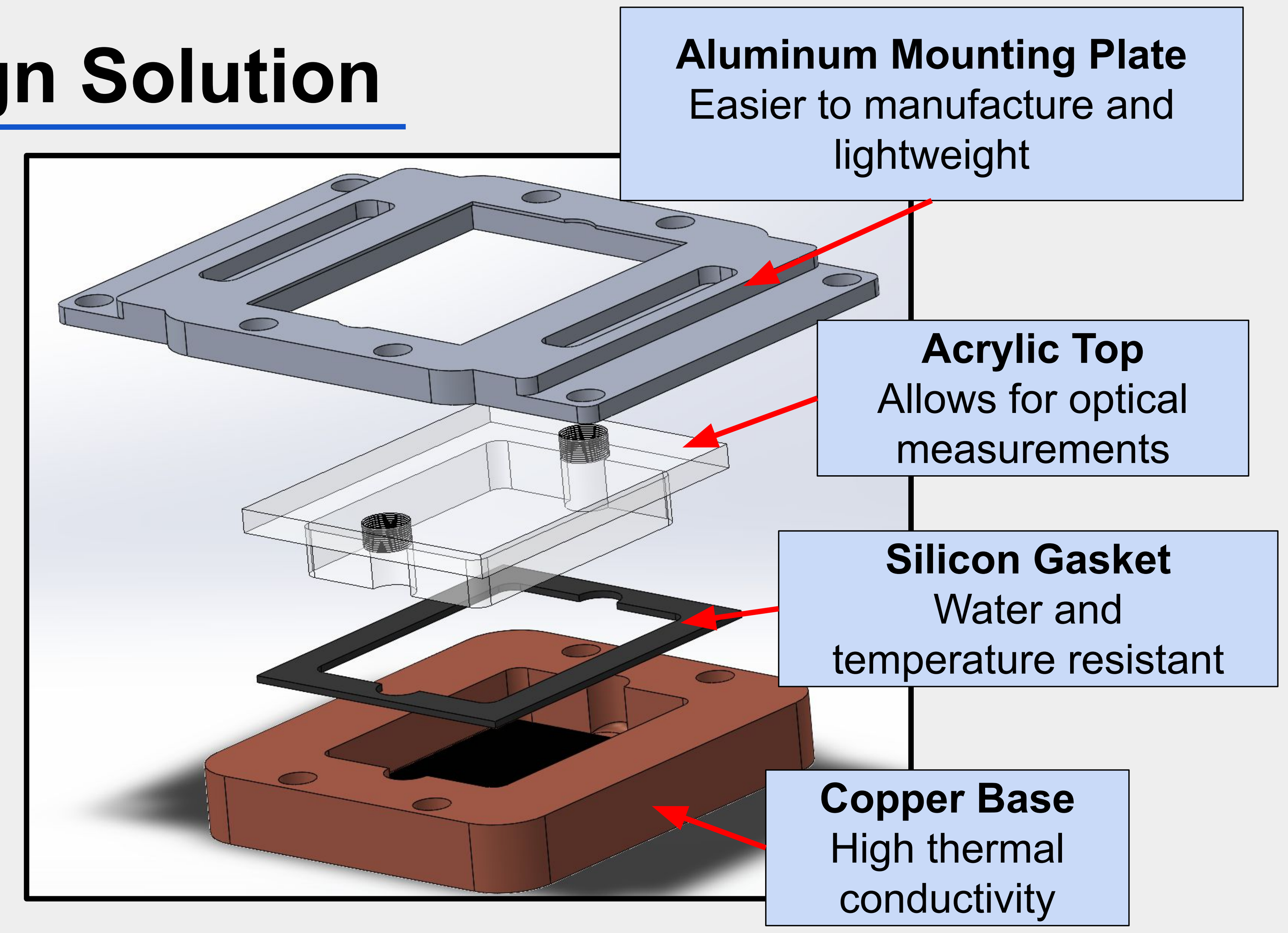
Liquid Cooler

+ Better cooling performance & low operation noise
- Expensive & no real time management

Design Solution

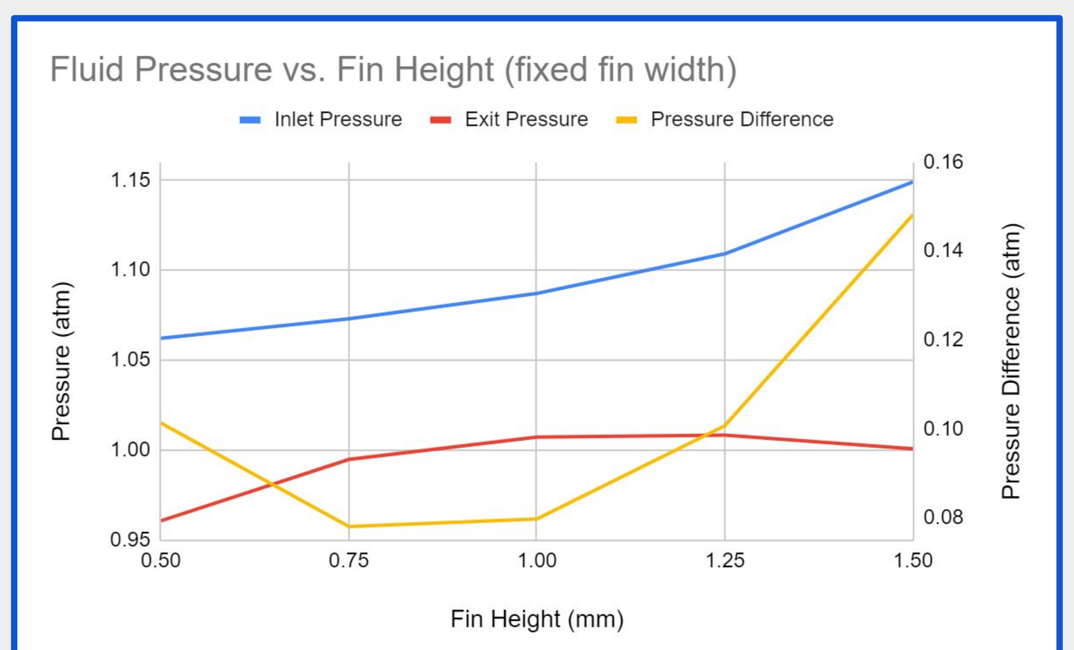
Waterblock Design

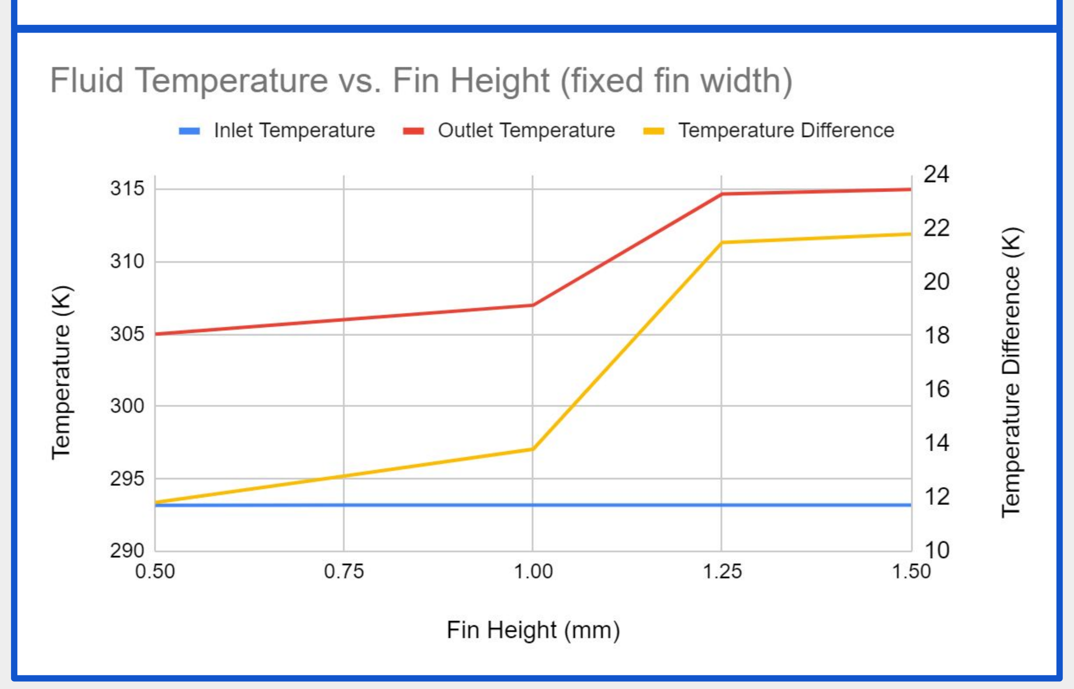


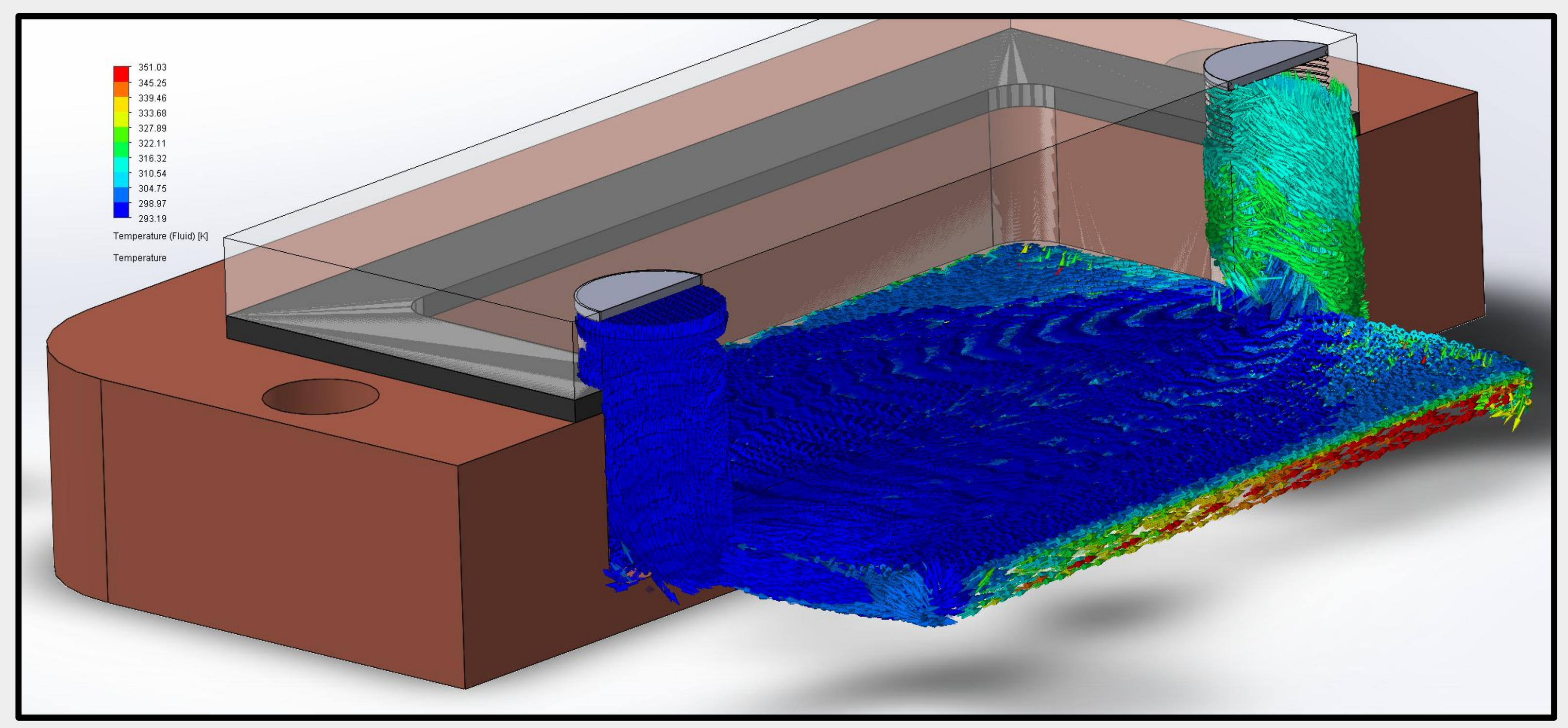


Pin Fins allow for a higher surface area for convection with little additional pumping power compared to other patterns such as striped and wavy. Pin Fins also offer the best bubble formation due to their higher number of nucleation sites for bubbles to form. Smaller fin and channel widths also help in increasing bubble production.

CFD Analysis







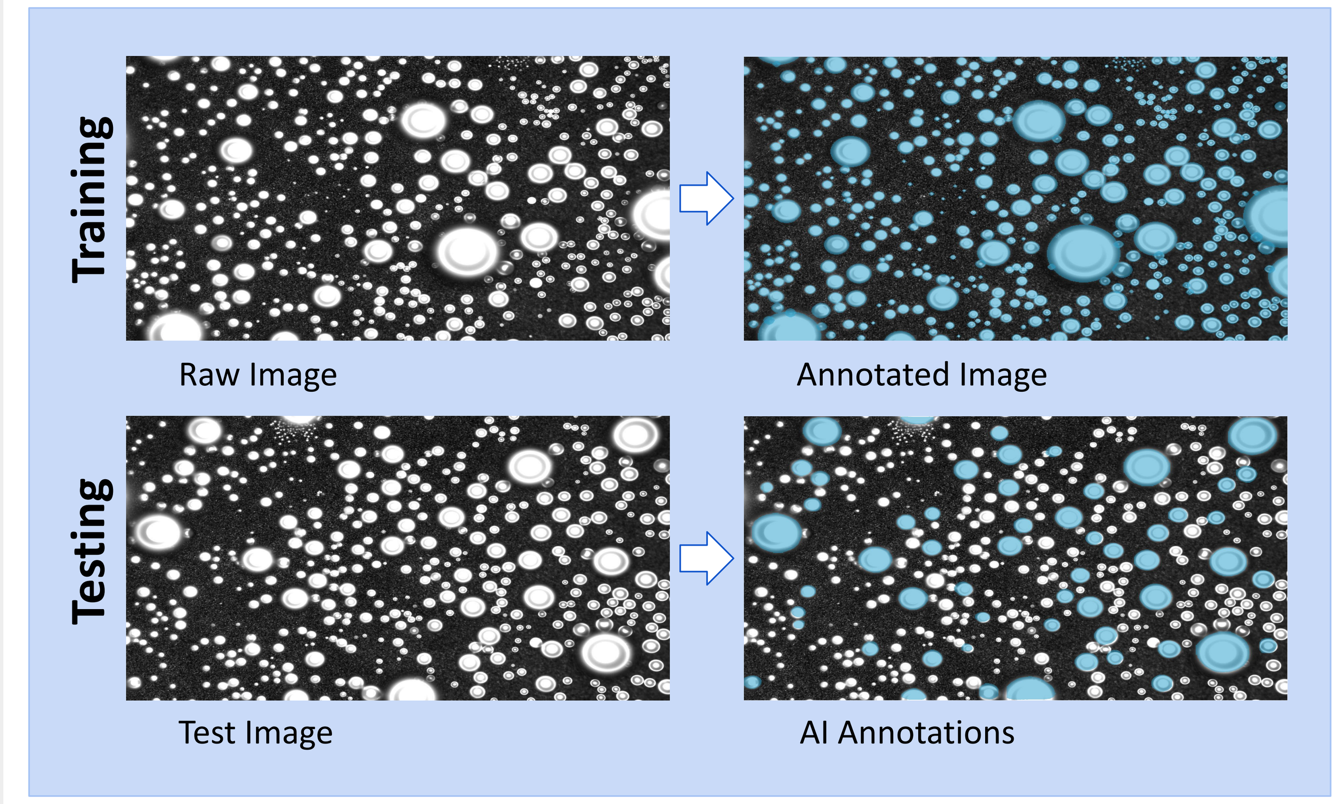
Input Parameters

- Inlet volumetric flow rate: 2L/min
- Inlet temperature: 20°C
- Copper base temperature: 80°C
- Fin area: 30x36mm
- Fixed fin width: 0.1mm
- **Variable fin height : 0.5-1.5mm**

Results

- 1.25mm and 1.5mm fin heights:
  - Provide best heat dissipation
  - Require more pumping power
  - Don't meet manufacturability requirements
- 1mm fin height:
  - Good heat dissipation
  - Low pumping power needed
  - Meets 10:1 height to width ratio for manufacturability

AI Model



- Trained AI model on 121 annotated CFD bubble images
- >50 bubbles per image for a total of 6,111 annotations
- Model did not perform well in bubble recognition
  - Only 10% of bubbles per image identified
- With a larger data set and more training time we expect our model would achieve greater instance recognition (>60% identification would be successful)

Future Improvements

Building prototypes

- Gather real data to improve CAD design
- Test AI integration

Exploring other object detection models

- Reduce human effort on annotations
- Other models could offer real time analysis

Test other working fluids

- Could provide greater heat dissipation
- Would allow for simpler fin structure

Conclusions

- Based on the research, modeling, and analyses we have conducted, we found that the incorporation of an AI system into a TPU cooling block can be an effective alternative to traditional methods of computer processor cooling.
- The incorporation of AI allows for more information about the working fluid to be extracted , resulting in greater understanding of heat dissipation throughout the system.
- We can use AI to track flow boiling bubbles and determine various bubble statistics, used to improve the performance of our cooling block.

Acknowledgements

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References

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(2) "Heat transfer correlation for flow boiling in small to micro tubes" https://www.sciencedirect.com/science/article/pii/S0017931013005966

(3) "Fundamental issues related to flow boiling in minichannels and microchannels" http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.454.1708&rep=rep1&type=pdf