Optimization of the density of a pin fin heat sink

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ABSTRACT

This project explores optimal pin fin employment and density for heat sink applications in harsh environments. Heat sinks are used to manage heat dissipation on electronics under thermal loads. Heat sinks are commonly used in central processing units (CPUs) in computers because when running heavy processing programs, computers tend to heat up, which can lead to damaging the computer CPU. The final goal is to find the optimal density of the pin fin array through numerical simulations.

BACKGROUND

Traditionally, heat sinks are used for thermal management of electronics. They are commonly used on central processing unit (CPU). Their purpose is to dissipate heat quickly and efficiently. Typically, they can be simulated by having boundaries conditions in Finite Element Analysis (FEA) software as the schematic of the setup can be seen in figures 1 and 2.

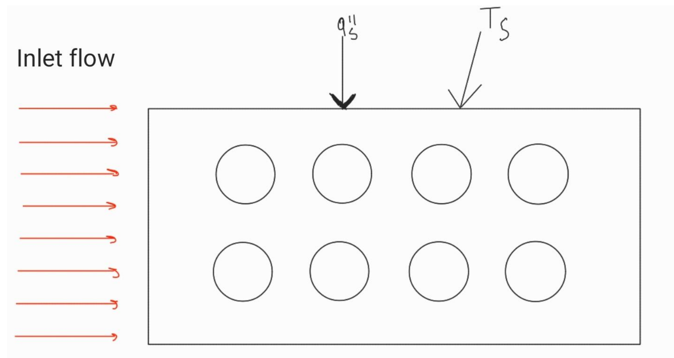

Figure 1: Heat Sink Schematic

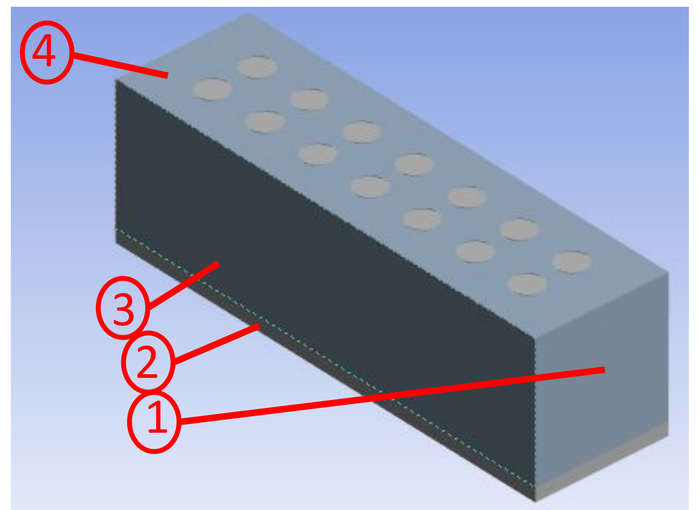

Figure 2: Boundary Conditions setup, 1 is the inlet, 2 is the solid domain (gray body), 3 is the fluid domain (dark blue), 4 is the outlet

For pin fin heat sinks determining heat perform and pumping power requirement is crucial. As doing this theoretical calculations, it's not easy to determine the requirements but it can be determine through simulations.

$$Area_{Pin\ Fin} = (r_{radius})^2 * N_{pin} * \pi \quad \text{Eq. 1}$$

In Eq. 1, Area of the Pin fin is found, where r radius, represents radius of the circular pin fin, as Npin, represents the number of pin fins.

$$Area_{Channel} = Length * Width \quad \text{Eq. 2}$$

In Eq. 2, Area of the channel array is found by multiplying length of the channel by the width of the channel.

$$\rho_{pin\ fin} = \frac{Area_{Pin\ Fin}}{Area_{Channel}} \quad \text{Eq. 3}$$

In Eq. 3, Pin Fin, represents the found density of pin fin heat, calculated by taking the area of the pin fin and dividing by the area of the channel.

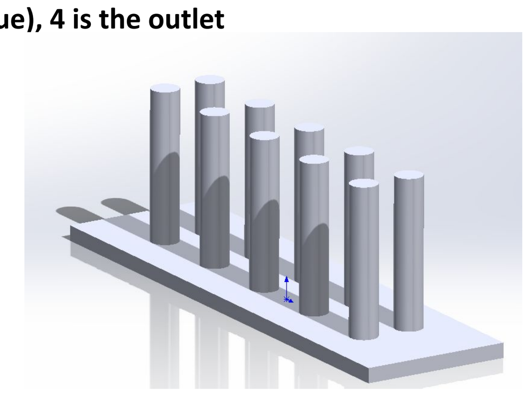
Figure 3: Isometric View of the Pin Fin Heat Sink

METHODOLOGY

1. Determine the optimal number of pin fin heat for heat transfer and pressure drop requirements.
2. Conduct experiments using an inline pin fin array with a set min and max number of pin fins.
3. Ensure the pin fin density meets the target density with a difference of less than or greater than 5%.
4. Create 19 pin fin designs in SOLIDWORKS and import them into ANSYS Software.
5. Conduct a mesh independence test on the densest pin fin density, aiming for a skewness of .5 or trendline.
6. Use the best mesh setting from the test for the remaining 18 experiments and run ANSYS Fluent Simulation using k-epsilon turbulent flow conditions with an inlet velocity of .1 m/s and heat flux of 100,000 W/ m^2
7. Document the pressure drop and temperature distribution.

RESULTS & DISCUSSION

Figures 4 and 5 show the schematic of the pin fin array with density of 13% with the number of pin fin of 14. In this pin fin array, the maximum temperature is 314.15 K and the pressure difference is 34.26 Pa.

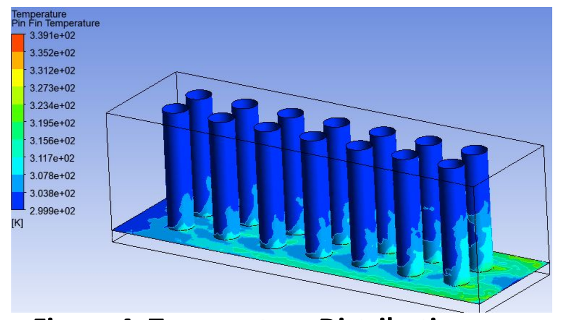
Figure 4: Temperature Distribution

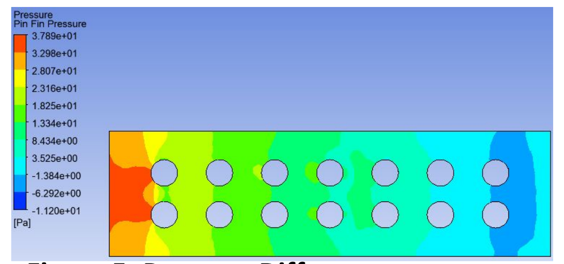
Figure 5: Pressure Difference

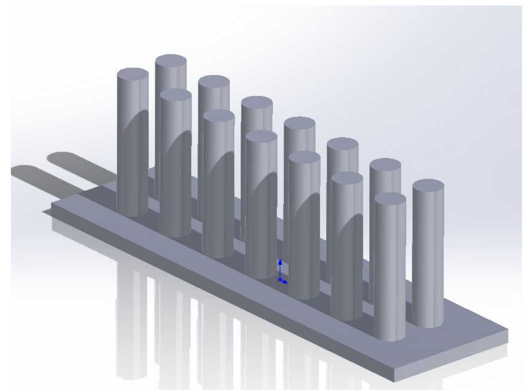
Figure 6: CAD Rendering Of Case 13

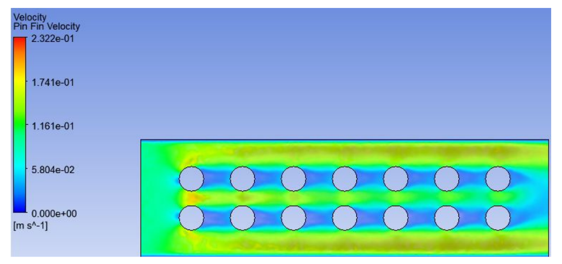
Figure 7: Velocity Profile Case 13

Figure 7 shows a peak velocity of .2322 m/s, limited by narrow spaces in the inline pin fin configuration. In contrast, Figure 7 shows a pin fin array with a density of 2.5%, which has a lower peak velocity of .1543 m/s due to larger spaces between pins, facilitating easier water flow.

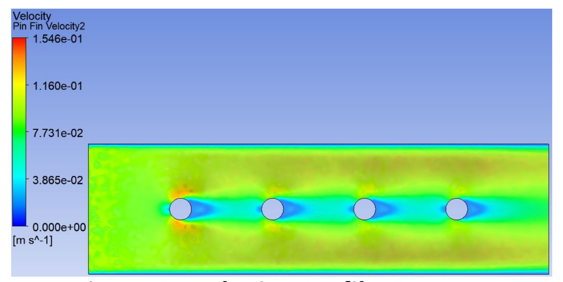
Figure 8: Velocity Profile Case 1

RESULTS & DISCUSSION

In figure 9 and 10, it was found that quadratic mesh with tetrahedral setup is the most accurate compared to linear mesh setup. The team looked for a trend of values and found that the best setup had constant skewness values between .63 to .54.

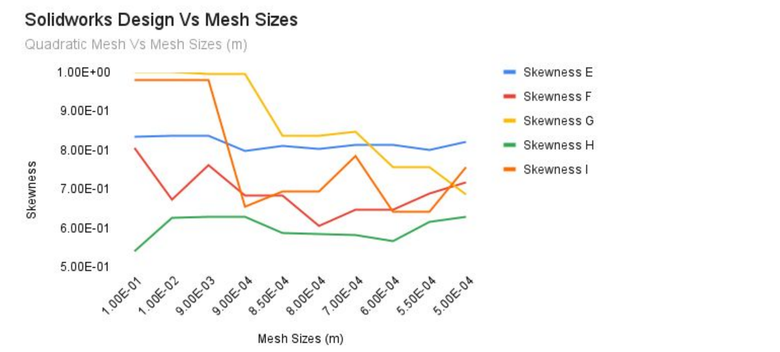

Figure 9: Solidworks Vs. Mesh Sizes (m)

A 13% pin fin density met the pressure drop and temperature needs at 314 K. The pressure difference spike between pin fin density 9 and 12 was due to increased velocity from the small pin fin cross-sectional area, resulting in the highest pressure per Bernoulli's principle.

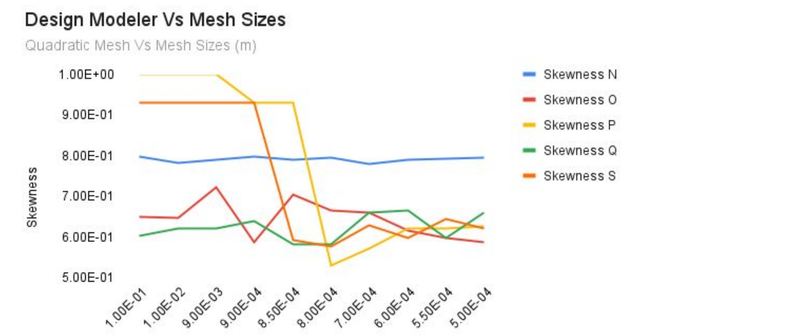

Figure 10: Design Modeler Vs. Mesh Sizes (m)

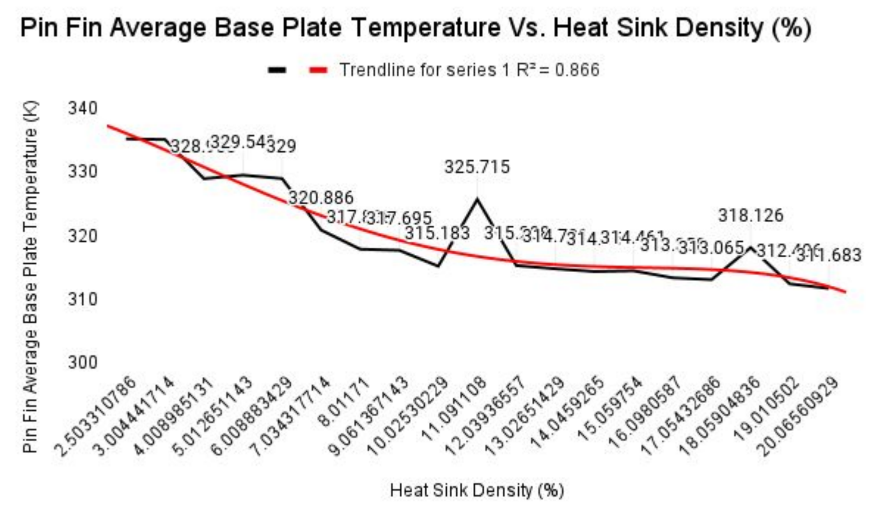

Figure 11: Pin Fin Average Base Plate Temperature Vs. Heat Sink Density

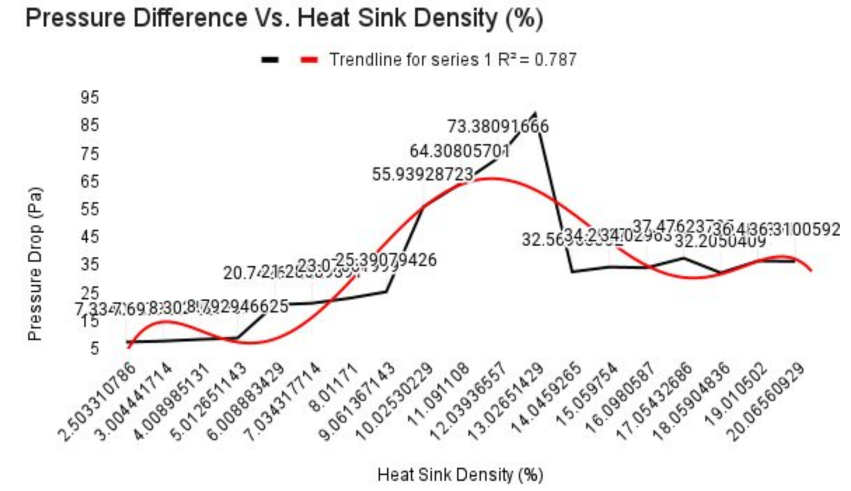

Figure 12: Pressure Difference (Drop) Vs. Heat Sink Density

CONCLUSION

We successfully found optimal mesh parameters for the most dense pin fin heat sinks. Among all of the pin fin design, we found that 14 pin fin is suitable to survive turbulent condition with 100,000 W/m^2 heat flux and a inlet velocity of .1 m/s. Next semester, the project is going to change by exploring adjoint shape optimization in ANSYS fluent of finding the optimal pin fin shape with the found 14 pin fin heat sink design in terms of heat transfer and pressure drop requirements using inline and staggered pin fin array configuration.

FURI

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