ASME IEEE Heat Sink Competition

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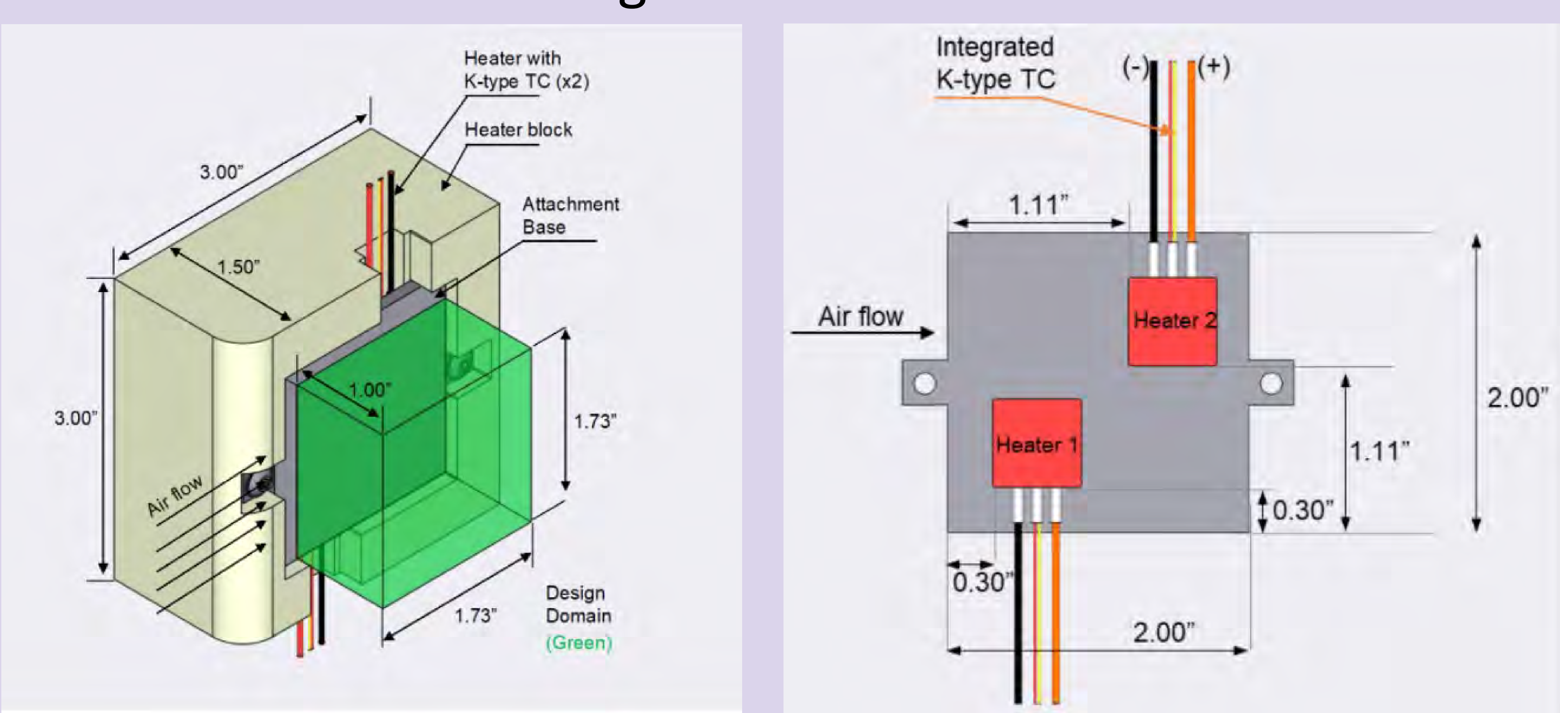
Problem Statement and Competition Setup

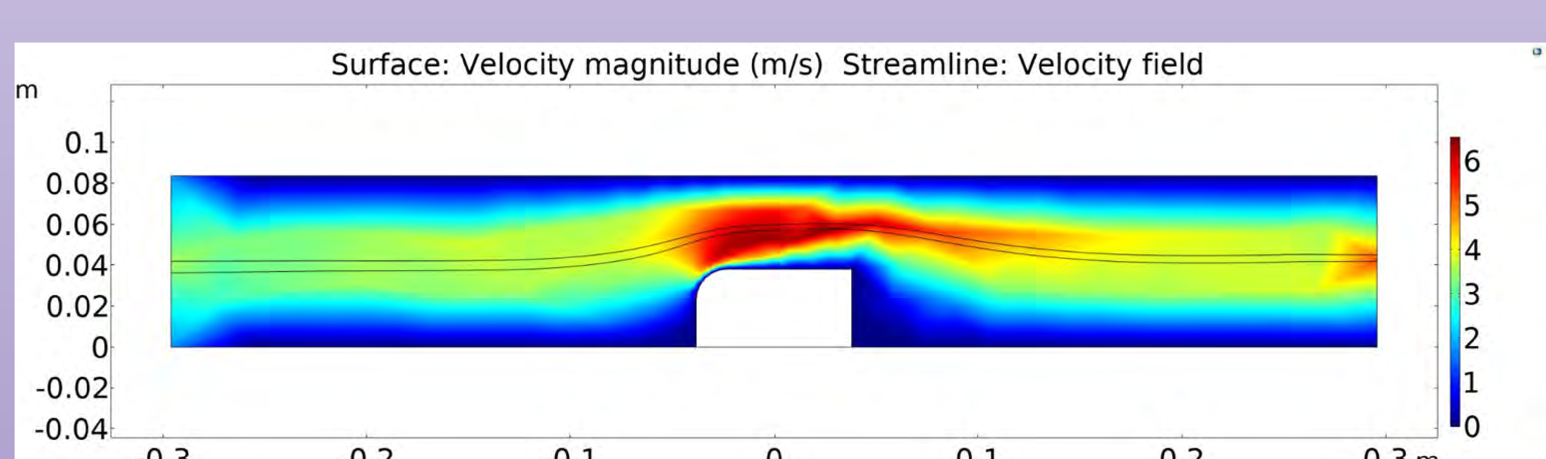
Our competition objective was to design and additively manufacture a heat sink which dissipates heat generated from two electric heaters using forced air convection within a wind tunnel. Heat is transferred into the sink via two asymmetric heaters. Heaters 1 and 2 generate 20W and 35W of heat respectively. Our design seeks to maximize heat transfer while minimizing volume.



Competition setup and design domain

Analysis with COMSOL Multiphysics

Before designing our heat sink, two preliminary verification models were made. The velocity profile of the airflow around the heater housing was investigated to assess flow conditions around the heater block and inform design decisions. We found that the airflow accelerates considerably and cannot be neglected in our design.

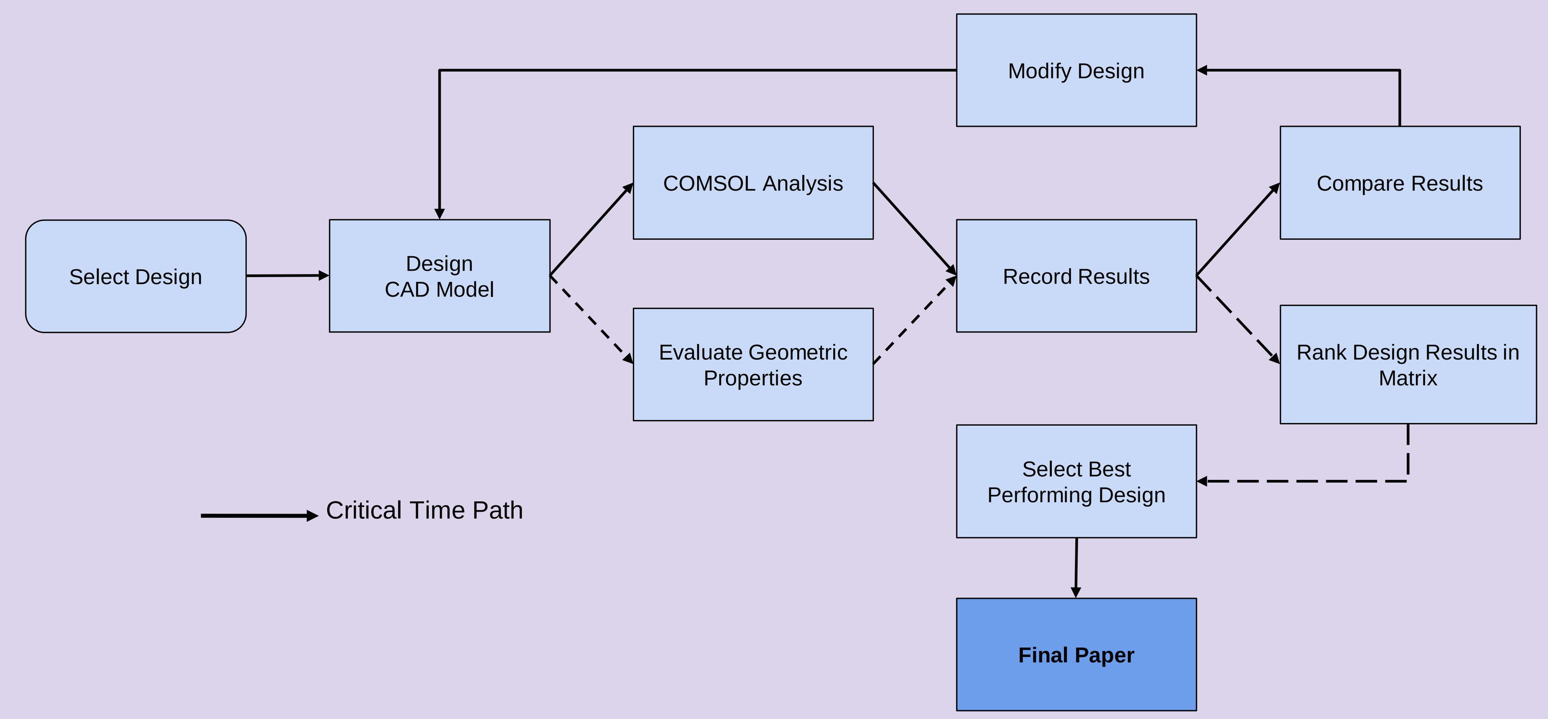


Wind tunnel velocity verification around design area

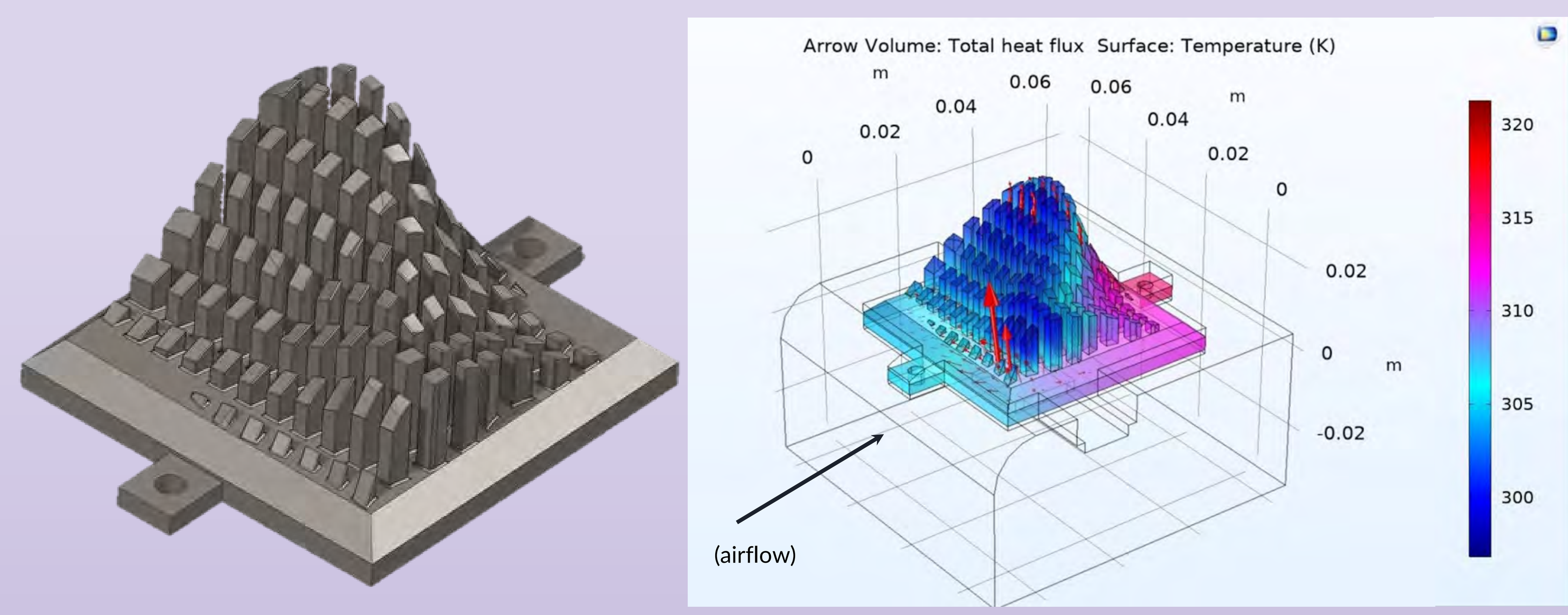
A following steady state heat transfer model of the base plate showed the heat distribution within the base plate, and indicated regions where temperature was the highest. These models helped guide the placement of geometry on the base plate. Then, a full 3D model of the competition test area was replicated within COMSOL, allowing detailed modeling of the performance of each iteration of our heat sink design.

Iterative Design Process

The following design process was used to guide our designs, and to ensure that forward progress was made.



Finalized Design



Final design, El Tiburon, 3D COMSOL heat flux analysis

El Tiburon, named after the design inspiration, is a shark fin style structure made up of lofted pin fins. The taller fins are placed over the hottest areas, utilizing material as efficiently as possible. The windward direction of the heat sink has sinusoidal cuts, used to disturb the thermal boundary layer, preventing thermal saturation of the flow, and maximizing cooling. The cuts perpendicular to the flow seek to accomplish the same effect but use a straight cut instead of a sinusoidal cut.

Verification and Results

El Tiburon was our highest performing design, achieving an FOM of 0.00905, 110.41% better than the base plate alone. Through our analysis, we found that the FOM is highly dependent on volume, so our design maximizes heat transfer while minimizing the volume used. Our results are tabulated in top right corner.

$$FOM = \frac{1}{\$_{Heat\ Sink} * (T_{Heater\ Avg} - T_{Amb})}$$

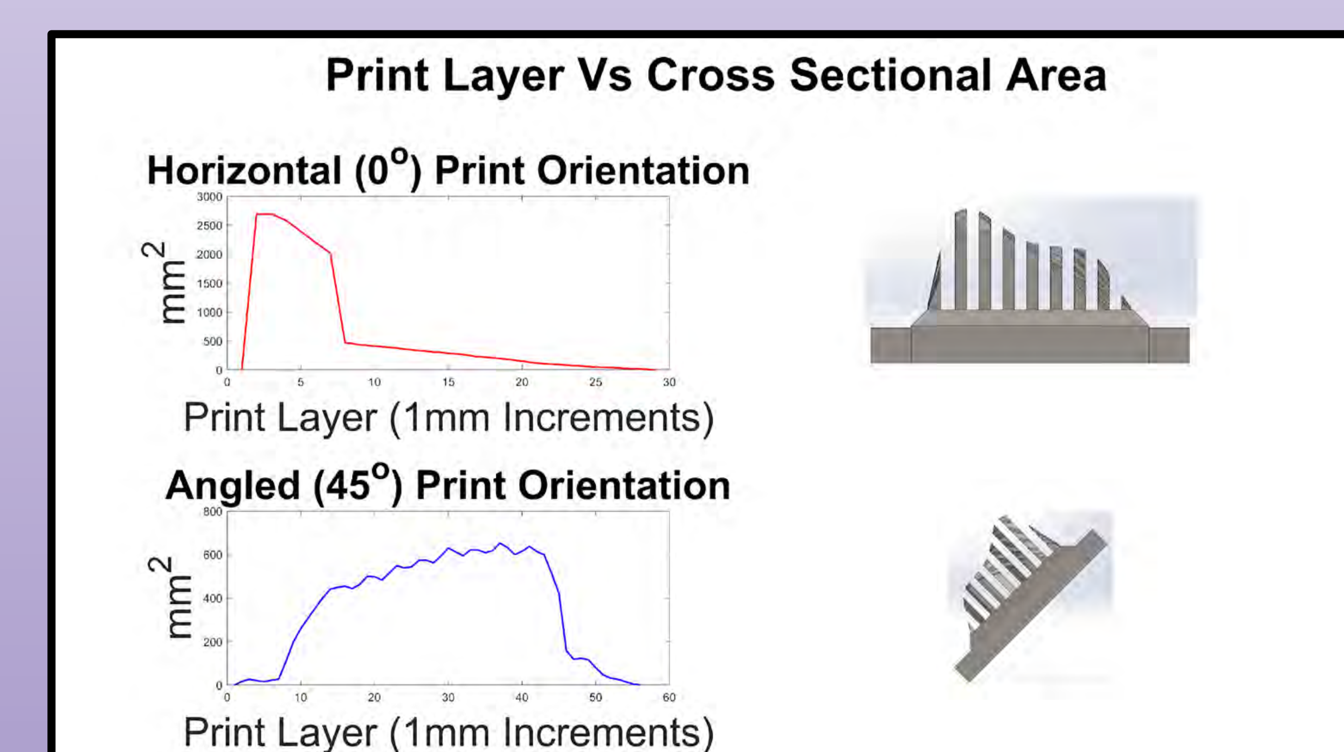
$$T_{Heater\ Avg} = 0.36 * T_{Heater\ 1} + 0.64 * T_{Heater\ 2}$$

$$\$_{Heat\ Sink} = \$_{Powder} * m_{Heat\ Sink}$$

Parameter	Value
Flow Inlet Velocity $[m/s]$	3.5
Flow Inlet Temperature, T_{amb} [°C]	20
Heat Sink Mass, $M_{Heat\ Sink}$ $[g]$	54.12
Heat Sink Cost, $\$_{Heat\ Sink}$ [$]	3.223
Heater 1 Temperature, $T_{Heater\ 1}$ [°C]	45.75
Heater 2 Temperature, $T_{Heater\ 2}$ [°C]	58.98
Figure of Merit, FOM $[\$^{-1}\ °C^{-1}]$	**0.00905**

Additive Manufacturing

El Tiburon was designed to benefit from the complex geometry capabilities of DMLM 3D printing, while reducing the likelihood of print failure. Burning, cracking, and warping were concerns due to thin structures and drastic changes in cross sectional area. One way to mitigate these issues is to print the sink at a 45° incline. This print orientation can help smooth area transitions and ensure print quality.



Conclusion

Our team has made it through to the semi-finals of the ASME IEEE Heat Sink Competition, which means that the performance of our sink placed in the top 6 of the competition. Our sink is currently being 3D printed and will be sent to the University of Utah to be tested in Dr. Sameer Rao's lab. Finalists will be chosen after testing is completed.