*Thermal Design for CPU cooling.*

MECH 5825: Heat Transfer 2

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Submitted to:

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## I. Introduction

Electronics cooling is one of the most important topics in modern era. Mobile phones, Laptops, Gaming console etc. are becoming part of our life. Such devices are very compact yet very powerful. For such performance, huge amount of power is released from the very compact chip of the device. Large number of data is to be processed to make mobile phone or computer work. A CPU works by either enabling electric signals to pass through its microscopic transistors or by blocking them. As electricity passes through the CPU or gets blocked inside, it gets turned into heat energy [1]. To dissipate the heat various methods are used. Thermal paste, heat exchanger, heat sink is commonly used in electronics. In this project two type of heat sink is compared to see the effectiveness. Plate fin heat sink and Pin fin hat sink is compared by using the ANSYS Icepak software package.

## II. CPU Package Overview

For this project, the 9$^{th}$ Gen Intel Core i9 9900k desktop processor was used. Core i9-9900K is a 64-bit octa-core high-end performance x86 desktop microprocessor introduced by Intel in late 2018. It has the clock speed of 3.6 Ghz with a Thermal Design Power (TDP) of 95 W and turbo boost frequency of up to 5 GHz. [2] TDP refers to the ability of the CPU cooling solution to dissipate heat. A CPU with 95 W TDP requires a 95W cooler, and so on. [3] Further specification of the CPU can be seen in Table 1.

*Table 1: Properties of Processor.*

| | |
|---|---|
| TDP | 95 W |
| $T_{junction}$ | 0℃-100℃ |
| $T_{storage}$ | -25℃- 125℃ |
| Dimension | 37.5mm ×37.5mm× 4.4 mm |


*Figure 1: Processor used in simulation.*

## III. Modeling

Geometry for the analysis was drawn on ANSYS Icepack. Geometry was made under the cabinet of dimension 400mm× 400mm× 250mm. Processor was kept above the PCB of dimension of 300mm×300mm×1.6mm. Processor was kept at the center of PCB. The effective conductivity of PCB is *k=0.35 W/m-K*. For the first case Plate-fin heat sink was placed above the processor. Fin of the heat sink was 2mm thick and 15 fins were used in the Analysis for quicker solution. The number of fins is usually higher in commercial heat sink. Openings on the heat sink fin was orientated in X direction. For the other case, rectangular pin fin heat sink was used. The number of fins in X-direction was 20 and the number of fins in Z-direction was 15. The Dimension of heat sink is summarized and can be seen in Table 2.

*Table 2: Dimension of Heatsinks used.*

| Heat Sink Dimension | | |
|---|---|---|
| Plate-fin heatsink | Number of fins | 15 |
| | Fin dimension | 2mm |
| | Base height | 10mm |
| | Overall height | 92mm |
| Pin-fin heatsink | Number of fins | 20×15 |
| | Fin dimension | 2 mm×2 mm |
| | Base height | 10 mm |
| | Overall height | 92 mm |

Fan was placed above the heat sink. Sanyo Denki fan with size 92m was used. Fan is 12 V DC fan and with the maximum speed of 9000 RPM. Sanyo Denki is a popular brand and most of the personal computer use those fans. The picture of the fan can be seen in Figure 2 and the properties of the fan can be seen in Table 3.


*Figure 2: Sanyo Denki Fan used in Project.*

*Table 3: Properties of fan used in project.*

| | |
|---|---|
| **Orientation** | X |
| **Fan radius** | 44mm |
| **Hub radius** | 22mm |
| **Case Size** | 92mm |
| **Case height** | 38mm |
| **Flow rate** | 120 cfm |
| **Speed** | 9000 RPM |

The cabinet is equipped with the opening in one side and grill in other in X direction as shown in Figure 3 and 4. The function of grill and opening is for the airflow from the cabinet to the surrounding. Both opening and grill has the dimension of 400mm×250mm but on the opposite side of the cabinet. The grill is more compact than the opening. The free area ratio was kept at 0.5.

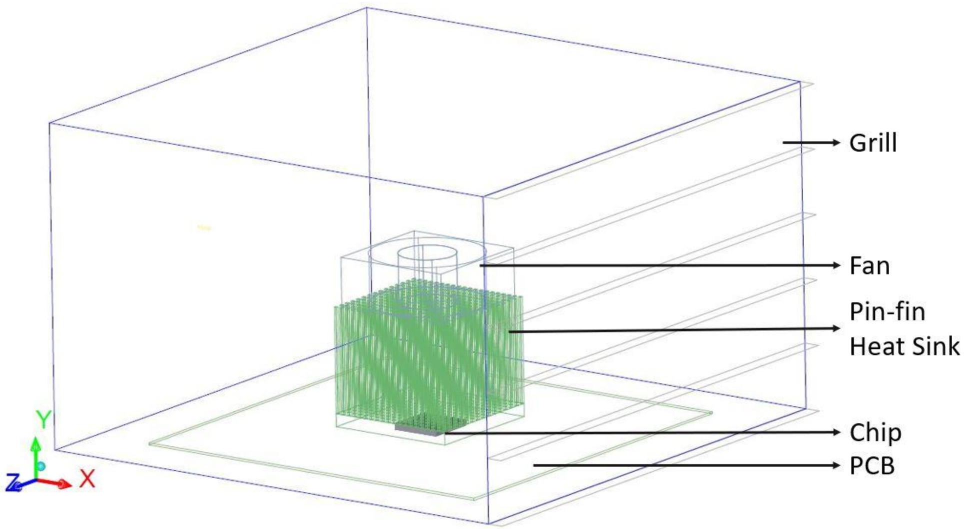


*Figure 3: CPU package with pin fin heat sink.*

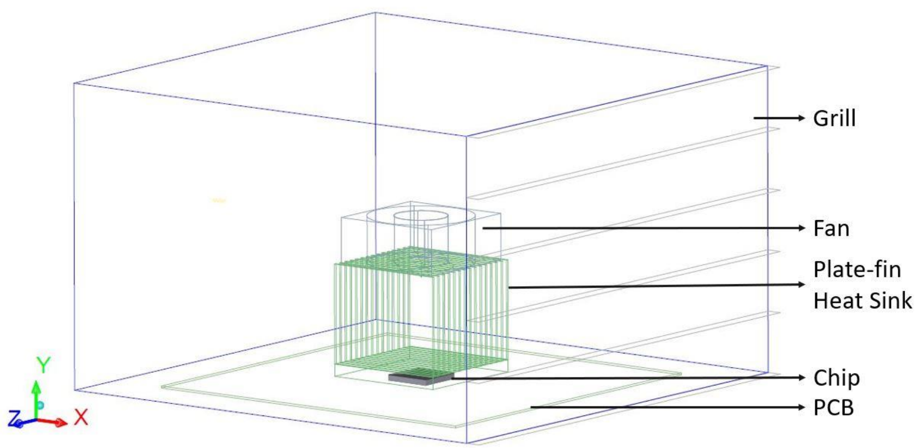


*Figure 4:CPU package with pin fin heat sink.*

After modeling the CPU package, meshing was done. Meshing was done with the default setting.

Mesh parameter for both models can be seen in Table 4.

*Table 4: Mesh Controls*

| | Mesh Control | |
|---|---|---|
| | Plate fin | Pin fin |
| Mesh type | Hexa Unstructured | Hexa Unstructured |
| No. of Elements | 1279448 | 1937153 |
| NO. of Nodes | 1315360 | 1984122 |
| Concurrency | 1 | 1 |
| Max Element Size | X axis: 4mm<br>Y axis :4mm<br>Z axis: 4mm | X axis: 4mm<br>Y axis :4mm<br>Z axis: 4mm |
| Mesh Parameter | Normal | Normal |
| Minimum Gap | X axis: 0.1 mm<br>Y axis :0.16 mm<br>Z axis: 0.1 mm | X axis: 0.1 mm<br>Y axis :0.16 mm<br>Z axis: 0.1 mm |

Figure 5 and 6 shows the mesh obtained for plate fin and pin fin respectively.

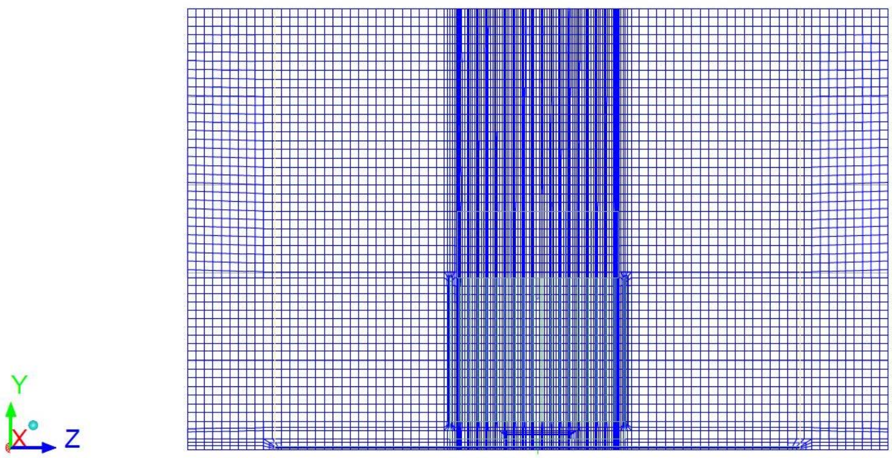


*Figure 5: Mesh in system with plate fin heat sink.*

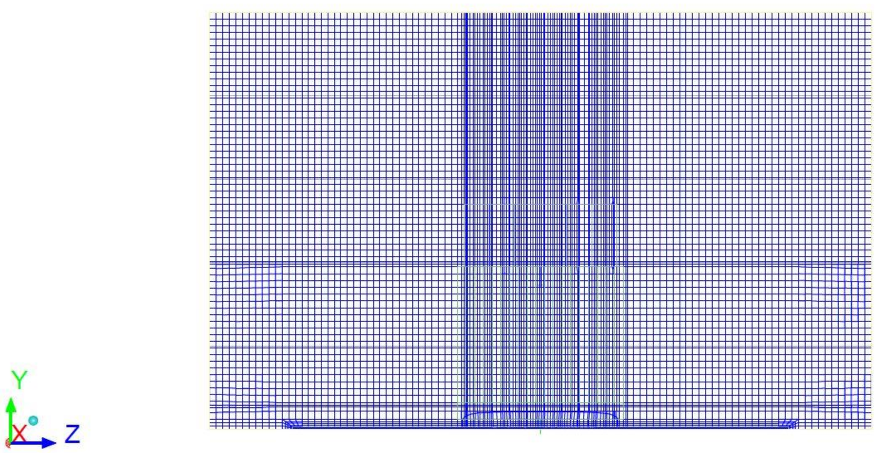


*Figure 6:Mesh in system with pin fin heat sink.*

Once the mesh was created, the basic parameter was set to run the solution. Both Flow (velocity/pressure) and Temperature was solved. Radiation was turned on and the flow regime was set to turbulent with two equations.

Ambient temperature was set to 24℃ and the fluid was set to air. Operating pressure was 1001325 N/m$^2$. Model was run for 1000 iterations for more accurate results.

## IV. Results and discussion

The objective of the project was to find the junction temperature of the processor using two types of heat sink. The junction temperature for two type of heat sink can be seen in Table 5.

*Table 5: Junction Temperature*

| Type | Junction Temperature |
|---|---|
| Plate-fin Heatsink | 39..80 ℃ |
| Fin-pin Heatsink | 45.33 ℃ |

The result was not as expected. Fin-pin Heatsink was expected to dissipate more heat due to the larger surface area but the result from the simulation was just opposite. This might be because of the position of opening and grill in the cabinet. In the case of plate fin heatsink, the position of grill and opening are in X axis and the position of the openings between the plates in the heatsink is in the X direction as well. Hence, the air from the fan was able to move out effectively by taking the heat away from the heatsink. On the other hand, the air gets trapped between the pins in the pin fin heat sink and the movement of the air outside the cabinet was not effective. So, the junction temperature of the processor while using Fin-pin heat sink was slightly greater than the pin fin. However, if the number of the pin in Pin fin heat sink is increased, the junction temperature will be lower.

Figure 7 and 8 shows the temperature profile of the system in XY plane for plate fin heat sink and pin fin heat sink, respectively.

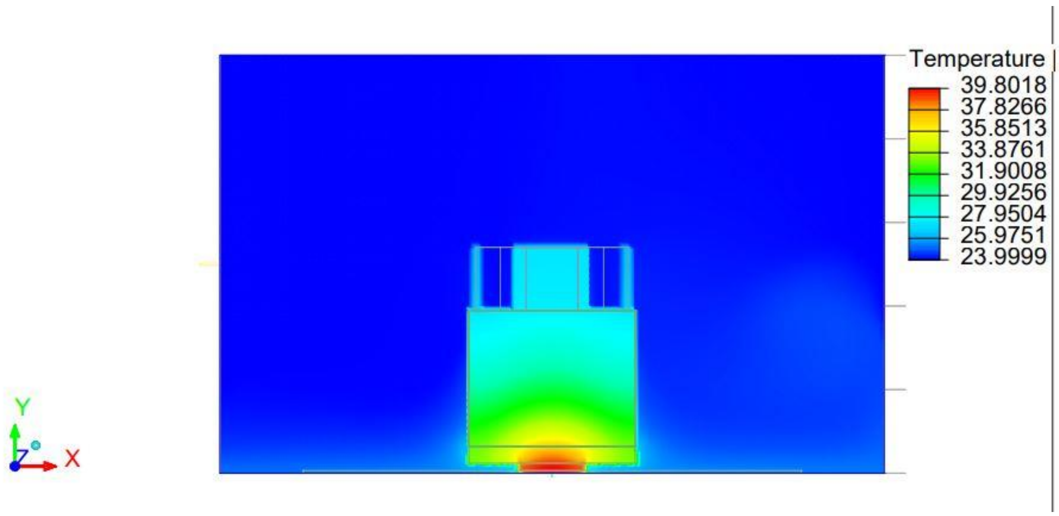


*Figure 7: Temperature profile of plate fin heat sink from XY plane.*

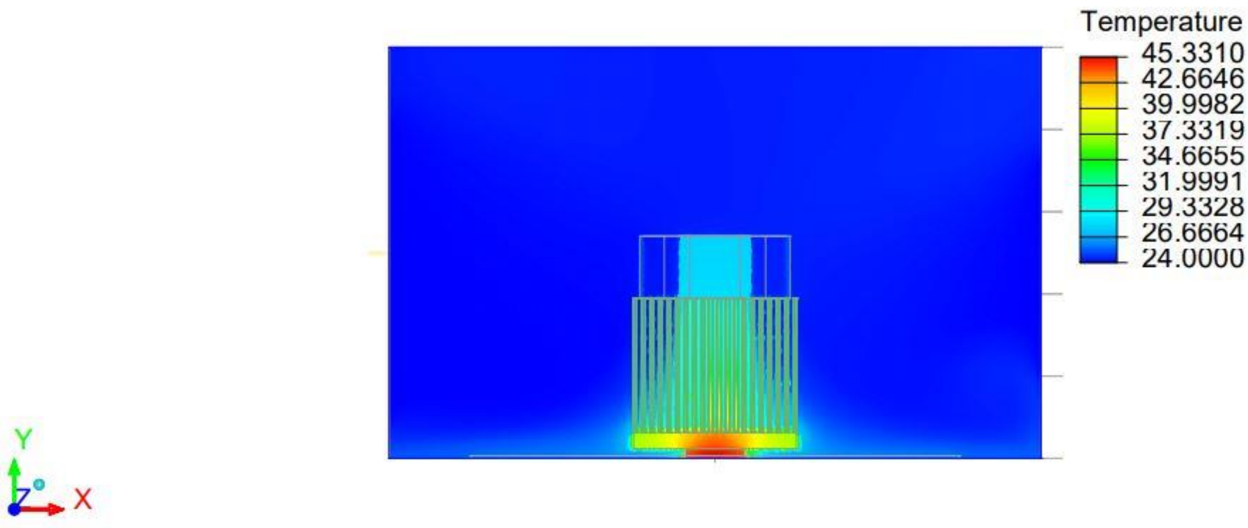


*Figure 8:Temperature profile of pin fin heat sink from XY plane.*

Figure 9 and 10 temperature profile of both block and PCB from the top view.

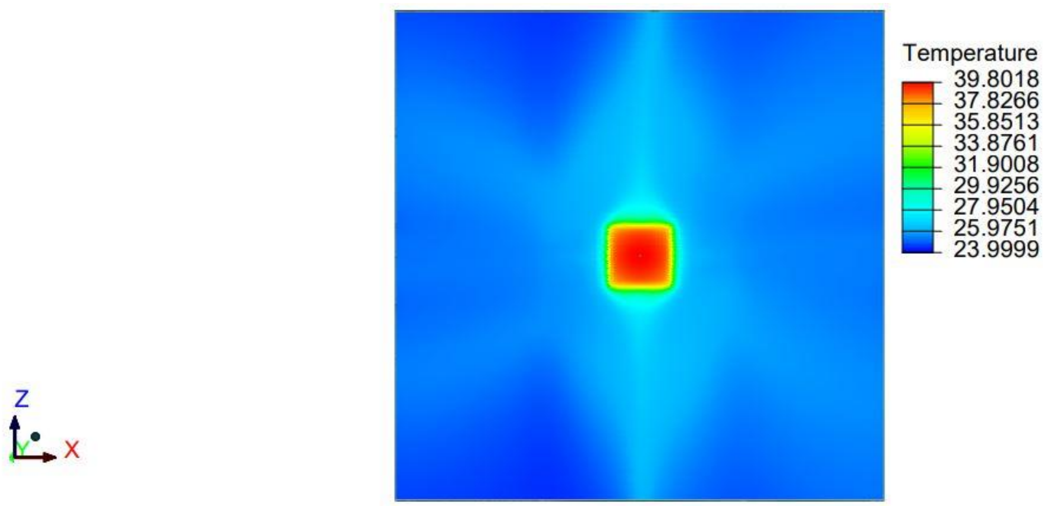


*Figure 9:Temperature profile of block and PCB in plate fin from the top view.*

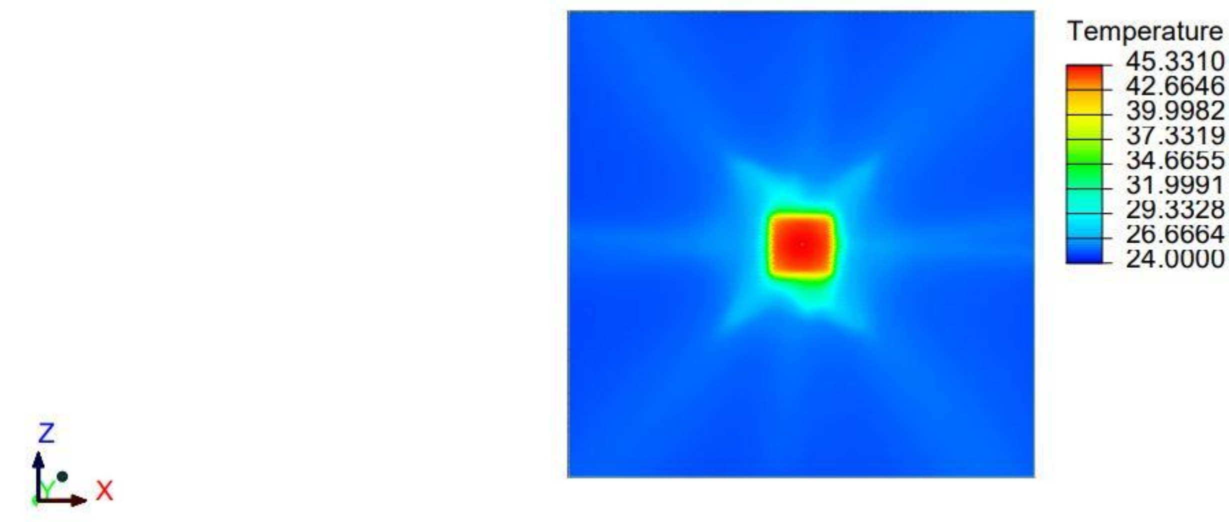


*Figure 10:Temperature profile of block and PCB in pin fin from the top view.*

Figure 11 and 12 shows the temperature profile of the plate fin heat sink and pin fin heat sink respectively. Most of the part of pin fin heat sink looks cooler which implies no good heat dissipation from the heat sink. Again, the reason might be the position of opening and grill on the cabinet.

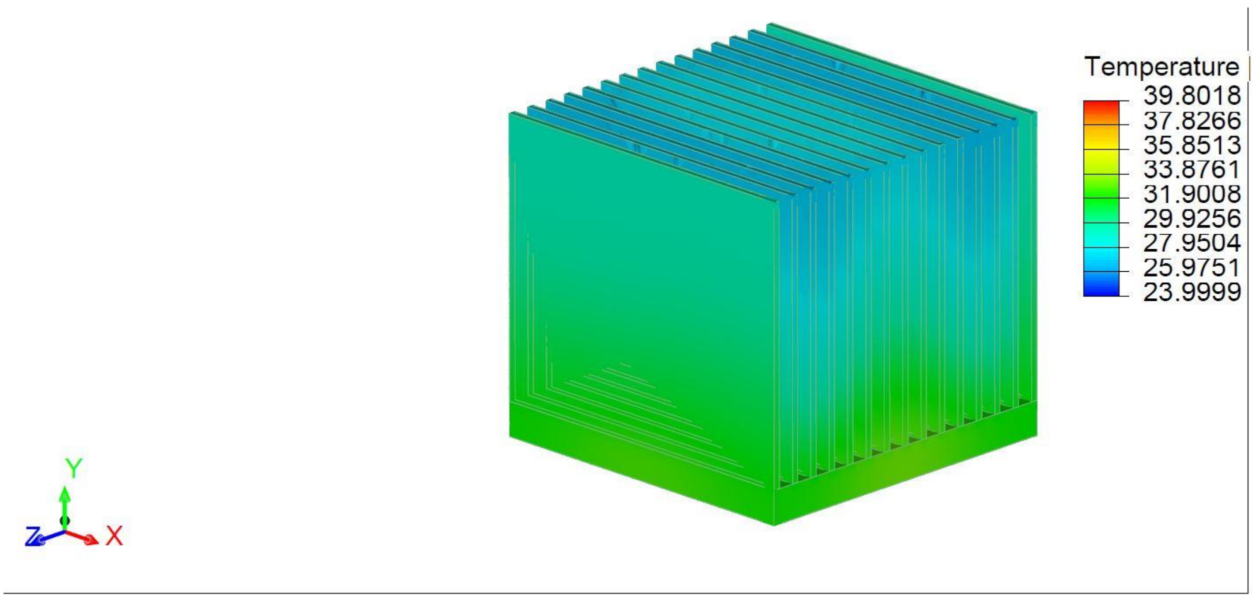


*Figure 11:Temperature profile of the plate fin heat sink.*

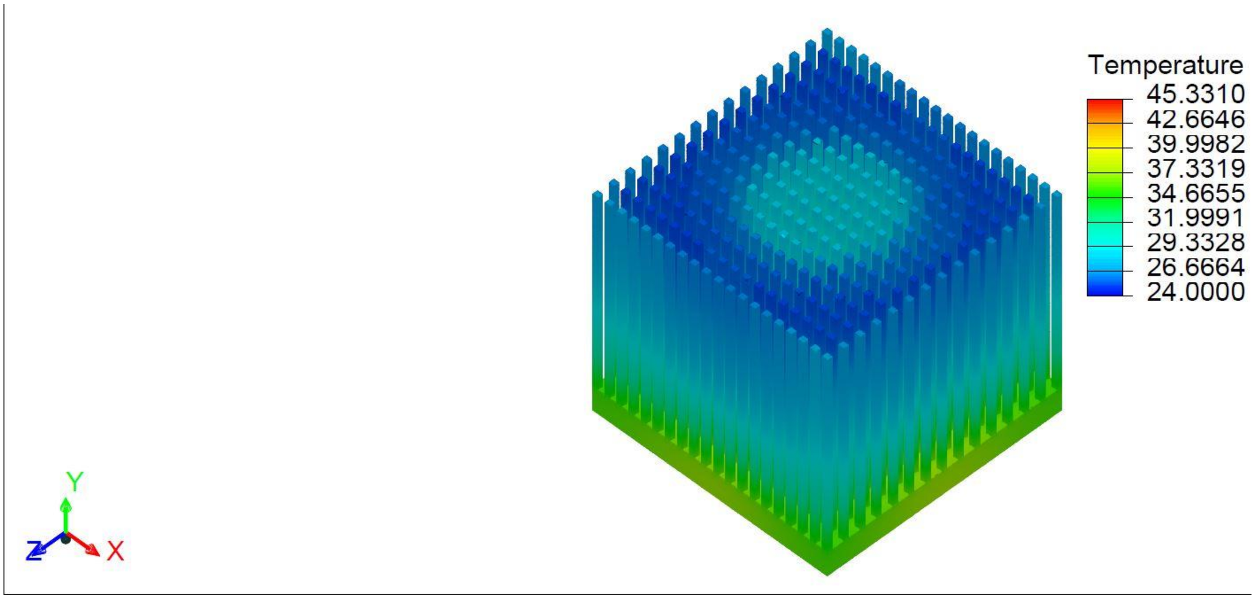


*Figure 12:Temperature profile of the pin fin heat sink.*

Figure 13 and 14 shows the velocity vector which helps to visualize the flow of the air inside the cabinet. The maximum velocity on the plate fin heat sink was 19.0974 m/sec while the maximum velocity on the pin fin heat sink was 18.77 m/sec.

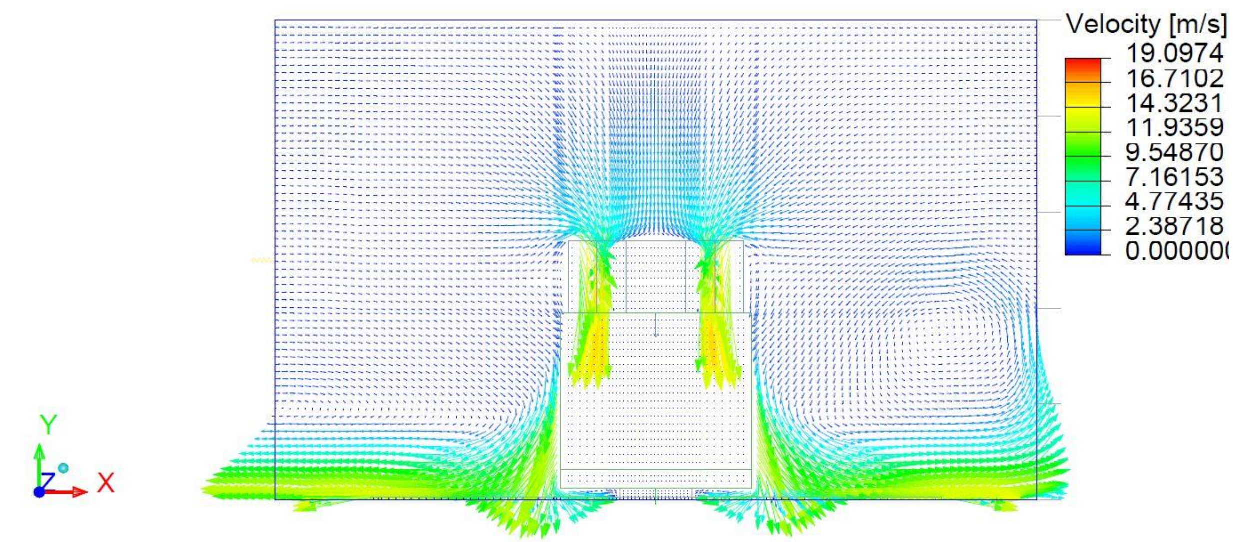


*Figure 13: Velocity vector on plate fin heat sink.*

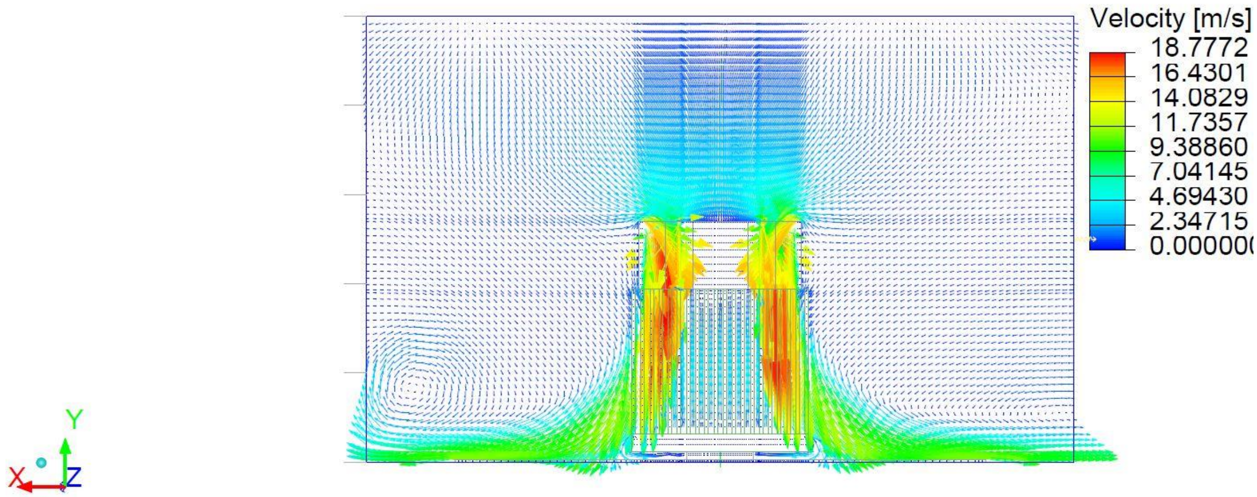


*Figure 14: Velocity vector on pin fin heat sink.*

## V. Conclusions and recommendation

Comparing plate fin heat sink and pin-fin heat sink, plate fin heat sink seems to have the higher dissipation rate as compared to the plate fin heat sink. The junction temperature when plat fin heat sink was used was 39.8℃ and the junction temperature when pin fin was used was 45.33℃. The maximum velocity of the air inside the cabinet was slightly higher for the pate fin heat sink than pin fin with 19.09 m/s compared to 18.77 m/s.

## VI. Reference

[1] Yeom J., Singh T. (2017). *Electronic cooling.* Retrieved from: Electronic Cooling - an overview | ScienceDirect Topics

[2] WikiChip (n.d.). Semiconductor and computer Engineering. *Core i9-9900K- Intel.* Retrieved from: Core i9-9900K - Intel - WikiChip

[3] Hruska J. (2018). *Why Intel TDP Measurements Don't Reflect Real-World Power Draw*. Rerived from: Why Intel TDP Measurements Don't Reflect Real-World Power Draw - ExtremeTech