Thermal Design of Electronic Equuipment - ME 409

Group 3

4th Year, 7th Semester

Department of Mechanical Engineering

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Contents

1 INTRODUCTION

1.1 Introduction to Heat Sink

Heat sinks are one of the most common forms of thermal management in technology, machinery, and even in natural systems. A heat sink is a component that increases the heat flow away from a hot device. It accomplishes this task by increasing the device's working surface area and the amount of low-temperature fluid that moves across its enlarged surface area. To understand the principle of a heat sink, consider Fourier's law of heat conduction. Fourier's law of heat conduction, simplified to a one-dimensional form in the x-direction, shows that when there is a temperature gradient in a body, heat will be transferred from the higher temperature region to the lower temperature region. The rate at which heat is transferred by conduction,

qk, is proportional to the product of the temperature gradient and the cross-sectional area through which heat is transferred.

$q_k = -kA\frac{\mathrm{d}T}{\mathrm{d}x}$

For example, the jetson Nano has a large heat sink to assist in cooling the onboard Quad-core ARM A57 CPU and 128-core NVIDIA Maxwell GPU, both of which create ample amounts of heat and require exceptional cooling to avoid thermal throttling. Similarly, Raspberry Pi microcontrollers have a built-in heat dissipator, which they use in conjunction with a heat sink to increase the onboard Broadcom chip's performance.

Why Heat Sinks?
Every electrical and electronic component in a circuit generates some amount of heat while the circuit is executed by providing a power supply. Typically high-power semiconducting devices like power transistors and optoelectronics such as light-emitting diodes, lasers generate heat in considerable amounts and these components are inadequate to dissipate heat, as their dissipation capability is significantly low.
Due to this, heating up of the components leads to premature failure and may cause the failure of the entire circuit or system's performance. So, to conquer these negative aspects, heat sinks must be provided for cooling purposes we need a heat sink.

1.2 Introduction to problemn statement

XYZ corporation makes electronics gadgets want to release a novel product in the market by June 2021. They have approached you for seeking solutions for the thermal design of their product. Hence, each group is requested to provide a thermal design solution for cooling of their equipment using CFD-HT (Computational Fluid Dynamics and Heat Transfer) software. The task for each group will also vary which is explained further. The solutions are to be provided for 2D (Two Dimensional) analysis only with the specified constraints. The figure below shows the domain.

1. Length of PCB = 250 mm
2. Thickness of PCB = 4 mm

3. Length of glue (epoxy) = 40 mm
4. Thickness of glue (epoxy) = 1.5 mm
5. Length of novel chip = 30 mm
6. Thickness of novel chip = 2.5 mm
7. Length of Heat Sink = 60 mm
8. Thickness of heat sink = 40 mm
9. Thickness of air from PCB top surface OR location of solid wall from PCB top surface = 80 mm. Solid wall is adiabatic.
10. The novel chip temperature 75 ℃ and uniform across the surfaces in contact.

2 METHODOLOGY

In this assignment, the design problem and relevant parameters were realized and the following methodology was adopted to get the most possible accurate and efficient results.

2.1 Design of heat sink

Considering the geometrical design as one of the primary factor, five different types of heat sink were designed, namely -
1) Heat sink (Fins) Perpendicular to Inflow
2) Heat sink (Fins) Parallel to Inflow
3) Tapered Fin Design
4) Angular (semi-Circular) Fin Design
5) I - section Design

Considering the number of fins in the heat sink as a crucial parameter, two heat sinks with different number of fins were designed, namely -
1) Heat sink (Fins) Perpendicular to Inflow – 6 fins
2) Heat sink (Fins) Perpendicular to Inflow – 8 fins

2.2 Selection of heat sink

Based on comparisons of all the various geometrical designs of heat sink under identical parameters, the Angular (Circular) Fin Design was selected as the optimum design and in-depth analysis were performed on the same heat sink design.

2.3 Simulations

Grid independence was achieved. Furthermore, the velocity, temperature and pressure profiles were generated for the selected heat sink design.

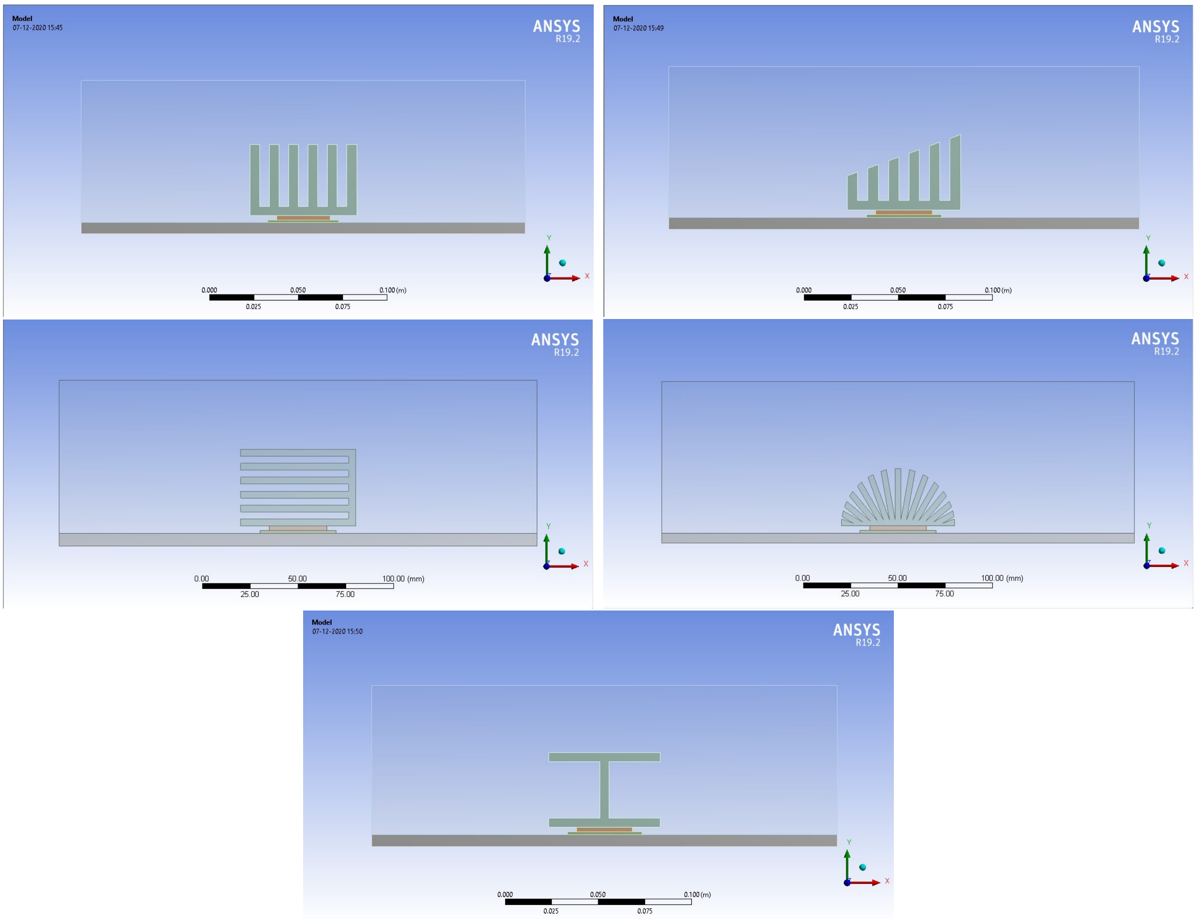

Figure 1: **Perpendicular, Tapered, Parallel, Circular, I section geometries**

3 SOLUTION

3.1 Introduction to different design of heat sink based on geometry

The design of the heat sink as a function of geometry acts as an important aspect in determining the heat dissipation rate and the overall cooling effect. The following are the primary heat sink designs proposed for this assignment.

1) Heat sink (Fins) Perpendicular to Inflow

The first model is based in an arrangement, where the fins are designed perpendicular to the chip and the inlet airflow as shown in fig.1. The distance between two consecutive fins is given 5mm (width distance). Fig.2 shows the heat dissipation from the chip after 1000 iterations.

2) Heat sink (Fins) Parallel to Inflow

The second model of heat sink is similar to the first model. The difference lies in the position of the fins. It is placed parallel to the chip and the inlet flow instead of perpendicular as shown in fig.1 . The fig.2 shows the total heat dissipation of the heat from the chip

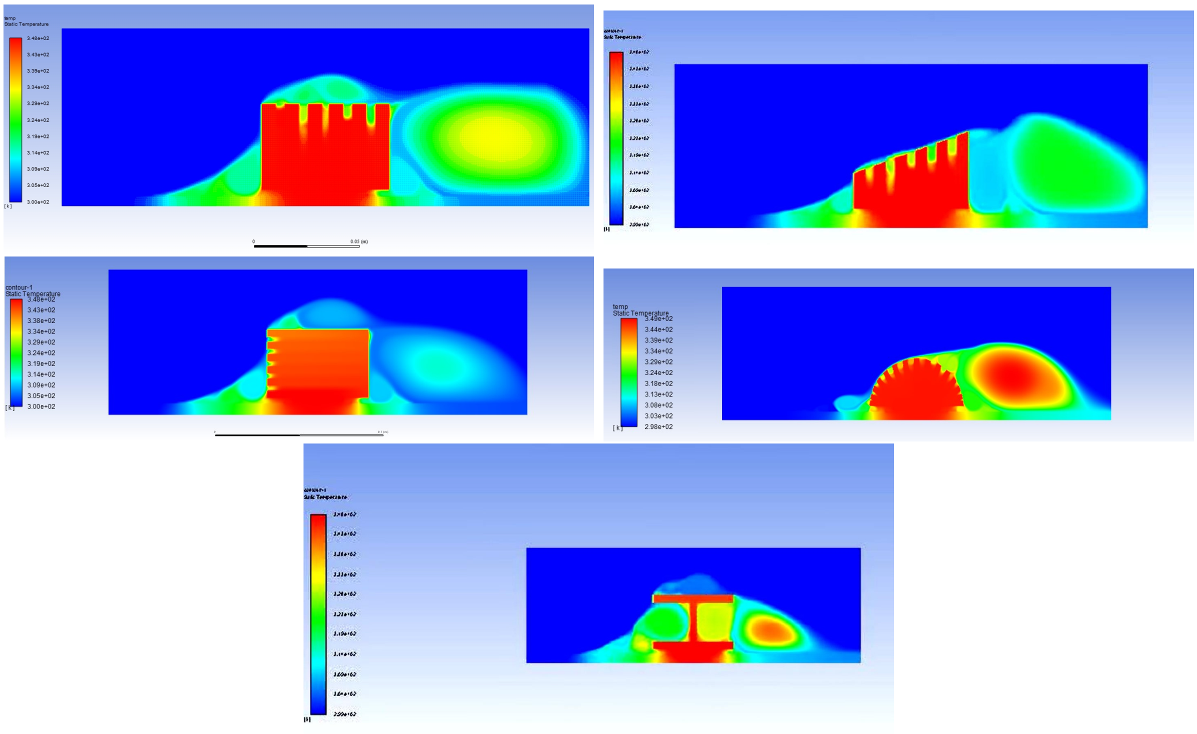

Figure 2: **Perpendicular, Tapered, Parallel, Circular, I section contours**

after 1000 iterations. It can be observed that this change in fin positioning has resulted in increased cooling effect as a result of continuous air flow Each fin has a width of 40/11 mm.

3) Tapered Fin Design

The third model has a variant design where the heat sink is cut diagonally at an acute angle of 70 degrees form $\frac{1}{4}$ th length (from the base) as shown in fig.1. The fig.2 shows the total heat dissipation of the heat from the chip after 1000 iterations. It can be observed that the heat dissipation is improved in the PCB level as a result of no discontinuity in the flow.

4) Angular (semi-Circular) Fin Design

In the fourth design, there is a complete change in the overall geometry of the heat sink from a rectangular cross-section to a circular cross-section as shown in fig.1. The fins are well placed above the chip in a semicircle with an equal angel spacing of 10 degrees . The fig.2. Shows the total heat dissipation of the heat from the chip. A good e overall cooling effect in the pcb, epoxy and heat sink region can be observed.

5) I-section design

In the fifth and final model of heat sink, a classic I -section geometry has been incorporated as the geometry for the heat sink as shown in fig.1. The fig.2 shows the total heat dissipation from the chip after 1000 iterations. It can be observed that there is a significant cooling effect in the epoxy region but not much change in the pcb and heat

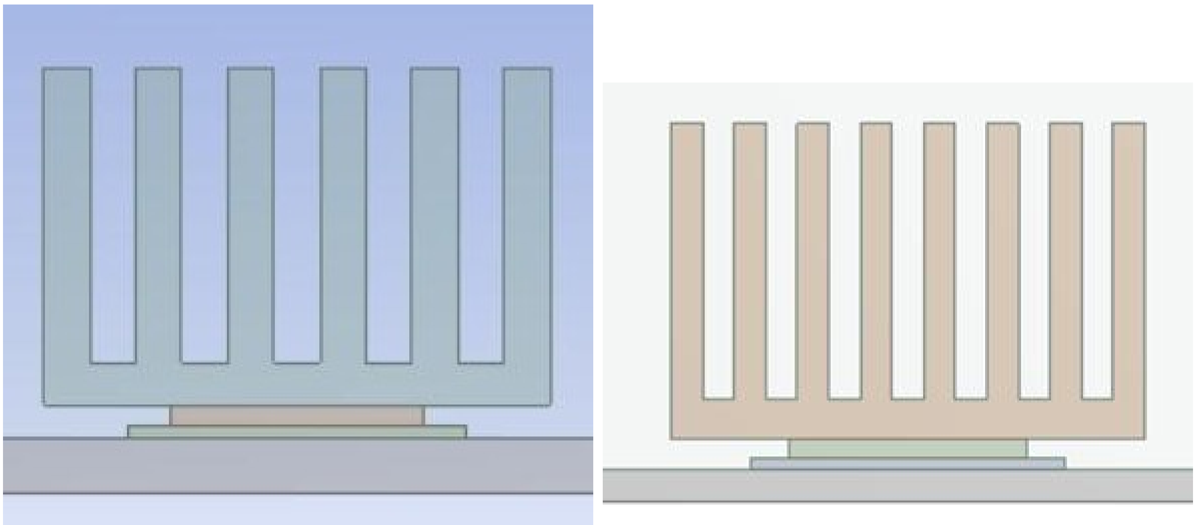

Figure 3: **Geometries of 6 fin and 8 fin heatsinks**

sink regions.

3.2 Introduction to different design of heat sink based on fins

Different parameters in designing of the heat sink determines the efficiency of the heat sink. One of such important parameters is the number of fins in the heat sink. Thus, in this assignment, the effect of such change in the cooling effect due to the change in the number of fins is also analysed. The test cases used for this analysis are -

1) Heat sink (Fins) Perpendicular to Inflow – 6 fins

This design is the same as explained in section 3.1. The number of fins selected are - 6 as shown in fig.3.

2) Heat sink (Fins) Perpendicular to Inflow – 8 fins

Similarly here, while the overall geometry lies the same, the number of fins have been changed from 6 to 8 as shown in fig.3.

4 SIMULATIONS and RESULTS

4.1 Heat Sink Analysis based on different geometrical designs

From the proposed primary designs of heat sink based on geometrical differences, a comparison was made on all these designs for heat dissipation and cooling effect under identical influential parameters. The constant parameters were:

a) Inlet air velocity - 5 m/s
b) Grid element size - 0.001 m
c) Number of Iterations - 1000

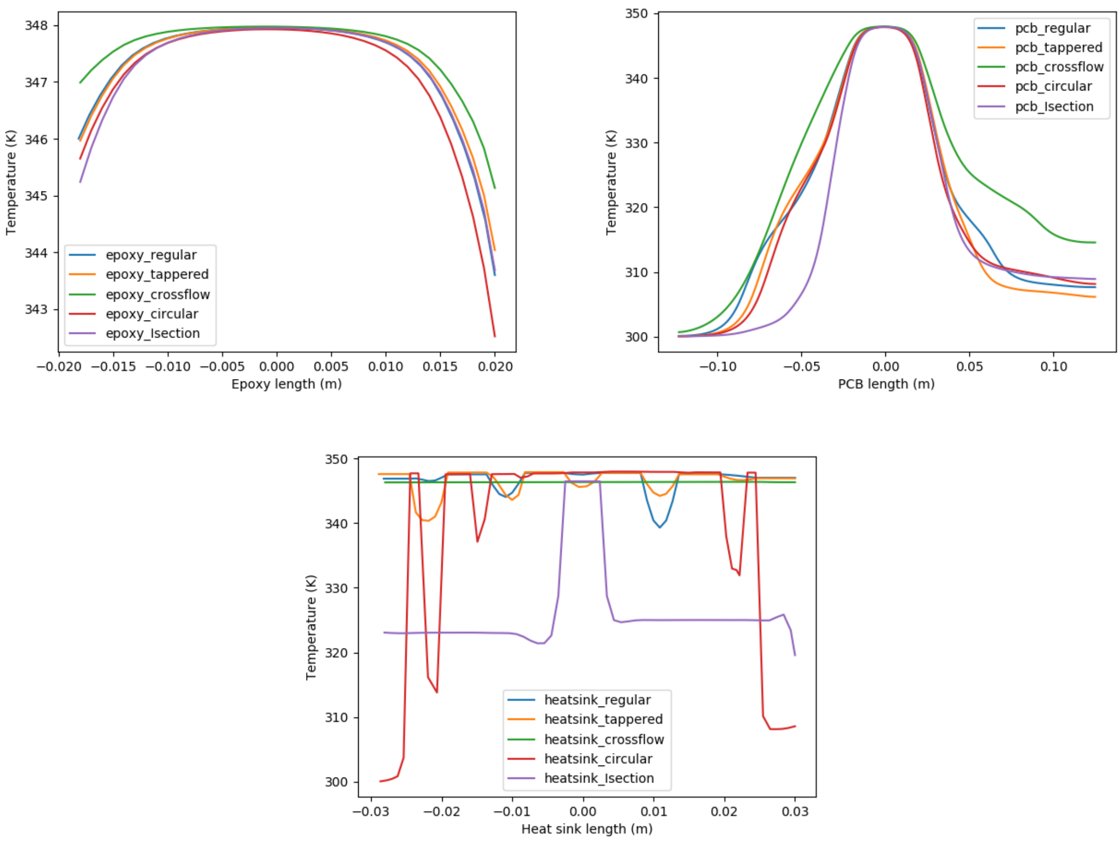

Figure 4: **Comparision between various geometries**

The following line plots in fig.4 show the various temperature changes across the epoxy, heat sink and pcb lengths. It can be observed that the angular design of the heat sink fits as an optimum design due to the following reasons:

a) The increased number of fins and the structure of the geometry allows no obstruction in the flow of heat.

b) Among all the designs, this design has the most effective cooling across both epoxy and heat sink length. Also, the cooling effect across PCB length, despite not being the most effective but is still comparable and efficient for consideration.

4.2 Heat Sink Analysis based on fins

It has been already established that the number of fins in a heat sink does affect the overall cooling effect. Thus, to analyse this theory, comparison was made on the two designs of heat sink with varying the number of fins from 6 to 8 for heat dissipation and cooling effect under identical influential parameters. The constant parameters were:

a) Inlet air velocity - 5 m/s

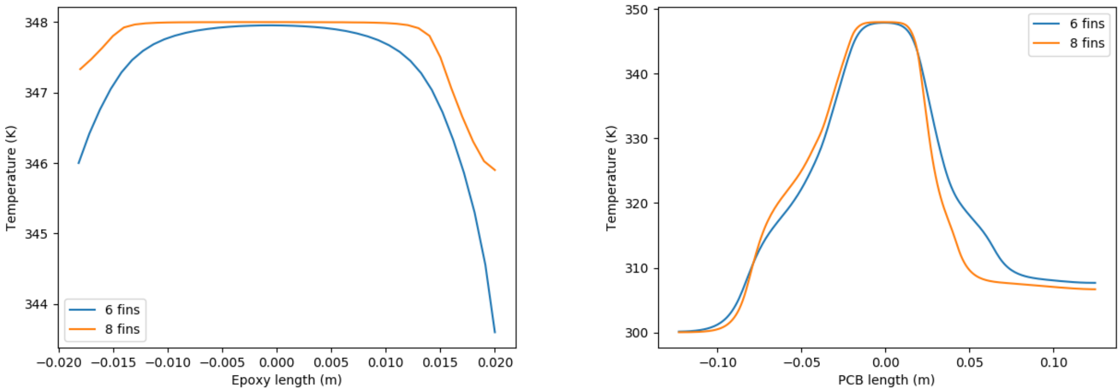

Figure 5: **Comparision between 6 and 8 fin lineplot**

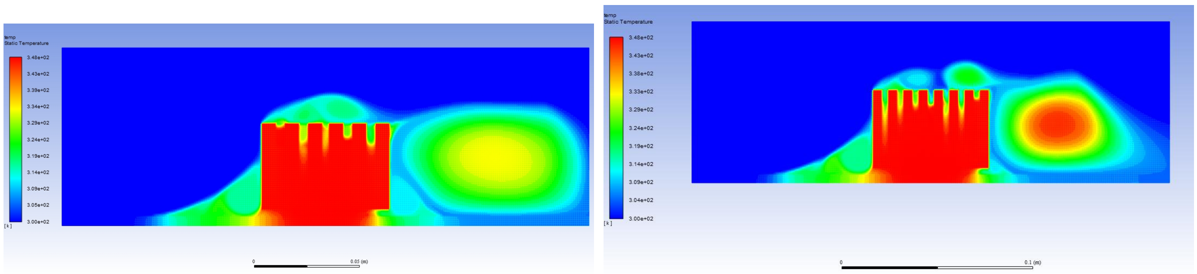

Figure 6: **Geometries of 6 fin and 8 fin contours**

b) Grid element size - 0.001 m
c) Number of Iterations - 1000

From the line plots in fig.5 and fig.6, the results show that the total heat that can be extracted from a heat sink, is a function of number of fins and the device thermal characteristics. Also, there is an optimum point with respect to heat transfer from the heat sink and the number of fins. In this analysis , it can be observed that there is improvement in the overall heat dissipation with the design consisting of 8 fins rather than 6 fins. Also, the cooling effect is found to be very effective with 8 - fins across the pcb length compared to having only 6 - fins.

4.3 Analysis of angular heat sink

4.3.1 Grid Independence

Three different element sizes were used -0.0005, 0.005, 0.01 as shown in fig.7. As a result, three different size meshes were generated for accomplishing grid independence . All the three meshes were refined at the heat snk and epoxy surfaces for better flow capturing.

The following line plots exhibits the temperature variations along the midline of epoxy and PCB lengths as shown in fig.8:
We can see that there is very little variation in the plots with increasing grid size. We can conclude that our results are grid independent.

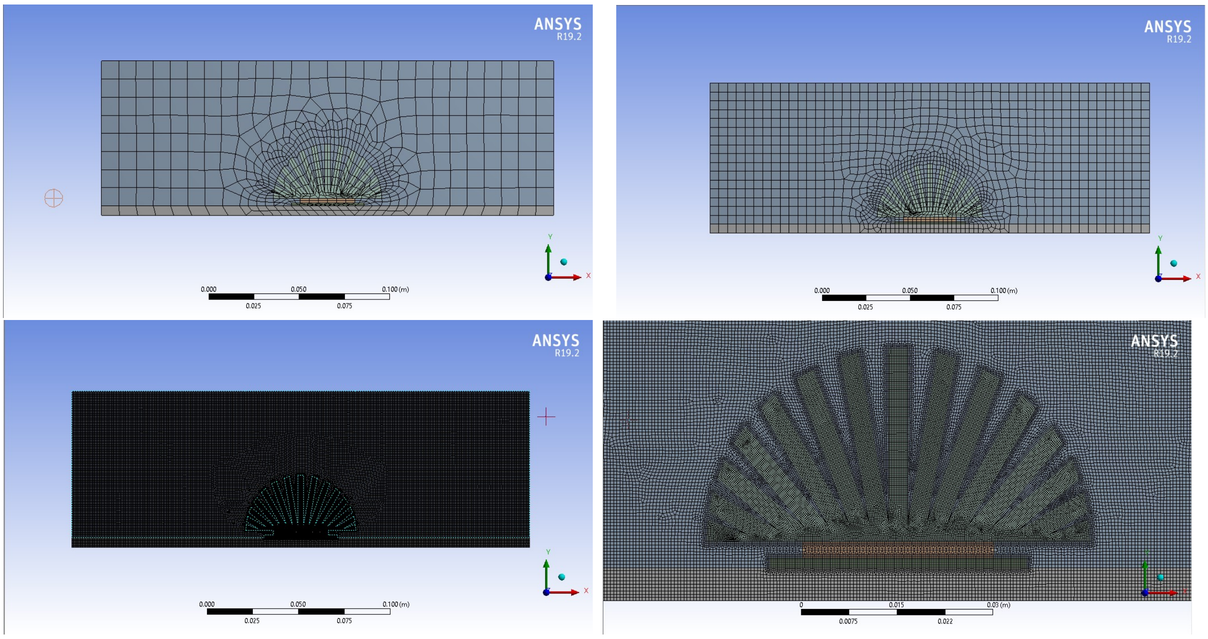

Figure 7: **Circular geometry mesh sizes**

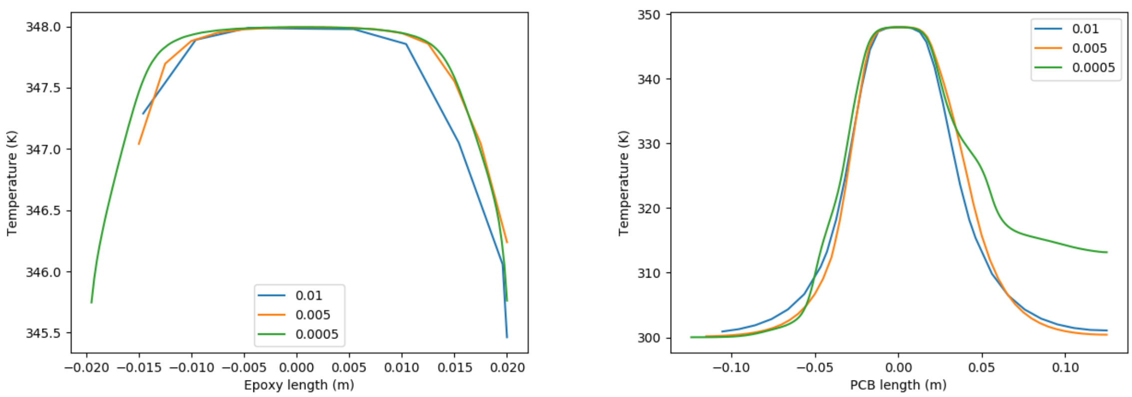

Figure 8: **Epoxy and PCB Midline**

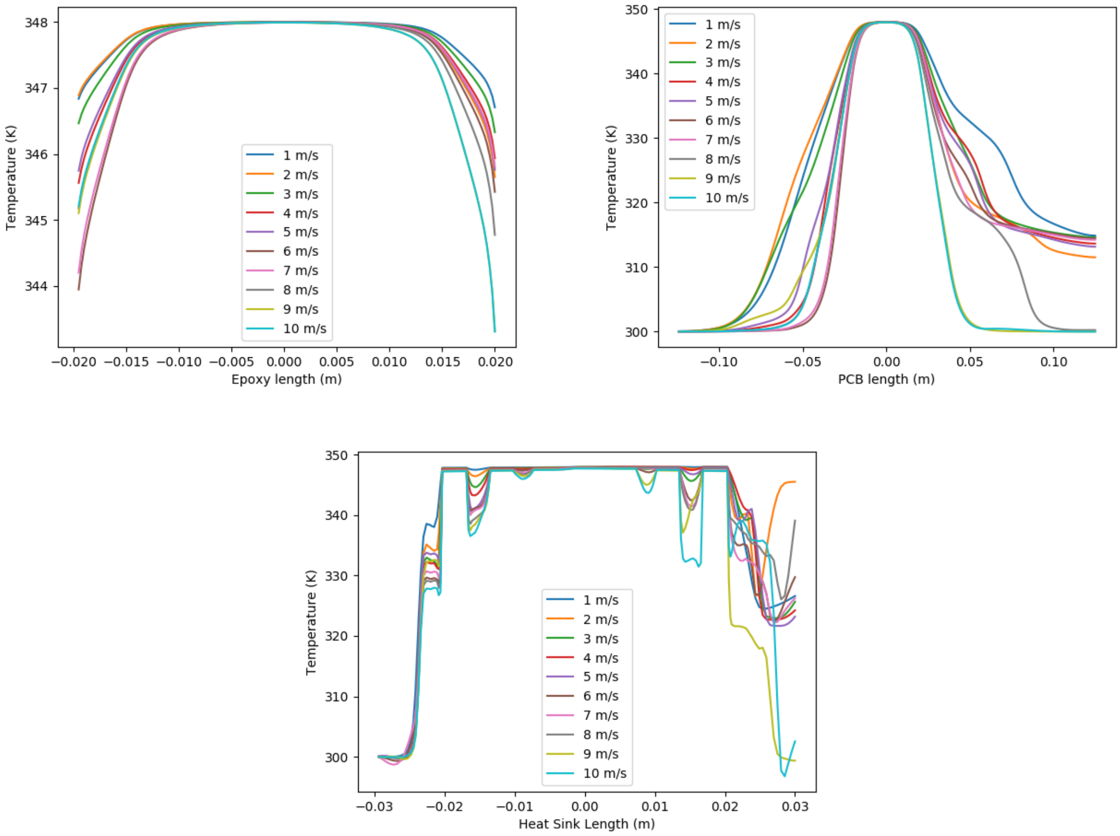

Figure 9: **Velocity at Epoxy, PCB and Heatsink Midline(clockwise)**

4.3.2 Temperature analysis

The primary and fundamental objective of this assignment is to study and analyse the heat dissipation patterns and cooling effects that occur in a thermal system. Thus , the line plots as show in fig.9 and fig.10 the various heat dissipation variations as a function of increasing velocities of inlet air.

Similarly, the variation of temperatures were also analysed at different locations of the entire thermal system.

Following are the contour plots of the heat dissipation at varying velocities as shown in fig.11.

4.3.3 Pressure analysis

After the main objective (temperature analysis), our solution also extends in other fields such as pressure. The following are the contour plots for the variation in pressure across the entire domain with increase in inlet velocity as shown in fig.12.

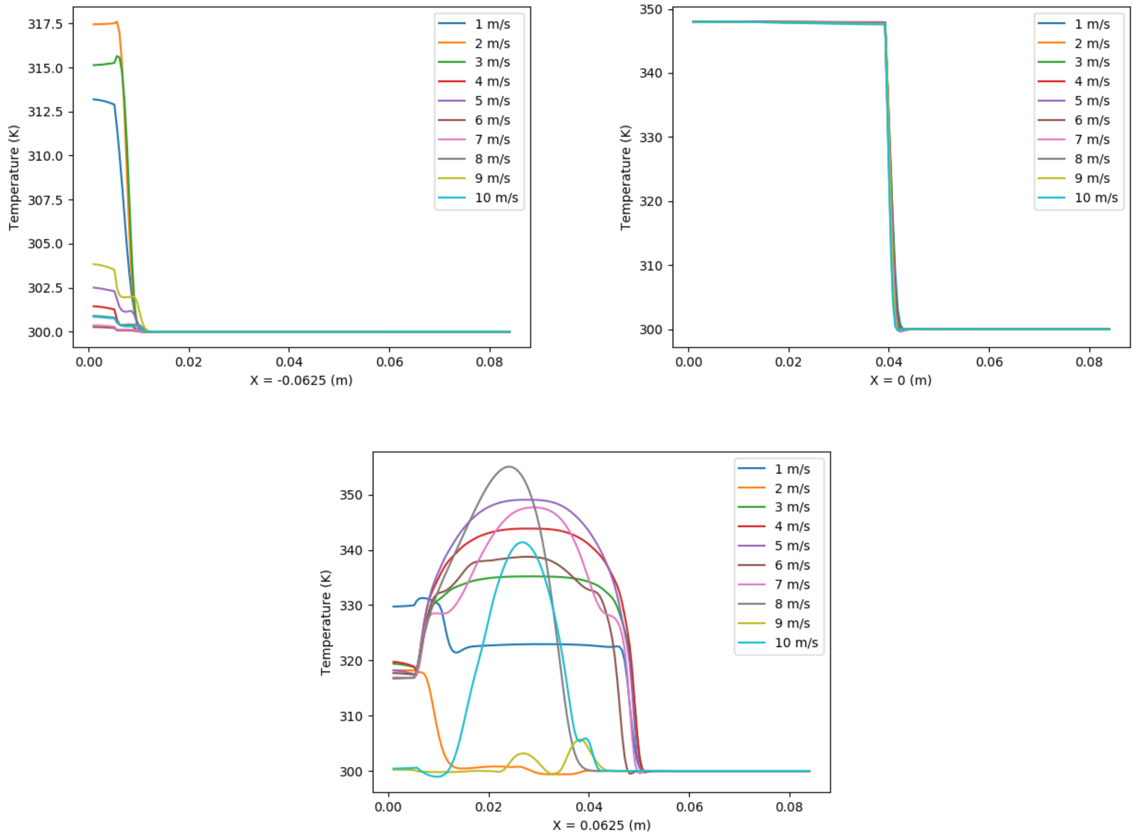

Figure 10: **Velocity at at X = -0.0625, 0, 0.0625(clockwise)**

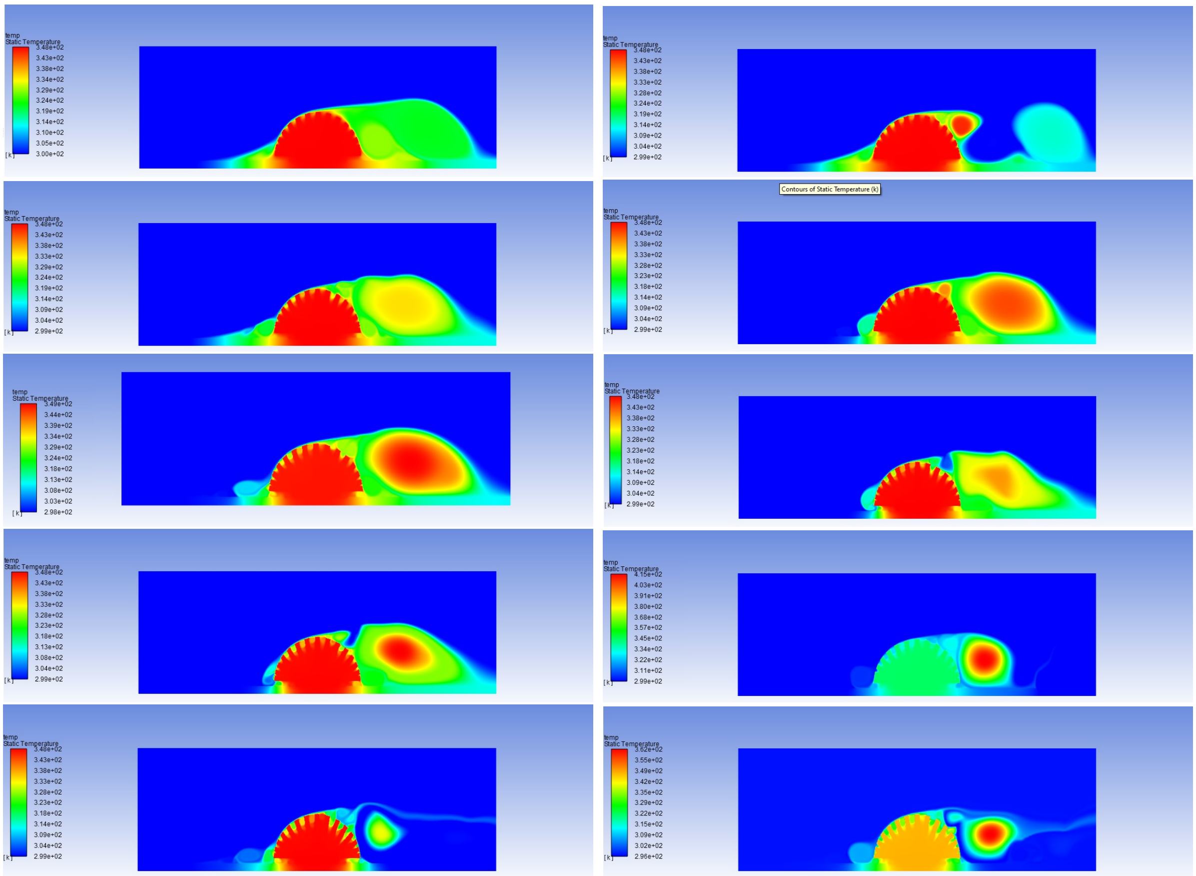

Figure 11: **Temperature variation with increasing velocity(clockwise)**

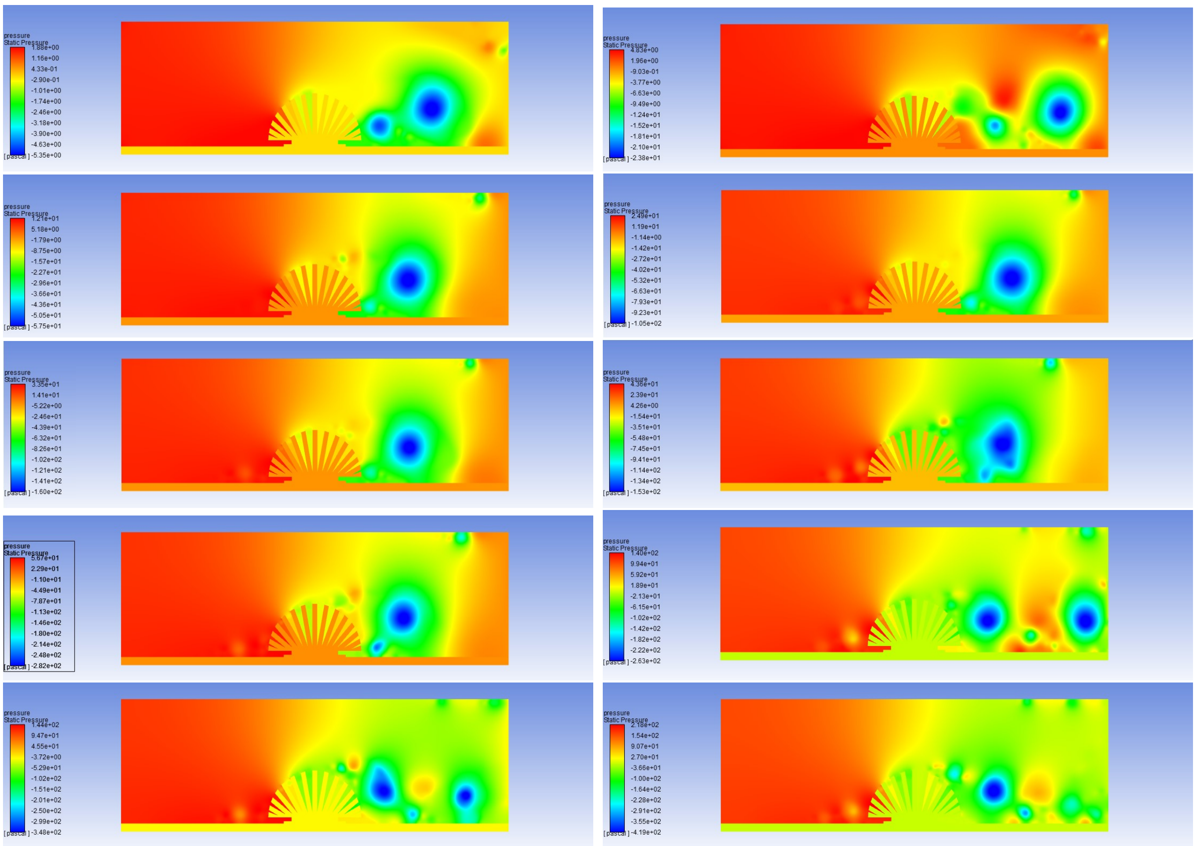

Figure 12: **Pressure variation with increasing velocity(clockwise)**

5 CONCLUSION

The analysis of the problem statement has provided some concrete information regarding the parameters and design techniques needed to design a thermal system, specifically a heat sink. This particular assignment, it has also helped to realize the following points:

a) Among all the designs, the angular design of the heat sink is a good blend of both the number of fins and geometry for obtaining optimum cooling.

b) The number of fins is directly proportional to the cooling effect for a particular inlet velocity and heat sink material.