DESIGN AND ANALYSIS OF HEATSINK FOR SPLIT AIR CONDITIONER

A Dissertation submitted in fulfillment of the requirements for the Degree
of

MASTER OF ENGINEERING

in
Thermal Engineering

Submitted by

Abhishek Yadav
802083002

Under the Guidance of
Mr. Sumeet Sharma
Associate Professor

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

2022

Mechanical Engineering Department
Thapar Institute of Engineering & Technology, Patiala
(Declared as Deemed-to-be-University u/s 3 of the UGC Act., 1956)
Post Bag No. 32, Patiala – 147004
Punjab (India)

DECLARATION

I hereby certify that the work presented in the dissertation titled "Design and Analysis of Heatsink for Split Air Conditioner," which was submitted to the Mechanical Engineering Department of Thapar Institute of Engineering & Technology (Deemed to be University) in partial fulfillment of the requirements for the award of the degree of Master of Engineering in Thermal, is an authentic record of the work I did under the guidance of Mr. Sumeet Sharma. It makes reference to the study of other researchers, which is carefully noted in the reference section. Except as noted in the text and references, the information in this dissertation has not been submitted, in whole or in part, for any other degree at any other institution or institute.

Abhishek

Place: Patiala
Date: 26/7/2022

Abhishek Yadav
Roll No.: 802083002

I certify that, to the best of my knowledge and belief, the student's aforementioned claim is true.

Sumeet Sharma

Mr. Sumeet Sharma
Associate Professor, MED
TIET, Patiala-147004

DECLARATION

I, Abhishek Yadav, hereby certifies that the project titled "Design and Analysis of Heatsink for Split Air Conditioner" is an accurate representation of the work I did at LG Electronics India Pvt. Ltd. as a part of the internship/training I undertook during my final year of M.E.I declare that I have successfully completed my Industrial Major Project, under the guidance of my industrial mentor, Mr. Vishal Bansal, from 18th August, 2021 till 31st July, 2022

Abhishek

Signature of the candidate

Abhishek Yadav

Roll no- 802083002

Date- 23-06-2022

Signature of Industry Mentor

Mr. Vishal Bansal

Deputy Manager (RAC Quality)

LG Electronics India Pvt. Ltd

Date- 23-06-2022

ACKNOWLEDGMENTS

Foremost, I would like to thank LG Electronics India for letting me be a part of their Air Conditioner Quality Department and entrust their testing processes to my seniors and me. The opportunity itself represented a plethora of learning about practical approaches, techniques, and procedures related to my Thermal background. I would like to thank my industrial mentor, Mr. Vishal Bansal, my senior colleagues-Vinay Sharma, Aman Sharma, and Shubham Singhal, and my Thermal Batchmates for always guiding me wholeheartedly in the best way in each and every step of my M.E. Industrial training. This project would have been impossible without their support.

I would also like to thank my university mentors-Mr. Sumeet Sharma, for supporting me in every way for completing my thesis work for my final year.

Finally, I would like to thank the Thapar Institute of Engineering and Technology for providing me with this Internship program for my Major Project and also an opportunity to hone my skills in my engineering career.

ABSTRACT

The advancement of the Air conditioner and their utilization is rapidly increasing day by day. But the reliability of electronic components is critically affected by the temperature at which the junction operates. So, for cooling the electronic devices heatsinks are used. In the air conditioner, the heatsink is used to cool down the PCB (which is the brain of the Air conditioner). The main focus of this project is to design a better Heatsink than the previous one that is used in LG. As the previously used heatsink causes faulty errors in the PCB. While checking by the field engineer it was found that the Heatsink temperature is high which causes short-circuiting in the IPM chip which is placed below the heatsink. As heatsinks main function in PCB (printed circuit board) is to cool down the main four chips which are IPM, IGBT, FR, and Bridge Rectifier.

The finest Heatsink for effective cooling of PCBs will be shown in this study. The selection of the best heatsink depends on a variety of geometric factors, including the height of fin, number of fins, baseplate thickness, shape of fins, and material. As a result, preliminary research on the fluid flow and heat transfer properties of common continuous heatsinks of various designs has been conducted through CFD simulations. The results show that a heatsink design with rectangular fins and holes produces the best cooling, however, we are unable to employ perforated heatsinks because of their high manufacturing costs. But in the future, if some advancement in the manufacturing field takes place and the cost of perforated fin decreases then it might be considered for use in HVAC heatsinks. For this reason, we go towards the Plate Fin heatsink as its manufacturing cost is the least and most easily available in the market. An experimental approach also takes place from which we can validate our result.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

A_c	Area of cross-sectional area of heatsink (mm^2)
b	Fin spacing (mm)
h_f	Height of fin (mm)
h	Heat Transfer Coefficient (W/m^2K)
k_{air}	Thermal Conductivity of air (W/mK)
k	Thermal Conductivity of aluminium (W/mK)
L_b	Length of baseplate (mm)
L_c	Characteristic Length (mm)
n	Number of fins
Nu	Nusselt Number
P	Perimeter (mm)
Q	Heat Load (W)
Re	Reynold Number
S	Source Term
T_a	Ambient Temperature (℃)
T_s	Surface Temperature (℃)
T_f	Film Temperature (℃)
T_{SH}	Temperature of surface of Heatsink (℃)
v	Velocity of air (m/s)

GREEK SYMBOLS

μ	Dynamic viscosity (N.s/m^2)
ν	Kinematic viscosity (m^2/s)
ρ	Density (kg/m^3)
η_{fin}	Fin Efficiency (%)
τ	Viscous Stress Component
ϕ	Porosity

ABBREVIATIONS

PCB	Printed Circuit Board
WBT	Wet Bulb Temperature
DBT	Dry Bulb Temperature
IDU	Indoor Unit
ODU	Outdoor Unit
PFHS	Plate Fin Heat Sink
IPM	Intelligent Power Module
IGBT	Insulated Gate Bipolar Transistor
FRD	Fast Recovery Diode
PC	Personal Computer
PCPFH	Plate-circular pin fin Heatsinks
IC	Integrated Circuit
AC	Air Conditioner
QA	Quality Assurance
RAC	Room Air Conditioner
DQA	Development Quality Assurance
CFD	Computational Fluid Dynamics

CHAPTER 1

INTRODUCTION

The design of electrical items is currently trending toward being lighter, thinner, shorter, and smaller. Due to the fact that, compared to earlier products, the size of these electronic components being smaller would result in a sharp increase in the rate of heat generation. In order to reduce the excessive heat generation and so preserve the goods' dependability and stability, an effective cooling system has attracted a lot of attention. The heatsink component has been extensively used to provide cooling benefit for electronic components and is the most popular type of heat exchanger for PCBs.

1.1 MOTIVATION

The motivation of doing this research is that some complaints of faulty PCB are registered by customers. When field engineer Mr. Satish Kumar check this problem, he found that the IPM chip which is placed below the heatsink in PCB gets damaged due to overheating. So, our motive is to cool down the chip. For this we have to improve the design and performance of heatsink.

When we first open up a PC or other electronic device (like an air conditioner, refrigerator, etc.), one of the first things we will see is one or more large metal objects called heatsinks inside an electronic device. Modern electronics pack an incredible amount of complexity into a very small space, which generates a lot of heat that if left unchecked could reduce the lifespan or even destroy the processor that created it outright. Utilizing a heatsink is primarily intended to remove heat from delicate components and increase their lifespans. The most popular thermal management equipment in electronics is heatsinks. They improve the thermal control of electronic components, assemblies, and modules by enhancing their surface area through the use of fins. Applications utilizing fin heatsinks for cooling electronics have increased significantly during the last few decades due to an increase in heat flux densities and product miniaturization. Today’s advanced electronic circuits disperse substantially heavier loads of heat than ever before. At the same time, the premium associated with miniaturized applications has never been greater, and space allocated for cooling purposes is on the decline. These factors have forced design engineers to seek more efficient heatsink technologies. Copper and aluminium are typically used to create heatsinks. Due to its many advantageous characteristics for durable and effective heat exchangers, copper is used. Copper is a superb heat conductor first and foremost. This means that heat may move through copper quickly due to its high thermal conductivity. Applications where weight is a major consideration use aluminium.

1.2 HEATSINK

A heatsink is an active cooling solution used to cool down the integrated circuits in an electronic system or we can say that by increasing heat dissipation from the device, a Heatsinking device could be employed to prevent thermally induced failures. A heatsink is a device that absorbs heat. In the air conditioner, there is a PCB where all the ICs situated over it. So we use a Heatsink there to cool down the ICs. The process of a heatsink is by redirecting heat flow away from a system, this happens by increasing the surface area. For the system to properly transfer heat the temperature must be higher than the temperature in the surrounding.

A heatsink is a part that enhances heat flow away from a hot device by expanding the working surface of the device. By transferring heat from an electronic or mechanical device to a fluid, where it is dispersed away from the device, the temperature of the device can be controlled. The metal The most frequently utilised element in thermal solutions is the heatsink. Copper has better thermal characteristics than aluminium. They are substantially lighter than copper, although they are equally conductive.

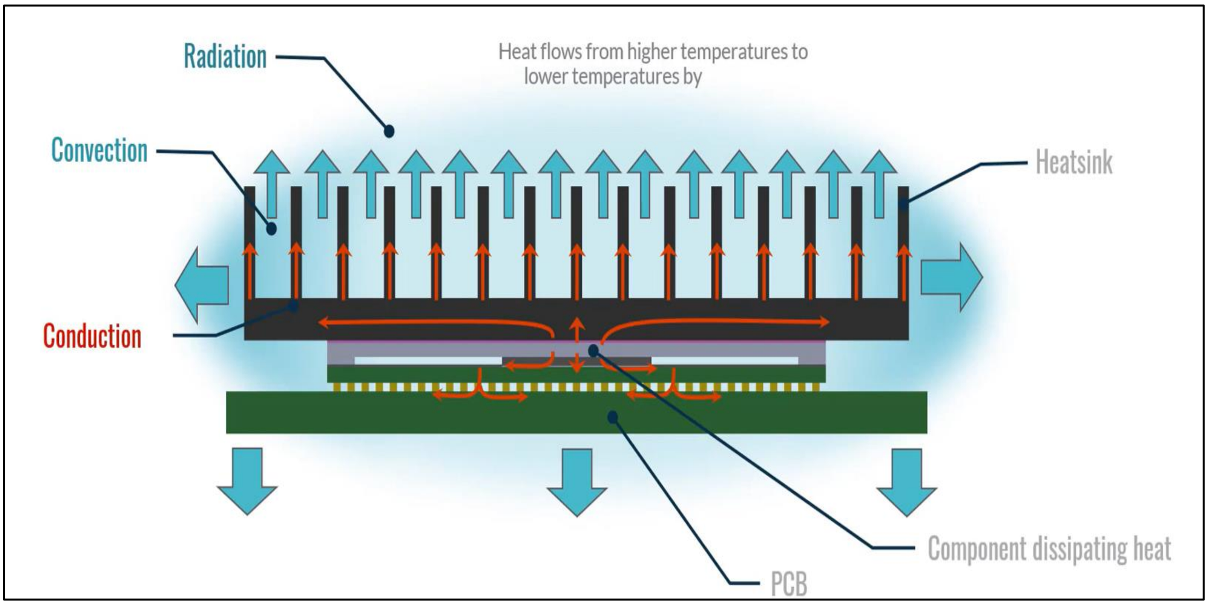


Fig 1.1. Heatsink Heat Transfer

Plate fin and pin fin heatsinks are the two primary types of Heatsinks according to their construction. The dimensions are L-Length, W-Width, and H-Height in Figure, which depicts a standard Plate fin Heatsink. Due to their straightforward design and ease of production, plate-fin heatsinks and circular pin fin Heatsinks are frequently utilized in a variety of electronics cooling applications. The classification of Heatsinks into forced and natural convective heat transfer is also dependent on the heat transfer method.

To reduce the size and weight of the electronic component, it is essential to remove high heat flux without increasing surface area. To improve heat transport, many researchers are conducting research on Heatsinks. By reducing the thermal barrier layer and increasing flow interruption, heat transmission can be made more efficient.

Aside from the diversity in physical structure, other factors that affect the heat exchange from a Heatsink include flow impingement, boundary layer separation, surface aerodynamics, and flow turbulence.

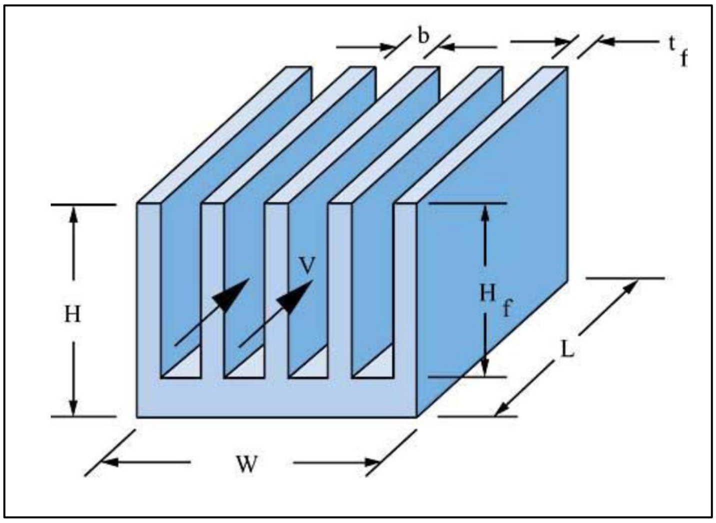


Fig1.2. Typical view of Plate fin Heatsink

Heatsinks will be produced utilizing a variety of techniques, mostly in high conductivity materials like copper and aluminium, such as extrusion, machining, and skewing. By lowering the thermal boundary layer and increasing flow interruption by placing obstructions in the flow route, heat transmission can be improved. For design and operation, it is essential to comprehend fluid movement and heat transmission in Heatsinks.

1.2.1 REQUIREMENT OF HEATSINK

During operation with a power supply, the complete electrical and electronic module produces heat. For instance, high-power semi-conductive devices like power transistors produce heat on an air conditioner printed circuit board. In optoelectronics, such as light-emitting diodes and lasers, a significant amount of heat is also developing.

Similar to this, every electronic device we use, from an air conditioner to daily household things, generates heat. For the electronic component to continue functioning, this heat must be evacuated promptly. If not, heat buildup could result in a system's connection failing on its own or breaking down suddenly. Heatsinks are required for cooling since the heat-generating components are unable to dissipate heat on their own.

In the modern world, it is essential to remove excessive heat from a Heatsink with a limited surface area as the size of gadget component components gets smaller. These factors prompted the investigation of improved heat transfer in Heatsinks. The results of numerous studies demonstrate the importance of thermal boundary layers in the transport of heat. Additionally, heat transfer in a Heatsink is influenced by a number of factors, including the material used for construction, the type of cooling, the velocity of the cooling media, the design of the Heatsink, flow impingement, pressure drop, the physical dimensions of the fins, the surface roughness of the base plate, the distance between the fins, the heating surface area, the velocity boundary layer, the flow direction, the flow turbidity, and the material's thermal conductivity.

The flow diversion and surface texture variation in Heatsinks are required for the following two major reasons:

1. Improvement of heat transferring capacity.
2. Highest heat flux removal from the minimum surface area.

Due to the reduction in component size, the newest modern electronic devices produce substantial heat flux in a specific region. When in use, any power-operated device—including computers, LEDs, medical equipment, and radio frequency devices—emits heat. In the 1990s, it was highly challenging to reach the heat dissipation limit of 200W/cm2, but today, thanks to technological improvement, it is feasible. The demanding heat dissipation limit for contemporary equipment is between 600 and 1000 W/cm2. In order to achieve high heat dissipation, the heatsinks dimensions must be reduced while using the proper cooling methods.

1.2.2 PRINCIPLE OF HEATSINK

According to Fourier's law of heat conduction, if a body has a temperature gradient, heat will move from a high-temperature region to a low-temperature region. And there are three different ways to do this: conduction, radiation, and convention.

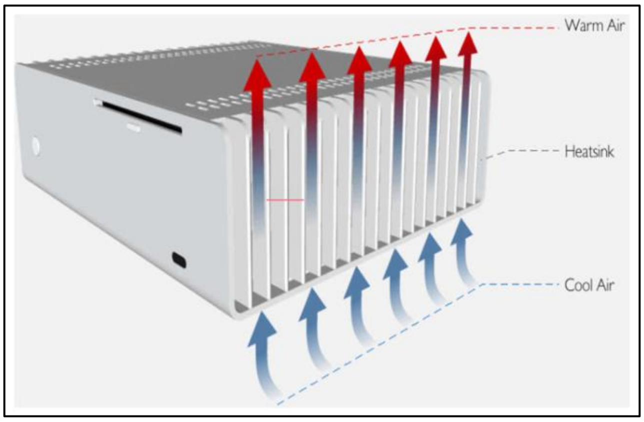


Fig.1.3. Heat Sink Mechanism

With the help of a heatsink, thermal energy can be transferred from a fluid medium with a higher temperature to one with a lower temperature. The fluid medium is often air, although in the case of heat exchangers, it can also be water, oil, or refrigerants. If the fluid medium is water, the phrase "Heatsink" is typically used to describe a chilly plate. To understand the concept of a heatsink, consider Fourier's law of heat conduction. Joseph Fourier, a French mathematician, made fundamental contributions to the analytical investigation of heat conduction. According to Fourier's law of heat conduction, which is compressed to a one-dimensional form in the x-direction, when there is a temperature gradient in a body, heat will be transmitted from the higher temperature zone to the lower temperature region. The conduction heat transfer rate is calculated by multiplying the temperature gradient by the cross-sectional area through which heat is transported.

1.2.3 TYPES OF HEATSINK

Active heatsinks and Passive heatsinks are the two main categories of Heatsinks. Similar to this, the construction and manufacturing methods of Heatsinks are used to differentiate them.

Classification Based on Heat Dissipation Technique

The heatsinks are primarily classified as an active heatsink and a passive heatsink based on the heat dissipation technique. All Heatsinks will come into these two major classifications are given below.

- Active Heatsinks - The active heatsink contains an internal power-operated fan to dissipate heat from the heatsink, as implied by its name. These heatsinks operate very well since they remove more heat. It needs repair or maintenance over time because it has rotating parts.

- Passive Heatsinks - Due to aluminium’s low weight, excellent thermal conductivity, and affordable price, passive Heatsinks are typical of the extended surface variety. These Heatsinks release heat by a convection process that is likely referred to as forced convection. Compared to active heatsinks, passive heatsinks are more reliable. Effective heat removal from the source is made possible by the forced convection approach, which helps to maintain constant airflow across the fins.

Classification Based on Material of Construction

In terms of its thermal conductivity, the building material has a significant impact on Heatsink performance. The ability to transport heat from a heat source is defined by thermal conductivity. Based on their material of construction, heatsinks are classified as:

- Aluminium Heatsink

The main benefits of aluminium include its excellent heat conductivity, light weight, availability, ease of manufacture, and low cost. More than any other material, aluminium is used to manufacture heatsinks. Aluminium has a 235 W/m K thermal conductivity. Aluminium Heatsinks are mostly produced via the extrusion method.

- Copper Heatsink

Copper is the next frequently used material for Heatsink construction. Compared to aluminium, it has better heat conductivity. Costlier, denser, and more difficult to fabricate than aluminium is some of the common downsides. However, because of its superior thermal conductivity, copper heatsinks are used in many applications. Copper has a 385 W/m K thermal conductivity. Copper heatsinks are primarily made via the forging and skiving processes.

Classification Based on Manufacturing Process

According to the production process, heatsinks are categorized in Figure 1.4. Every manufacturing method has benefits and cons of its own. Based on criteria including heat dissipation, complexity, heat removal rate, and building material, the manufacturing technique can be chosen. Heatsinks are categorized according to their production process as mentioned below:

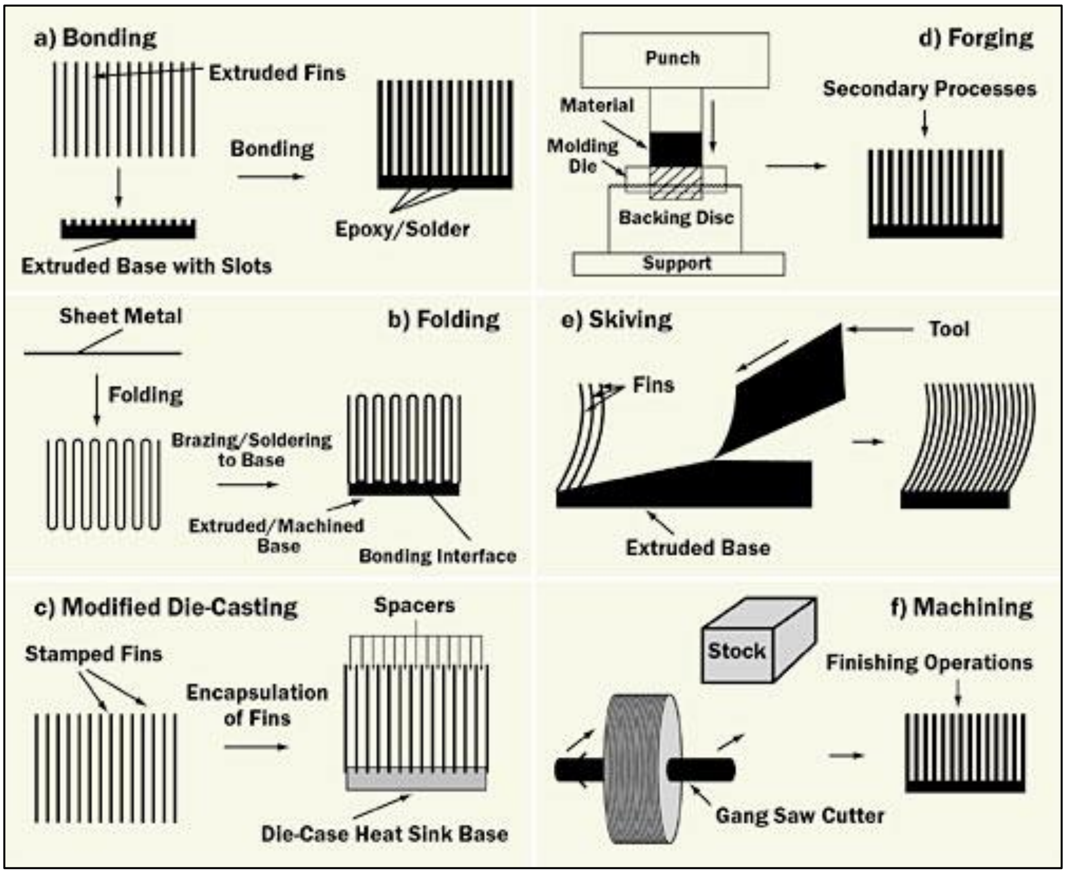


Fig 1.4. Classification of Heatsinks based on the manufacturing process

- ❖ Extruded Heatsinks

Extrusion is the primary method used to create aluminium heatsinks. This fabrication technique is comparatively quick and inexpensive. Its narrow width is one of its shortcomings. These Heatsinks are of the custom variety and function averagely.

- Stamped Heatsinks

In this technique, metals are stamped to create a precise heatsink shape. When metal is agitated during the stamping process, this stamp creates Heatsinks. When compared to the extrusion technique, it is a less expensive method. Stamped heatsinks are typically utilised in low-power applications.

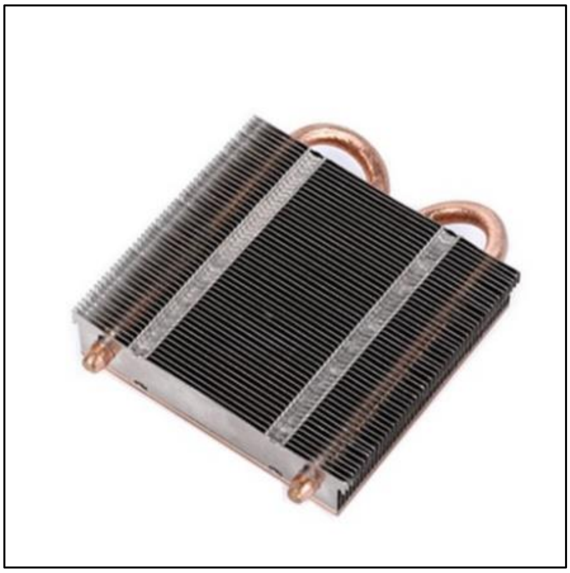


Fig.1.5. Stamped Heatsinks

- Machining Heatsinks

It is a pure machining procedure in which the heatsink block's undesirable material is removed using a gang saw in accordance with the required fin spacing. When compared to other manufacturing processes, it is a little more expensive because some metal is wasted during the machining process. Modern manufacturing techniques include Computer Numerical Control (CNC) and Voice Numerical Control (VNC).

- Bonded Fin Heatsinks

Applications that require such large heatsinks are numerous. Individual metal fins must be joined to the Heatsink foundation using electrical welding techniques. Fins are bonded using brazing and thermal epoxy procedures.

- Folded Fin Heatsinks

Depending on our needs, the thin material is folded into a huge surface area. It performs better and has a higher heat-flux density because the cooling air is being directed to flow across this folded Heatsink.

- Skived Heatsinks

These Heatsinks are produced using a procedure known as the skiving process. It entails the production of tiny metal chunks, often made of copper. It is utilized for medium- to high-performance applications and is also known as skived Heatsinks.

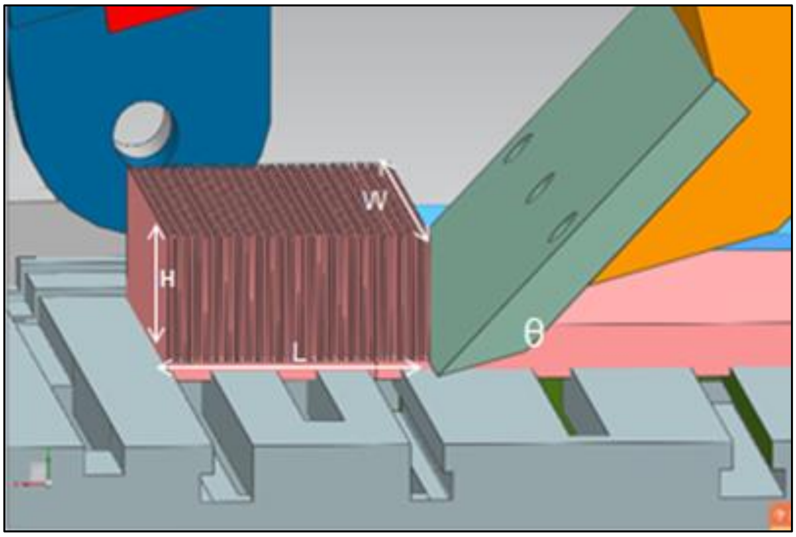


Fig.1.6. Skived fin Heatsink Process

- Forged Heatsinks

These Heatsinks are fabricated by forging operation; usually, copper and aluminum are used as materials. The forging operation means the application of compressive forces to the form required shape. The Heatsinks fabricated using the forging method of operation are called forged Heatsinks.

Fig.1.7. Forged Heatsink

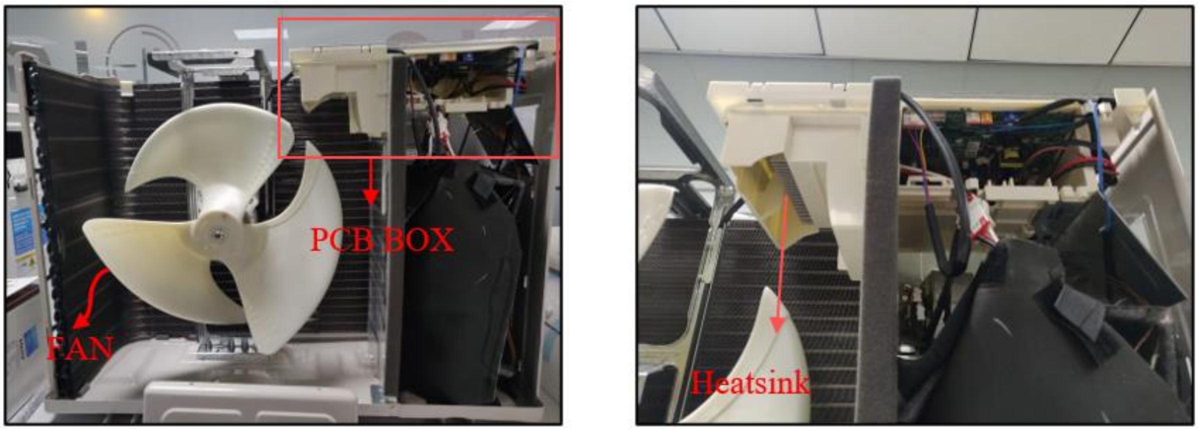
- Swaged Heatsinks

To provide the necessary shape Heatsinks, a die is employed during the cold or hot forging process. Swaged Heatsinks are inexpensive and of middling performance.

1.2.3 APPLICATION OF HEATSINK

Today, heatsinks are sold all over the world and used in a variety of industries, including audio, electronic cooling, industrial control, telecommunications, and defense.

Heatsinks are frequently used to cool electronic, power electronic, telecommunications, and automotive components in a variety of industrial applications. As in my project, we make use of the heatsink application in the air conditioner PCB that is depicted in fig.



(a) *(b)*

Fig.1.8. Application of Heatsink in ODU of Air conditioner (a)PCB box in ODU (b)Heatsink Placement in PCB Box

These parts could be integrated circuits like audio amplifiers, microcontrollers, microprocessors, or high-power semiconductor devices like diodes and thyristors. In order to be more precise, passive cooling Heatsinks are frequently used in the cooling of CPUs, audio amplifiers, and power LEDs. In order to be more precise, passive cooling Heatsinks are frequently used in the cooling of CPUs, audio amplifiers, and power LEDs.

CHAPTER 2

LITERATURE REVIEW

The review of the literature on Heatsinks for growing Numerous scholars have studied heat transfer. According to the study's findings, only a few key components are responsible for the characteristics of heat transport. In the Heatsink heat transfer process, the flow distribution profile is crucial. Additionally, it is influenced by the production of vortices, wakes, boundary layer separation, turbulence, and primary and secondary flow. The variance in the physical shape and design of Heatsinks is also included in the literature review.

2.1 ANALYSIS OF HEATSINK

Emre Ozturk et al. (2004) studied the CPU mounted heatsink under forced convection. CFD tool is used to numerically analyse the effectiveness of Heatsinks, the effects of turbulence, the effects of radiation heat transfer, and various Heatsink geometries. Navier-Stokes equations are solved to simulate conjugate heat transfer for all electronic cards and packages. An analysis computational model has been developed by **Seri Lee** (2007) to forecast and optimize the heat transfer performance of omnidirectional fin heatsinks in a substantially confined configuration. This article outlined the development of the general thermal model and provided a simple formula for determining the fin flow velocity. An overview of several Heatsink kinds is provided, along with relevant design standards. The optimization of heatsink designs and common parametric behaviours are explored in light of the sample simulation findings.

Pawar Shreekant Prabhakar et al. (2015) studied the ideal parameters for a naturally air-cooled Heatsink at which the system will continue to operate in natural convection mode while performing a thermal analysis and comparing the impact of fan orientation on cooling efficiency are the main objectives of this work. With the goal of maximizing the heat transfer coefficient, CFD simulations were ran to optimise the Heatsink parameters. Finding the ideal parameters for a naturally air-cooled Heatsink at which the system will continue to operate in natural convection mode while performing a thermal analysis and comparing the impact of fan orientation on cooling efficiency are the main objectives of this work (i.e., Fan-failed condition). **Pawar S.P et al** (2015) research to identify the point at which a natural air-cooled

Heatsink will operate optimally, allowing natural convection to take over in the event that the fan fails to function. With the goal of maximising the heat transfer coefficient, CFD simulations will be run to optimise the Heatsink parameters. A commercially available Heatsink will be compared with the ideal set of parameters and results.

Prakash T. et al. (2016) used CFD analysis to find the cooling solution for computers. Computational fluid dynamics software and fluent are used to numerically analyse the impact of heat dissipation and Heatsink geometries. To achieve the greatest amount of heat dissipation, the best Heatsink design is chosen and modified. With just one case fan and the power supply fan, the design can effectively cool the chassis. **Amer Jameel Shareef Al-damook et al.** (2016) studied the design optimisation and analysis of Heatsinks. This study's primary objective is to examine the advantages of using different shape of Heatsinks in various geometries to lower CPU temperature and fan power consumption, overcome pressure drop, and maximise heat transfer rate through the Heatsink.

Hari Raghavan. J et al. (2017) studied the advantages of a porous pin fin heatsink over a traditional pin fin heatsink in terms of thermal performance. The heatsink used in the analysis has a square-shaped cross-section. Assuming steady-state conditions, a numerical analysis of the heatsink is required to determine natural convection. The thermal analysis is performed using a CFD tool, and the finite volume method is taken into consideration.

S.Ravikumar et al. (2017) used ANSYS software for Thermal analysis. Thermal analysis is used in this project to find a cooling solution for a desktop computer with a 5 W CPU. This study takes into account the control of CPU Heatsink processes as well as the design of circular cylindrical pin fins and rectangular plate Heatsink fins with aluminium base plates. **I. T'Jollyn et al** (2017) studied the construction of an analytical model of a thermoelectric generator (TEG) with a fixed thermal resistance at the cold side and a constant temperature at the hot junction. The modelling outcomes demonstrate the importance of accounting for thermal resistance in order to produce accurate modeling outcomes.

Dr. Haejune Kim et al (2020) studied the thermal analysis of a Heatsink with a metal 3-D printer. Students were able to learn to define the problem, develop a hypothesis and experimental procedure, and evaluate the thermal performance of Heatsinks as a result of their experiment on the thermal performance of Heatsinks produced using a metal 3D printer. The ability of the students to pick and construct Heatsinks that satisfy the cooling demands of a specific application was successfully demonstrated. **Angel Marinov et al** (2022) presented a study of various Heatsink designs using finite element modeling. The study's primary goal is to identify and assess solutions that make better use of natural convection for heat dissipation. There are 17 different cases studied, including both traditional cases and cases the authors proposed. Each case is looked at using three different heat source powers (in the case of the proposed study, a transistor). Results for the power source's temperature and the studied volume's velocity magnitudes are shown and compared. For a few chosen cases, experimental validation of the modelling is presented. **Benyamin Naranjani et al.** (2020) studied the conjugate heat transfer in Heatsinks with different configurations and coolants which were examined through three-dimensional simulations. For various coolant mass flow rates, the effects of using corrugated channels and water-Al2O3 nanofluids with different volume fractions and nanoparticle sizes were investigated. Additionally, semi-empirical correlations for the suggested design were introduced, and the impact of various heat loads on the Heatsink's maximum temperature rise was examined.

2.2 PLATE FIN HEATSINK

The following literature reviews use a variety of plate-fin Heatsinks (PFHSs) to cool electronic components while airflow is laminar.

Yu et al. (2003, 2004, and 2005) investigated the thermal airflow through plate-circular pin fin Heatsinks (PCPFHSs), which have some circular pin fins interspersed with plate fins. According to the findings, the PCPFHS's thermal resistance is almost 30% less than the plate fin Heatsinks (PFHS). However, compared to the PFHS, the PCPFHS has a much higher pressure drop.

The compact Heatsink was the subject of two papers written by **Yang & Peng (2009a and 2009b)**. With a mixed-height pin design, the thermal properties and pressure drop of the plate-circular pin fin Heatsink (PCPFHS) are taken into consideration. The results show that the PCPFHS's Nusselt number enhancement is over 30% better than the plate fin Heatsink's (PFHS). However, the PCPFHS's pressure drop is almost one hundred and ten percent greater than the PFHS's. The profit factor is higher for the in-line arrays design than for the staggered arrays model.

Poojitha Madupu et al. (2017) determines the heat transfer rates in a Heatsink by means of the varying pitch of the fin with air as the working fluid. Analysis is done for a Heatsink with constant wall heat flux in a closed enclosure. Aluminum alloy 6061 was chosen for analysis because it had the highest temperature, the best heat transfer coefficient, and the highest efficiency values. To calculate the heat transfer coefficient, pressure drop, mass flow rate, and heat transfer rate for various cases, CFD analysis is used.

2.3 EFFECT ON HEATSINK WITH CHANGING THE GEOMETRY

The different arrangements of fins—plate fins, strip fins, square pins, and circular pins in-line and staggered arrays, all of which affect the Nusselt number and pressure drop, were examined by **Jonsson & Moshfegh** (2001). The height, thickness (diameter), and spacing of the pins, as well as the width and height of the wind tunnel, are all factors that affect Nusselt number and pressure drop. Additionally, due to the length of the plate fins, the lowest pressure drop is seen there. Additionally, the pressure drop of the circular PHSs is lower than that of the square PHSs.

Arularasan and Velraj et al. (2008) investigated the optimal design of parallel flat plate fin HSs in turbulent airflow. The results show that the optimal plate-fin Heatsink design is found at the specific parameters of the fin height, fin thickness, pitch of the fin, and base height based on the base temperature, thermal resistance, and pressure drop. **Mathias Ekpu et al.** (2011) investigated how changes in Heatsink geometry affect the thermal efficiency of copper and aluminium heatsinks used in microelectronics. The thermal conduction through an electronic package made up of a Heatsink, a chip, and a thermal interface material was studied numerically. The study varied the height of the Heatsink fins and the thickness of the Heatsink base. Using steady-state thermal conduction analysis, the minimum and maximum temperatures of the copper and aluminium Heatsinks in the two models were examined. **Channamallikarjun et al.** (2014) studied the best plate fin and cylindrical Heatsink designs, with variable copper base plates and CPU Heatsink process control. An ideal set of plate-fin is sought using computational fluid dynamics to improve heat dispersion performance. Due to frequently occurring space restrictions, base plate thickness, fin thickness, fin profile, and fin material parameters must be handled collectively. ANSYS design modeller is used for modelling, ANSYS meshing is used for CFD meshing, and ANSYS fluent is used as a CFD solver to analyse the various Heatsink designs.

Santosh Kansal et al. (2015) investigate Heatsinks are widely used devices for enhancing heat transfer in electronic components, and studied that Heatsinks have fins of various profiles, including rectangle, Trapezoidal, rectangle Interrupted, Square, circular inline, and staggered. In his work, a brand-new idea for cooling electronic components with Heatsinks made of aluminium alloy is put forth. He deduced from the outcomes that a Heatsink design with circular pin fins produces the best cooling. By using less material, these Heatsink designs promise to keep electronic circuits cooler than standard Heatsinks while also being less expensive. **Mohamed H.A. Elnaggar et al.** (2015) explains an analytical investigation into how a Heatsink's performance is impacted by the number and thickness of its fins. The findings demonstrated that both an increase in fin number and thickness leads to an increase in heat transfer rate, but that the effect of an increase in fin number is noticeably greater than that of an increase in fin thickness. The heat transfer rate increases as fin thickness increases, but as fin thickness increases even further, the distance between fins decreases. To ensure that the cooling fluid reaches every cooling fin and that there is adequate heat transfer from the heat source to the fins, the distance between the fins must be maintained.

Akshendra Soni1 et al. (2016) used Ansys and Solidworks in order to create a numerical model in three dimensions to study the effects of various fin geometries. According to the results, changing the fin geometry of base plate fins with vertical orientation improves their thermal performance while also lightening the weight of the fin arrays, which lowers manufacturing costs. The ideal spacing for the best thermal performance of the fin array is discovered. According to this study, the ratio of fin diameter to center-to-center spacing is the most crucial geometric factor affecting the heat transfer from pin fin arrays.

Harpreet Singh et al. (2016) discovers the thermal efficiency of various perforated Heatsinks, both solid and perforated (Rectangular, Circular, and Slotted). To investigate the thermal performance of various perforation designs, CFD analysis was conducted. A forced draught fan-equipped horizontal, rectangular duct has been used for the test. In this computational analysis, he determines the outcome by computing the Heat transfer coefficient, Reynolds number, and Nusselt number. **V Naga Raju et al.** (2017) examined the impact of pin-fin shapes on Heatsink performance. On various fin types, including rectangular, circular, triangular, and interrupted rectangular fins, we performed steady-state thermal analysis. Temperature distribution, total heat flux, and directional heat flux had all been calculated.

M. Prashanth Reddy et al. (2017) studied the manufacturing process and thermal analysis of Heatsinks. To determine the best heatsink designs, the results of the heatsink temperature difference comparison were compared with an experimental result, and it demonstrates a good correlation. For accelerating CPU heat dissipation, the thickness of the base plate and the fin profiles were investigated. Additionally, to space reduction and material savings, some thermal improvements were made. A new Heatsink design that uses less material and has better thermal performance may eventually be achieved. **M. Praveen Kumar et al.** (2018) focused on creating a Heatsink for a high-wattage electronic printed circuit board. Through the use of the ANSYS workbench package, various fin arrangements and material combinations have been analysed in this work. Temperatures and other thermal quantities that change over time can be determined using transient thermal analysis.Through analysis of the package, it was discovered that the Copper-Aluminum based composite produced a high level of heat dissipation, ensuring the safety of the electronic circuit board. **Nilesh Khamkar et al** (2019) studied the Thermal resistance, material, fin configuration, fin size and shape, fin efficiency, heatsink attachment method, and thermal interface material are a few of the important aspects that should be taken into account when designing a Heatsink.

G. Naresh et al. (2020) carried out a comparative thermal analysis on heatsinks with various configurations. Among the design configurations taken into consideration, this study aims to select the best Heatsink design in order to maximise natural convection. Utilizing the software Solid Works, the Heatsinks are created. The software ANSYS WORKBENCH has been used to analyse these designed models. The outcomes point to the rectangular flat plate heatsink as the best design among the heatsink models under consideration.

S Sushma et al. (2021) main objective was to improve heat transfer by utilising various Heatsink shapes. According to experimental analysis, the honeycomb-shaped Heatsink has a higher heat transfer coefficient for a 100V input voltage of 20.01 and 22.73 percent, as well as a higher Nusselt number of 9.7 and 8.9 percent and a decrease in thermal resistance of 20.1 and 22.73 percent in comparison to radial and flared Heatsinks, respectively. It results in the discovery of various Heatsink shapes that can be applied to electronic components for improved heat dissipation. **Kota Leela Sai Bharath et al.** (2021) studied the heat by varying its geometry and material. The design and assessment of the thermal characteristics of rectangular fins with varying geometry and content, as well as the expansion of the rectangular fin plate using Catia5R tools, are the main goals of this paper. The geometries are created using

Catia and Ansys, and analyses of thermal properties are then applied to them. The thermal conductivity of the aluminium alloy used to create the rectangular fin body.

Numan Habib et al. (2022) studied the thermal analysis on heatsink under natural convection. On the thermal resistance and fluid flow, the effects of the parameters fin height, fin count, and Heatsink size are reported.

2.4 FABRICATION TECHNIQUES OF HEATSINK

The following literature reviews use a variety of techniques to fabricate the plate-fin Heatsinks (PFHSs) to cool electronic components while airflow is laminar.

Anna Dziubinska et al. (2014) presented a new technique for forging Heatsinks. The most prevalent industrial uses for Heatsinks are presented in the first section of the paper, along with an overview of production techniques for Heatsinks. The problem of forging these products using a three-slide forging press is then examined in the paper. **Kiran Beldar et al.** (2017) studied the production and CFD analysis of cylindrical heatsinks with rectangular notched longitudinal fins. The heat transfer will be improved by creating a cylindrical Heatsink with rectangular notch fins. The convective heat transfer coefficient of a fin with a different notch size for the specified fin spacing is the measuring parameter when free convection heat transfer is used. Stable thermal analysis, airflow analysis, and pressure drop analysis were performed using the Ansys Fluent software.

2.5 FINAL COMMENTS FROM THE LITERATURE REVIEW

The analysis of the above-mentioned research papers led to the following conclusions regarding improving heat transfer and optimizing Heatsinks with space as the primary constraint.

- Improvement of Heat Transfer in Thermal Management Different cooling techniques, such as the use of varying fin thickness, phase change materials, a variety of heatsink profiles by using an air-cooling fan, the use of various cellular materials, etc., can be used to achieve systems of electronic cooling applications.
- Manufacturing plate fins for a heatsink is relatively easier than other fins.

- Cost reduction is the major point in the application of industry.

2.6 THE SCOPE OF PRESENT WORK

- Many researchers carried out heat transfer characteristics study on the heatsink for the application of computer systems only by varying their shape, physical dimension, orientation, etc. But Heatsink for the application of PCBs used in Air conditioners is not yet covered by any study. So this study aims to understand heat transfer's effect by changing the heatsink's shape and physical dimension.
- The experimental result of the modified Heatsink compared with the numerical study.

2.7 OBJECTIVE OF THE PROJECT

- Fabrication of heatsink for the application of Air conditioner.
- Carry out numerical and experimental analysis, identify transfer capabilities and heat enhancement opportunity of the rectangular fin heatsink.
- Choose a perfect material for the fabrication of the heatsink.
- To design a heatsink for a PCB cooling application with a given heat load to keep the part temperature below the critical limit while adhering to space constraints (cooling area).

  Parameters to be designed:

  1. Fin Profile
  2. Number of Fins
  3. Fin Length
  4. Baseplate thickness

In order to optimise the heatsink parameters while maximising the heat transfer coefficient, CFD simulations will be run. The performance of the optimised heatsink will then be compared with the previously used Heatsink in terms of maximum temperature of new heatsink.

CHAPTER 3

METHODOLOGY

This section deals with the methodology that we followed to achieve our goal. The basics of thermal analysis are also discussed in this section. As it can be well defined through the following flow chart as shown in Fig.3.1.

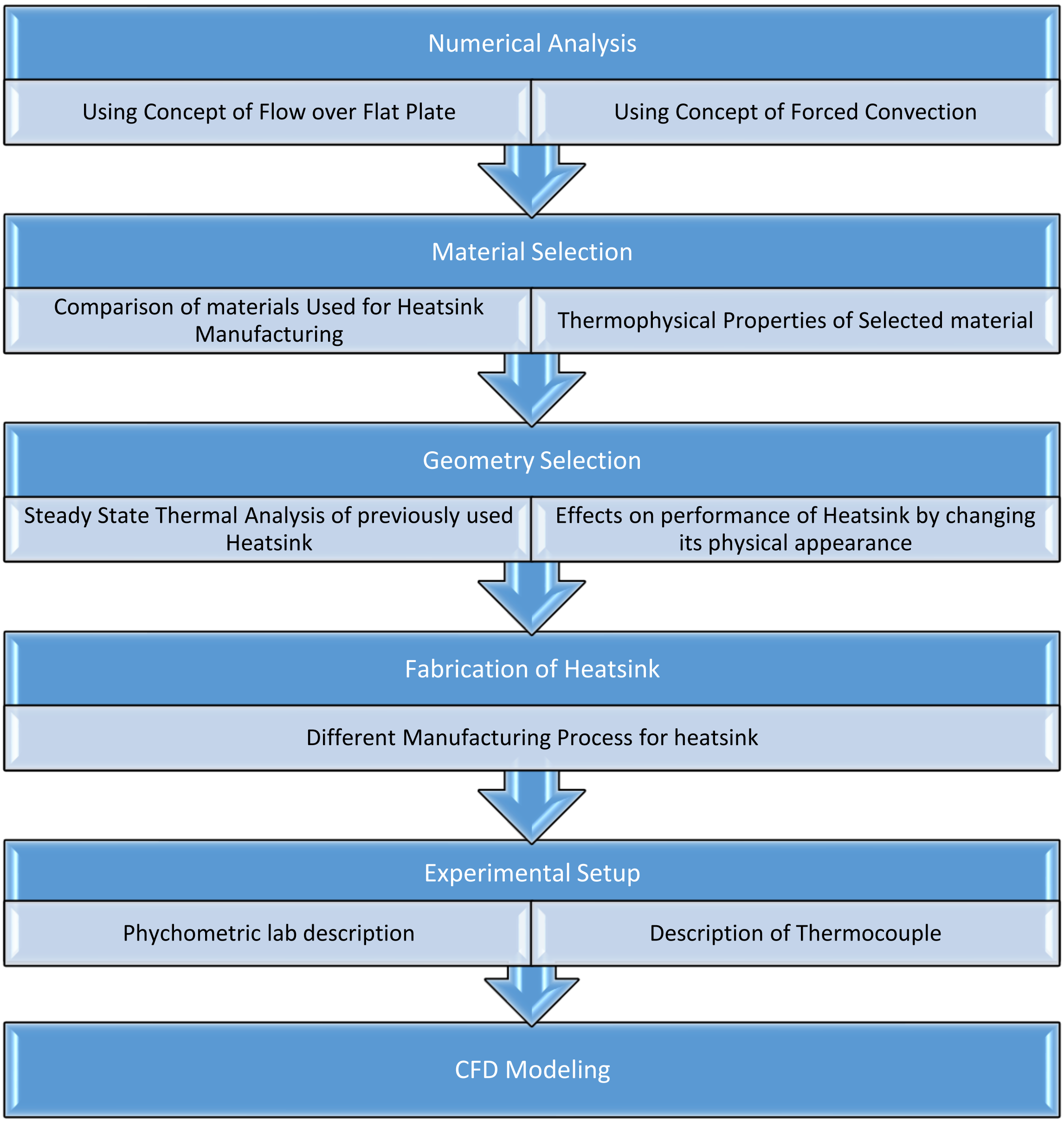


Fig.3.1 Flow Chart of Methodology Followed

3.1 NUMERICAL APPROACH

In the numerical approach, the concept of forced convection is used for calculating the heat transfer coefficient. If we are aware of h, we may determine the heat transfer rate from a given surface of unit area and a given temperature differential. The thermal analysis of the Heatsink is done on the Ansys software in which we are required to put the value of the heat transfer coefficient for further analysis. So, our first step in the numerical approach is to calculate the value of the heat transfer coefficient [22].

For this we have to set some parameters of heatsink i.e., the optimum fin height and fin type, optimum fin spacing, optimum number of fins, and optimum fin thickness [25]. From this we prepare a table 1 of dimensions and properties taken in numerical analysis which is given below.

Table 1.
Dimensions and properties taken

Heat load*	57 W
Base size*	140 × 50 mm^2
T_a	42 ℃
T_s	110 ℃
h_f	38 mm
t_f	2.96 mm
k (aluminium)	201W/mK
v*	4 m/s
Total Base Width*	140 mm
Fin Spacing	2.95 mm

**Values are from LG standards*

Because of its electrical functioning, a PCB uses electricity. Due to its very low efficiency, the remaining power is lost as heat energy. PCB is made up of numerous active components, each of which produces a different heat load from 0.1 to 5.27 watts. For components to operate safely and reliably under 35°C ambient conditions, this PCB heatsink temperature must be kept below 105°C. The other values of the constant and exponents are determined through literature surveys or experiments. The properties of the fluid are evaluated based on film temperature.

3.1.1 FLOW OVER FLAT PLATES

- Laminar Flow – The local value of the heat transfer coefficient is given by

  $$Nu_l = \frac{hL}{k} = 0.332\ (Re)^{0.5}(Pr)^{0.33}, \tag{1}$$

  when Re < 5×10^5

- Turbulent Flow – The local value of the heat transfer coefficient is given by

  $$Nu_l = 0.029(Re)^{0.8}(Pr)^{0.33}\ , \tag{2}$$

  when Re > 5×10^5

Even while forced air convection cooling is a straightforward and frequently chosen thermal management method for electronic applications, it is sufficient for high-power applications. Figure 3.2 depicts a Heatsink with measurements.

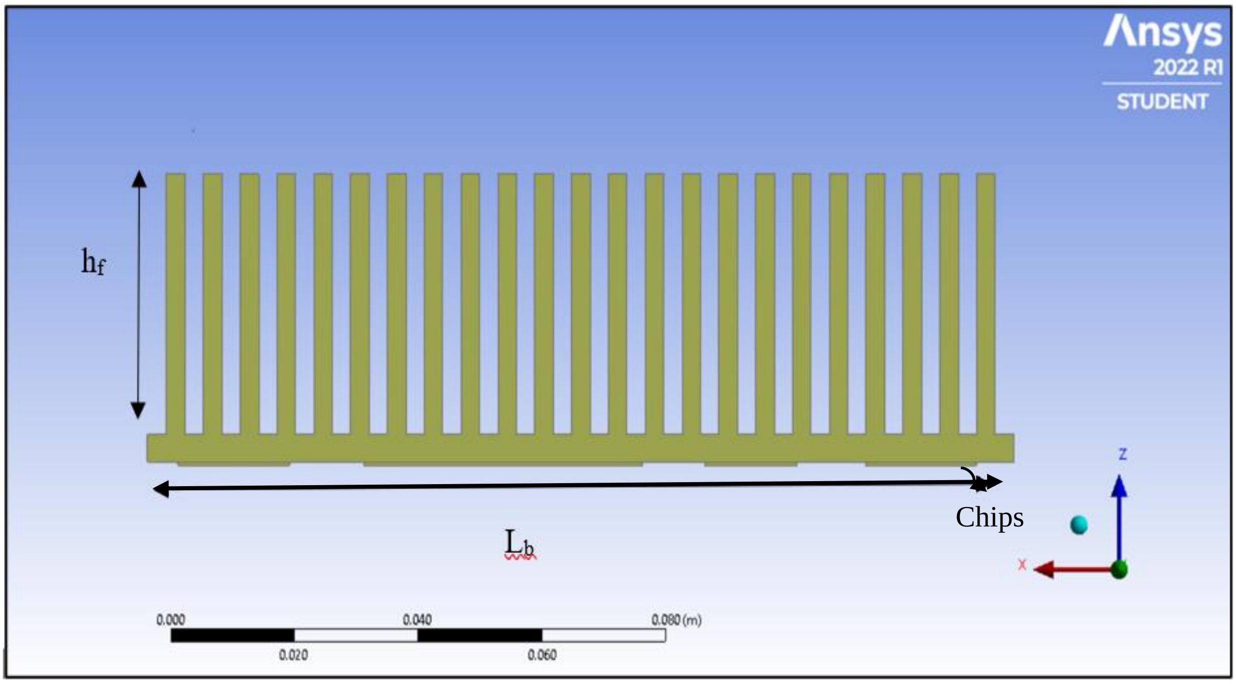


Fig.3.2 Plate Fin Heatsink

Assumptions-

The following assumptions are made for the most simplified analysis:

(1) For numerical analysis we have consider a steady state condition.

(2) The flow is incompressible.

(3) Radiation heat transfer is neglected.

(4) Fluid Properties are constant.

(5) Local convective heat transfer coefficient h for the cross-section.

3.1.2 HEAT TRANSFER COEFFICIENT OVER THE FLAT PLATE

$T_f = T_s + T_a / 2 = 76°C$

The properties of dry air at 76°C from the reference [23] are:

$\nu = 19.75 \times 10\text{-}6\ m^2/s$

$Pr = 0.694$

$k_{air} = 0.02881$ W/mk

As we know Reynolds number is calculated by formula

$$Re = \frac{\rho v L}{\mu} \tag{3}$$

Now by using equation (3) we get the value of the Reynolds number which is:

Re = 4500, which is less than 5×10^5. Therefore, it’s a laminar flow.

Now for laminar flow we know the Nusselt number formula. So, from equation (1) we get

Nu = 17.08

Now using this Nusselt number value in the below formula:

$$Nu = \frac{hL}{k} \tag{4}$$

By substituting the values of the Nu in equation (4) we get the value of the heat transfer coefficient i.e.,

$$h = 28.12\, W/m^2K$$

So, we use the above value of h for our thermal analysis of the Heatsink.

3.1.3 FORCED CONVECTION CALCULATION

In order to increase heat transfer, fluids are forced to circulate during a unique type of heat transfer called forced convection. A ceiling fan, a pump, a suction tool, or another tool can be used to force something. In our case, there is a fan which is placed in an outdoor unit of an Air Conditioner.

- HEAT FLUX:

Heat flux is the quantity of heat that is moved to or from a surface per unit area per unit time. Since it incorporates the principles of two quantities—the amount of heat transfer per unit time and the region to or from which the heat transfer occurs—it is essentially a derived number. Mathematically it's given by:

$$Heatflux = \frac{Q}{A} \tag{5}$$

Substituting the values of Q and A in the above equation we get,

$Heatflux$ = 0.0064 W/mm^2 < 1

Therefore, the Heatsink is suitable for forced convection cooling.

- NUMBER OF FINS (n): The number of fins is given by,

$$n = \frac{Total\ Base\ Width}{(Fin\ Thickness + Fin\ spacing)}$$

= 140 / 3+2.95 = 23.17

= 23

- SURFACE TEMPERATURE OF HEATSINK

Heat transfer:

$$Q = kA\frac{\Delta T}{L} \tag{6}$$

Where, Q = 57 W, k = 201 W/mK and L= h_f

A = 140mm×50mm and T_a= 42 ℃

Substituting all the values we get

57= 201×140×50×10-6× (T_{SH}-315)/ (38×10^{-3})

$$T_{SH} = 57.4\ ℃$$

- FIN EFFICIENCY (η_{fin}) –

In our case, the fin is of finite length. So, we use the below formula for our further calculation:

$$\eta_{fin} = \frac{\tanh(m\mathrm{Lc})}{m\mathrm{Lc}} \tag{7}$$

Where, $L_c = L + \frac{Ac}{P}$

And, $m = \sqrt{\frac{hP}{KAc}}$

So, by inserting values we get,

L_c = 12.45mm

m = 11.24

So, putting these values in equation (8) we get,

$$\eta_{fin} = 91.4\%$$

Now for designing, Factor of safety (FOS) have to be considered before its fabrication [14]. So, the detailed information related to FOS for required application are mentioned in the below table:

Table 2.
Factor of Safety According to its Application

Application	Factor of Safety
For use with materials in light loads and constant environmental conditions	1-2
For use with materials in light loads and Changing environmental Conditions	1.5-2
For use with materials in high loads and Changing environmental Conditions	2.5-3.5
For use with materials in high loads and constant environmental conditions	2-3

So, from table 2 it is clear that our application comes under the FOS 1.5-3. For previously used heat sink the FOS is 1.5. So, this time we chose FOS as 2 [14].

3.2 MATERIAL SELECTION

Heatsinks are generally made of aluminium and copper. When choosing a Heatsink that fulfils the needed thermal criteria, it's important to consider several factors that affect the Heatsinks performance and the system's overall performance. The thermal budget available to the Heatsink and the external conditions surrounding the Heatsink plays a big role in deciding the sort of Heatsink to use. It is important to note that a single value of thermal resistance can never be ascribed to a Heatsink since thermal resistance fluctuates with external cooling conditions. So, by studying different research papers we prepare a comparison table 2 between copper and aluminium materials and on this basis, we choose Al-6063 for our project.

Table 3
Comparison of materials Used for Heatsink Manufacturing

MATERIAL (Series/Alloy)	THERMAL CONDUCTIVITY k (W/mK)	MANUFACTURING PROCESS
Aluminium-5052 H36	137	Stampings
Aluminium-6061 T6	167.1	Extrusion
Aluminium -6063 T6	201.4	Milling
Aluminium -1100 H14	219.7	Stampings
Copper- CDA110	300.2	Bonded-Fin
Copper- CDA101	397	Heat Spreaders

The previously applied material in LG is Al-6061 as its cost is less as compared to copper and its weight is less. The details like the physical properties of the material are given by us to the vendor’s side. Then after this, the vendor company like we choose Esskay as a fabrication company for the Heatsink, give us a proper FPA (First party Approval) Sheet in which there is a material sample detail and they mentioned there to check the material quality. The quality of the material is checked by a technique called XRF (X-Ray Fluorescence).

- XRF (X-Ray Fluorescence)-

A routine, comparatively non-destructive chemical analysis of rocks, minerals, sediments, and fluids is performed using an X-ray fluorescence (XRF) spectrometer. It operates similarly to an electron microprobe using wavelength-dispersive spectroscopy (EMPA).

Fig.3.3 XRF Machine

The behaviour of atoms, when they contact with radiation, makes it possible to analyse major and trace elements in geological rocks using x-ray fluorescence. Materials can ionize when they are stimulated by high-energy, short-wavelength radiation (like X-rays). The atom becomes unstable and an outside electron replaces the missing inner electron if the radiation's energy is high enough to loosen a securely bound inner electron. Due to the inner electron orbital's lower binding energy compared to the outer one, energy is liberated when this occurs. Fluorescent radiation is the word for the radiation that is released and has lesser energy than the X-rays that are initially incident. the outcome's fluorescence Since the energy of the emitted photon is typical of a transition between specific electron orbitals in a particular element, X-rays can be used to identify the abundances of elements that are present in the sample.

If there is some hazardous content (like lead) present in the material then it gets rejected. And if no hazardous content is found, then we have to complete that FPA sheet and send it to the vendor. So, this is the correct procedure for the selection of material in LG.

- Why use Aluminium instead of copper?

It's crucial to remember that copper has higher levels of thermal conductivity. In actuality, copper has heat conductivity that is around 60% greater than aluminums. But aluminium is adaptable, inexpensive, and lightweight. Furthermore, the heat conductivity is still strong. As a result, it is suited for the majority of applications.

So, from the above explanation, we conclude that aluminium is best for our requirements. Table 3 mentioned below is the thermophysical properties of the air and aluminium.

Table 4
Thermophysical Property Data

Fin material	Aluminium (Al-6063)
Fluid medium	Air
Initial Temperature	315 K
ρ (air)	1.235 kg/m^3
k	0.0251 W/(m K)
C_P	1005.43 J/(kg K)
μ	1.7994e-05 kg/(m s)
Density (Al)	2719 kg/m^3
k_{air}	202.4 W/(m K)
C_P (Aluminium)	871 J/(kg K)

3.3 SELECTION OF HEATSINK GEOMETRY

As we know that there are different types of Heatsinks available. So for our project, we have to choose the most effective Heatsink in terms of performance, and also its cost is not so much expensive. Due to this, we have first to analyze the different geometries on Ansys software. As mentioned before I worked in the DQA department of RAC where Mr. Satish Kumar told me that LG prefers a rectangular type Heatsink. But the problem with their Heatsink is that there is a lot of PCB short-circuiting occurring in the field area. So from LG headquarters, they give us a project to solve the PCB issue.

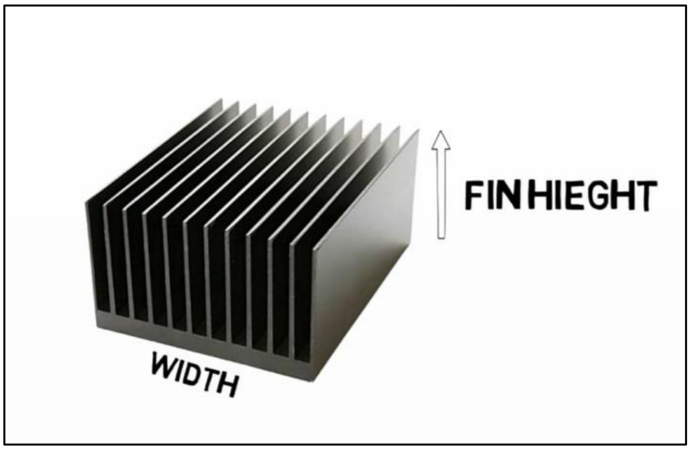


Fig 3.4. Heatsink

As there are two types of chassis running in the Noida LG plant i.e., UL2 and U24A. For 1.5-ton Split AC we use UL2 body and for 2 ton Split AC we use U24A body. So, by considering the space restriction we design our new Heatsink. I got the previous Heatsink information from my QA RAC team i.e., they use a square type Heatsink. They also give me the idea of geometry. The previously used Heatsink analysis has been done by me on the Ansys software. A detailed description of the previously used Heatsink is mentioned in table 4.

Table 5.
Description of the previously used plate-fin Heatsink

Heat Load	57 W
Base Size	140*50 mm
No. of fins	19
Fin height	35mm
Fin spacing	4.2mm
Fin Material	Al-6061
Thermal Conductivity	167 W/mK
Base Thickness	5.5mm
Fin Thickness	4mm

- Previously used Model Description

Version 22 of Ansys Workbench was used to create a geometric model. The electronic package model's schematics, including a chip and a top-mounted Heatsink, are shown in Fig. 3.5. The IPM chip measures 20 x 25 mm and is 1 mm thick. In this study, a Heatsink with flat plates and rectangular fins is employed. The Heatsink measures 140 x 50 mm and has a 5.5 mm thick base. There are 19 rectangular fins, each measuring 50 x 4 mm, with a fin spacing of 4.2 mm and a height of 35 mm.

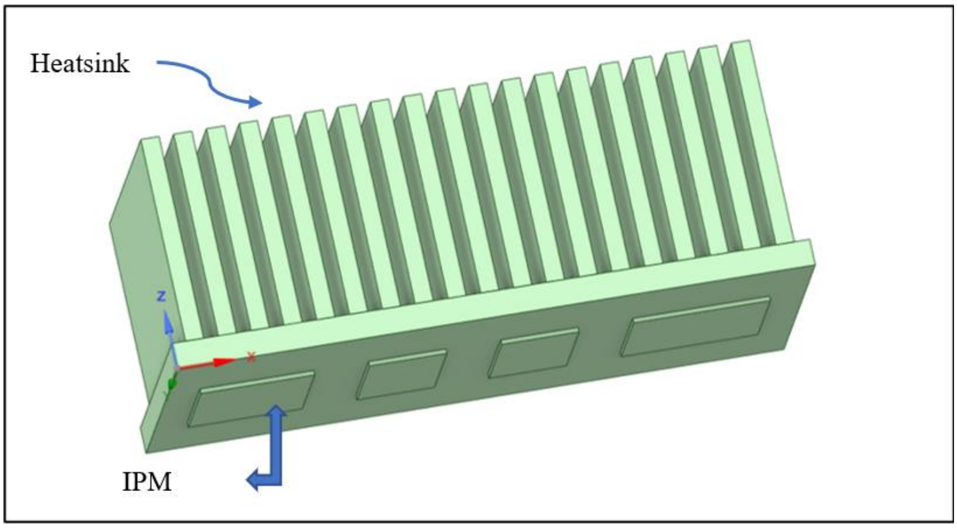


Fig 3.5. Previously used Plate Fin Heatsink Geometry

<u>Temperature Contour</u> – The steady-state thermal analysis is performed on ANSYS software, giving 73.245℃ of maximum temperature where the IPM chip is placed. This temperature is the only reason for the failure of PCBs as the specification according to the IS-1391 have to be under 80℃ for the IPM chip. But our temperature value is much closer to the specification which make the IPM chip get hotter and required cooling time increases. So, we have to decrease the max temperature so the cooling time of IPM gets decreases.

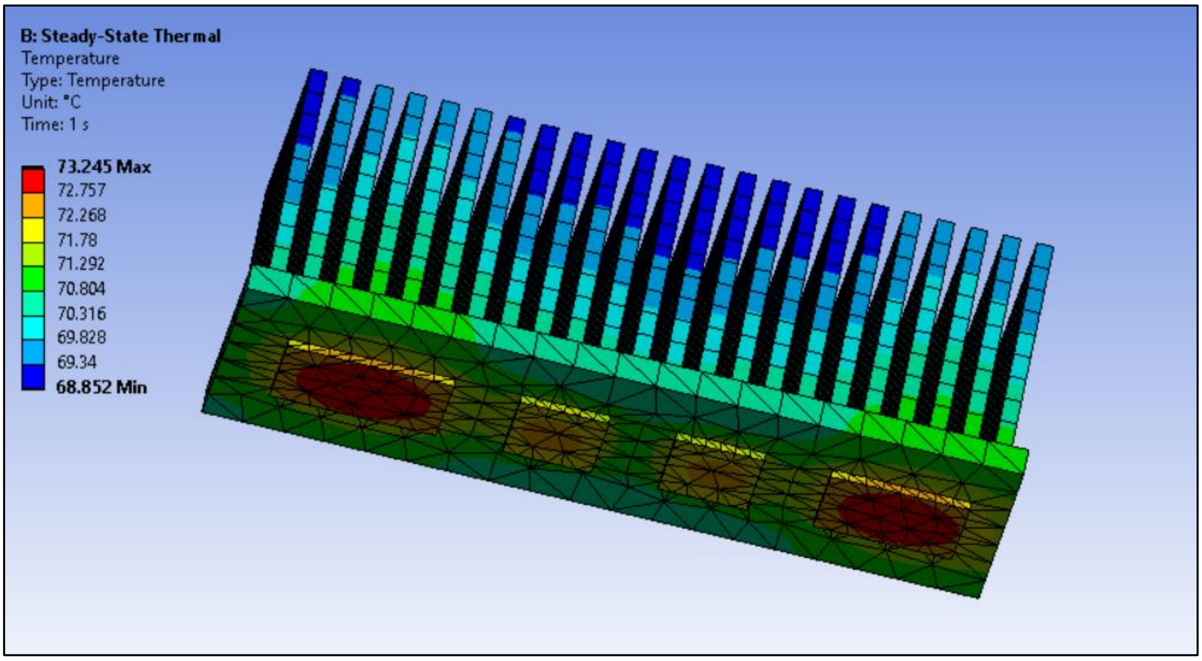


Fig.3.6. Steady State thermal Temperature contour

So, for the new geometry of the Heatsink effect of different fin shapes, number of fins, height of the fin, and base thickness were studied.

3.4 FABRICATION OF HEATSINK

Heatsinks can be produced using a variety of manufacturing processes depending on their shapes and materials. Extrusion, forging, casting, and stamping are among the most widely used and economically advantageous techniques. Other more expensive techniques include skiving, swaging, and CNC machining. Despite their high cost, they can create Heatsinks with unique features that cannot be achieved by other means. In this study, rectangular fin Heatsinks (RFHS) based on aluminium are used, and the Heatsink has been manufactured uniquely.

Table 5 summarizes the constraints for five distinct manufacturing processes (extrusion, bonding, folding, skiving, and milling), which were collected from various manufacturers. In each instance, the height is restricted to 45 mm, which is typically advised for the manufacturing process and the structural integrity of the fins.

Table 6.
Heatsink parameters and air properties

Manufacturing Process	Thermal Conductivity	Thickness of Fin	Spacing between Fins
Extrusion	Aluminium (200 W/mK)	>4 mm	>1 mm
Bonding	Aluminium/Copper (200/385 W/mK)	>3.2 mm	>0.5 mm
Folding	Aluminium/Copper (200/385 W/mK)	>2.5 mm	>0.2 mm
Skiving	Copper (385 W/mK)	>0.25 mm	>0.15 mm
Milling	Aluminium/Copper (200 W/mk)	>3.5 mm	>1 mm

But from where we were given the order to manufacture the Heatsink was using a CNC milling operation. So as a trainee we are not allowed to go to a vendor's side company but they tell us the detailed information related to the CNC milling operation which was discussed below.

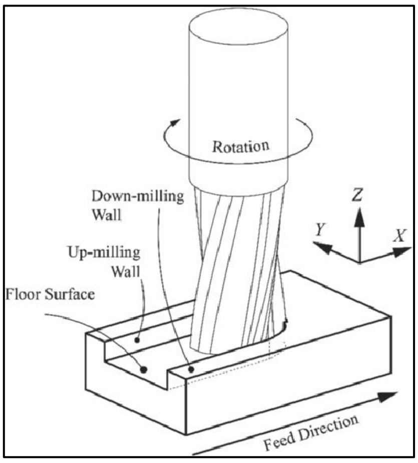


Fig.3.7. CNC Milling Operation

Three factors must be present for milling to be successful and of high quality:

1. A cutter with numerous teeth and the perfect level of sharpness for a material
2. Rotating a tool quickly enough to properly process a material.
3. The right feed rate to move the selected material along the process

The PFHS was created by milling an aluminium bar with dimensions 140 mm x 50 mm x 42 mm (width x length x depth). The finished aluminium plate-fin type Heatsink is depicted in Figure 3.4. To insert a temperature probe and measure the temperature, five holes with a 1.5 mm diameter and 3.4 mm depth each are drilled below the heat sink. The position of holes are exactly same where the 4 chips are placed over the PCB.

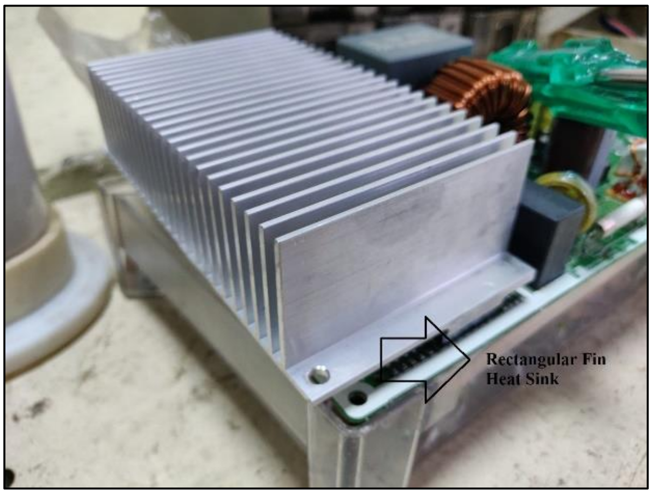


Fig.3.8. Fabricated Plate fin heatsink

3.5 EXPERIMENTAL SETUP

Experimental Analysis was performed at Development Quality Assurance (DQA) in LG Electronics Pvt Ltd under the guidance of Mr. Promod Singh. As shown in the figure, the Heatsink we used is the rectangular fin Heatsink. So, under IS 1391, we perform our test. We perform the test to check whether the PCB works properly or not. This test follows the IS 1391 which is related to the electrical safety parts. The two main components we use to perform the test are K type thermocouple and the calorimeter lab. The list of other components and equipment we use while performing the test are listed below:

1. Plate Fin Heatsink
2. Thermocouple
3. Printed Circuit Board
4. Split Type Air Conditioner
5. Calorimeter LAB
6. Heatsink Paste.

3.5.1 Description of Each Component

- Plate Fin Heatsink (PFHS) – After fabrication of the Heatsink, we use this to perform our test. The aluminium material we used to fabricate our Heatsink. The temperature range of this Heatsink is from -8℃ to 150℃. For our goal, we require a temperature under 110℃. So, this Heatsink is best for our project. As discussed in chapter 1 the main function of the heatsink is to take heat flow away from a hot device. The used Plate fin heatsink is shown in fig. 3.9.

Table 7.
Description of Fabricated Plate Fin Heatsink

Number of fins	*23*
Fin Spacing	*2.95mm*
Material used	*Al- 6063*
Fin height	*38 mm*
Temperature Range of PFHS	*-10℃ to 150℃*
Base Size	*140 X 50 mm^2*
Thermal Conductivity	*201 W/mK*
Fin thickness	*3 mm*

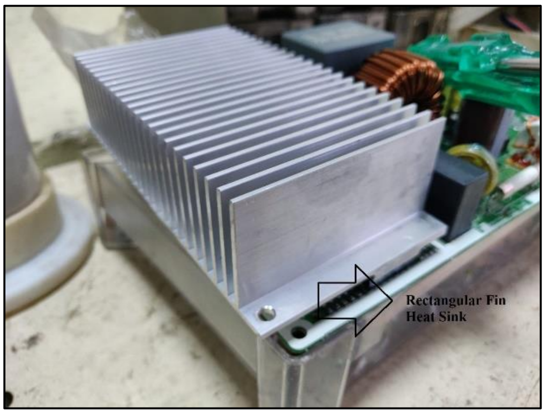


Fig.3.9. Used Plate Fin Heatsink

- Thermocouple - The most popular thermocouple and one that offers the widest operating temperature range is the Type K thermocouple, as shown in Figure 4.8. The integrated composition of Chromel and Alumel wires used in Type K thermocouples makes them suitable for a wide range of applications. The thermocouples have good corrosion resistance because they are nickel-based.

Table 8.
Thermocouple Specification

Specification	Range
Accuracy	+/- 2.1°C, or +/- 0.77 percent
Temperature Range	-200 to 1260°C.

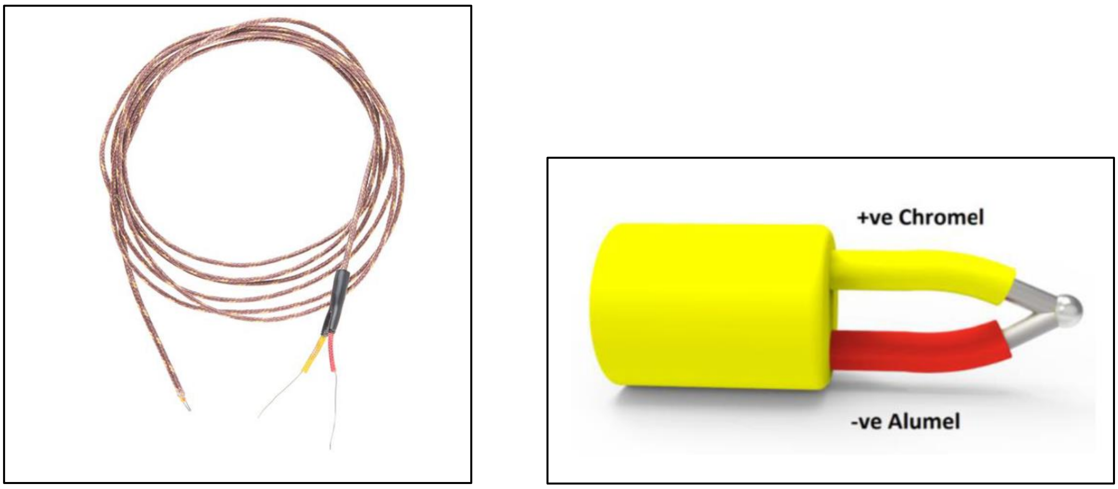


Fig.3.10. K type thermocouple

- Printed Circuit Board – Printed circuit board is referred to by the abbreviation PCB. The gadgets resemble a computer's CPU or motherboard. It's crucial to understand that an air conditioner still houses a motherboard. The small green boards or microchips that act as the air conditioner's brain are referred to as printed circuit boards in an AC. Both the indoor and outdoor units of the air conditioner contain these PCBs. These are employed to carry out a number of intricate communication and output operations.

  The wiring for various components, including transistors, capacitors, resistors, etc., is done on a green board called a PCB. Conductive tracks are the connections that run between the different parts. They are constructed with a layer of copper and covered in a silkscreen made of fiberglass.

The primary purpose of a PCB is to incorporate various components to carry out data communication, a particular command, or compute the output for controlling the AC.

But for us, we have to only focus on the 4 chips i.e., IPM, IGBT, FRD, and Bridge

Rectifier as shown in figure 3.11. Because four chips are placed below the Heatsink. As our Heatsinks main role is to cool down these four chips. The detailed description of these four chips with their functions are described below:

1. **IPM-** It stands for the intelligent power module. It is a high-performance module that mounts a dedicated drive circuit to get more power from an IGBT chip. It also includes a custom IC for self-protection functions (short circuit, supply under voltage, and over temperature). It works under the temperature of 80℃ and above this there is a chance of short-circuiting.

2. **IGBT-** A BJT that is designed to enable quick switching with minimal power losses is known as an Insulated Gate Bipolar Transistor (IGBT), and it is the perfect choice for use as a switch in high-power circuits. It frequently comes packaged with a flyback diode, also known as a freewheeling diode, to guard against inductive kickback damage. It works under the temperature of 105℃.

3. **FRD-** A semiconductor component with a rapid reverse recovery time is referred to as a fast recovery diode (also called a fast diode, fast switching diode, or fast diode). Fast recovery diodes are more appropriate for high-frequency rectification applications because they have a faster reverse recovery time than conventional diodes. It works under the temperature of 105℃.

4. **Bridge Rectifier**- A bridge rectifier is an alternator that produces direct current (DC) from mains AC input. Power supply that provide the necessary DC voltage for electronic components or devices usually contain bridge rectifiers. They can be created using four or more diodes or any other controlled solid-state switch. Based on the demands for load current, a suitable bridge rectifier is selected. Under 105°C, it operates properly.

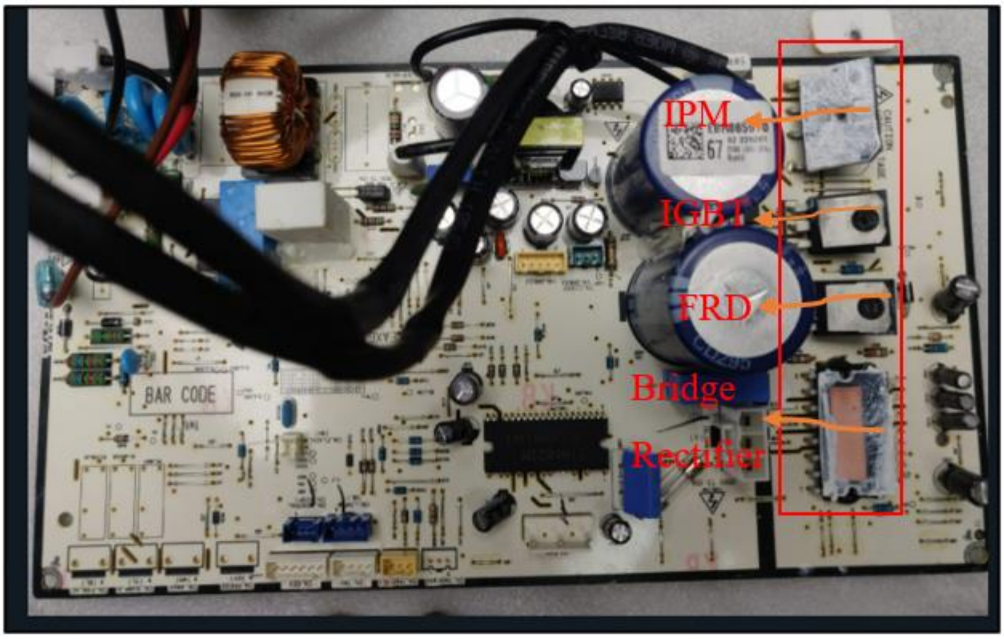


Fig.3.11. Printed Circuit Board

- Split Type Air Conditioner – A 2-ton split air conditioner is used in this experiment. This air conditioner works under 60℃ of ambient temperature. And the voltage range is between 165V to 255V.

(a) (b)

Fig.3.12 (a) IDU (b) ODU of Air Conditioner

- Calorimeter LAB - The calorimeter provides a way for simultaneously assessing cooling capacity on both the interior and outdoor sides. The room side capacity is determined by balancing the cooling and dehumidifying effects with measured heat and water inputs. The external side capacity provides a validating test of the cooling and dehumidifying effect by balancing the heat and water rejection on the condenser side with a specified amount of cooling medium. An insulated wall with an entrance into which the room air conditioner is attached separates the room side and outdoor side calorimeter compartments from one another. To install the air conditioner, filler parts and supporting members must be used in a way akin to a standard installation. No attempt should be made to seal the interior components of the air conditioner to prevent air leakage from the evaporator side to the condenser side or vice versa. Any connections or alterations to the air conditioner must not have the potential to impair its normal operation.

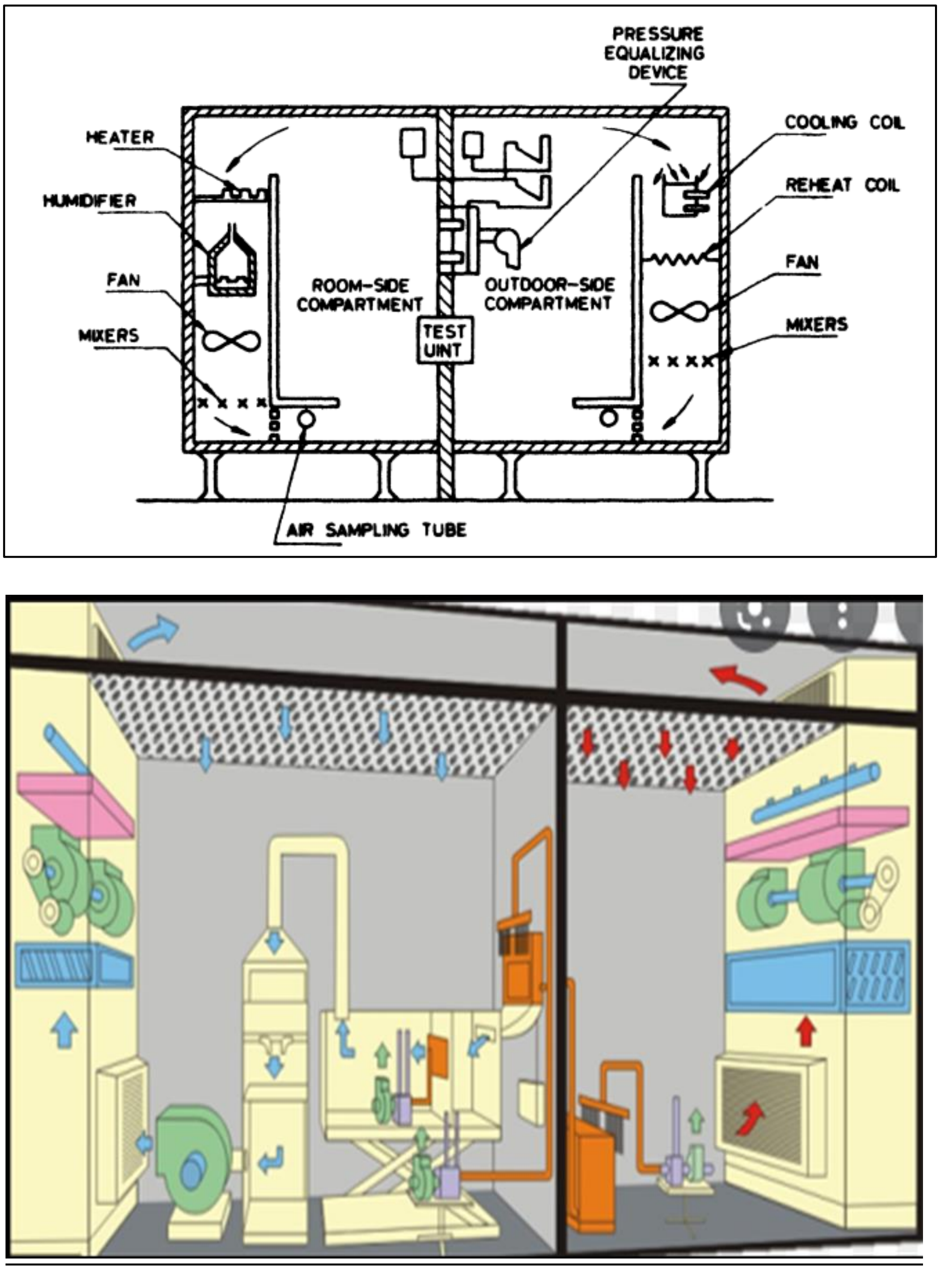


Fig.3.13. Calibrated Room Type Calorimeter

From figure 3.11 (b) we can set the temperature of the indoor and outdoor side compartments. This control panel shows the input voltage, current, and pressure of the air conditioner i.e., running inside the compartment. The voltage range of this lab is 165-245V.

Table 9.
Calorimeter Lab Specification

Capability	**Temperature Control Range**	**Test Items**
Cooling : 2,000-7,600 kcal/hr	Indoor : 15-45℃	Cooling/ Heating Performance/ Reliability/Safety
Heating : 2,000-8,000 kcal/hr	Outdoor : 15-60℃	
Air Flow *:* 2.54-1.64 m^3/min		All kinds of International Test Condition

- <u>Heatsink Paste</u> - As an interface between Heatsinks and heat sources, such as high-power semiconductor devices, thermal paste is a chemical compound that is thermally conductive. To increase heat transfer and dissipation, thermal paste's primary function is to remove air gaps or spaces from the interface area.

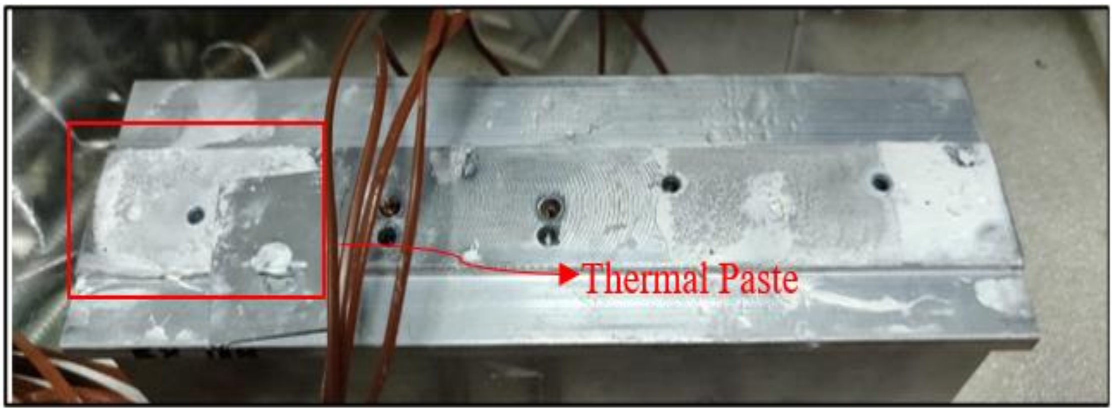


Fig.3.14. Thermal Paste

3.5.2 Test Procedure

The following are the test procedure steps that has been followed during experimental analysis:

1. Make a 5 hole through the Heatsink as show in below fig. so that we can place a thermocouple there where we can note down the temperature of 4 chips i.e., placed below the heatsink.

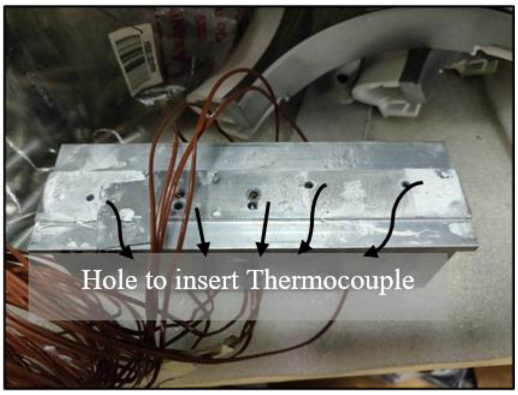
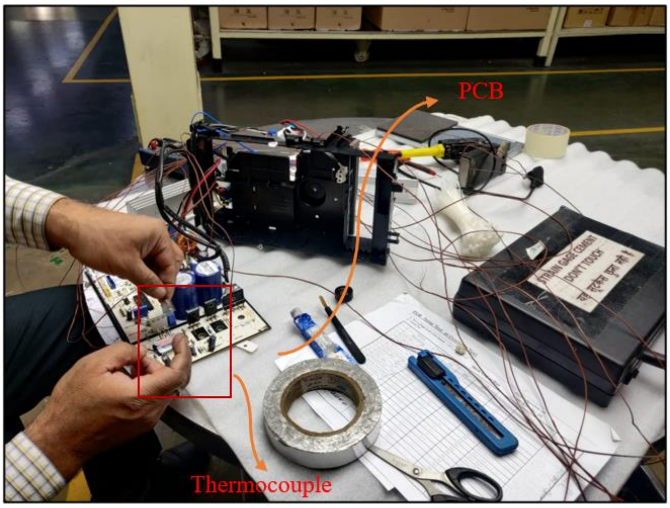
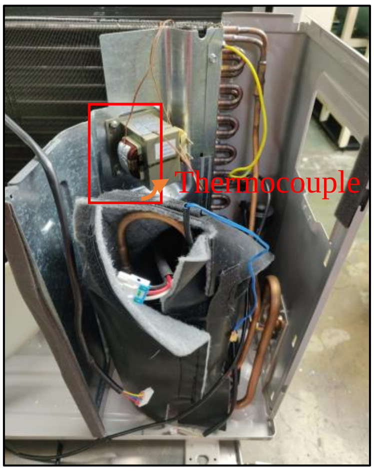


Fig.3.15. Heatsink with hole

2. The thermocouple is attached to the PCB and ODU as shown in figure 3.14. We must run the air conditioner before recording the temperature reading. The first end is connected to the PCB and the other end is connected to the thermocouple box i.e., inside the calorimeter. As shown in fig.3.14 (b), there are some thermocouples attached to the air conditioner's outdoor unit. The compressor's outlet pipe, the thermistor, and the condenser's outlet pipe all have thermocouples attached to them.



(a)

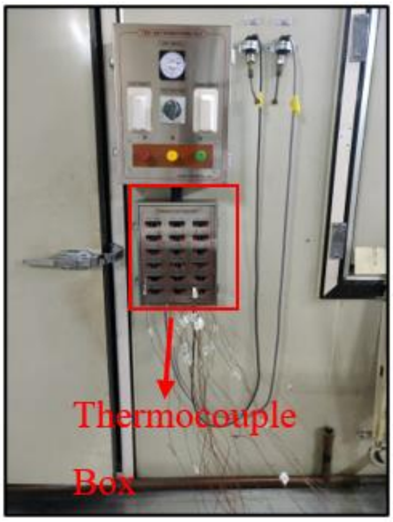


(b)

Fig.3.16. Attachment of Thermocouple in (a)PCB (b)Outdoor Unit of Air Conditioner

3. After attachment of thermocouple to PCB, we put the air conditioner unit in the calorimeter lab as shown in the below fig. We attach the other end of thermocouple to the thermocouple box. After that we switch on the power supply of air conditioner and run continuously for 5 hours.

(a) *(b)*



(c)

Fig.3.17. (a) Outdoor Unit (b) Indoor Unit (c) Thermocouple Box. All are placed inside the calorimeter

4. Now set the indoor and outdoor condition through the PC.
   Outdoor Condition: WBT- 24℃, DBT- 35℃
   Indoor Condition: WBT- 32℃, DBT- 23℃
   Voltage: 230V

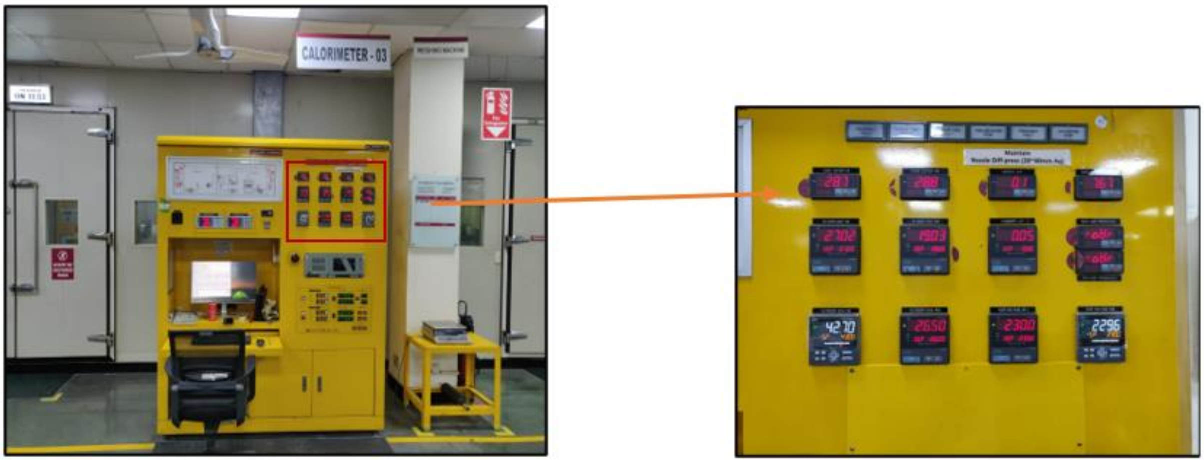


Fig.3.18. Calorimeter lab Control Panel

5. Now run the whole unit for 5 hours and every 20 min increase the outdoor side WBT by 1℃ till the WBT reaches 40℃. Similarly, increase the value of DBT of ODU by 3℃ till it reaches 50℃ after that increase it by 1℃ till it reaches 60℃. This test condition clearly mentioned in the table 8. And check the final temperature of thermocouple at the end of the test as shown in fig. 3.17.

Table 10.

Test condition for variable Temperature

IDU		**ODU**	
DBT	WBT	DBT	WBT
32	23	35	24
32	23	38	25
32	23	41	26
32	23	44	27
32	23	47	28
32	23	50	29
32	23	51	30
32	23	52	31
32	23	53	32
32	23	54	33
32	23	55	34
32	23	56	35
32	23	57	36
32	23	58	37
32	23	59	38
32	23	60	40

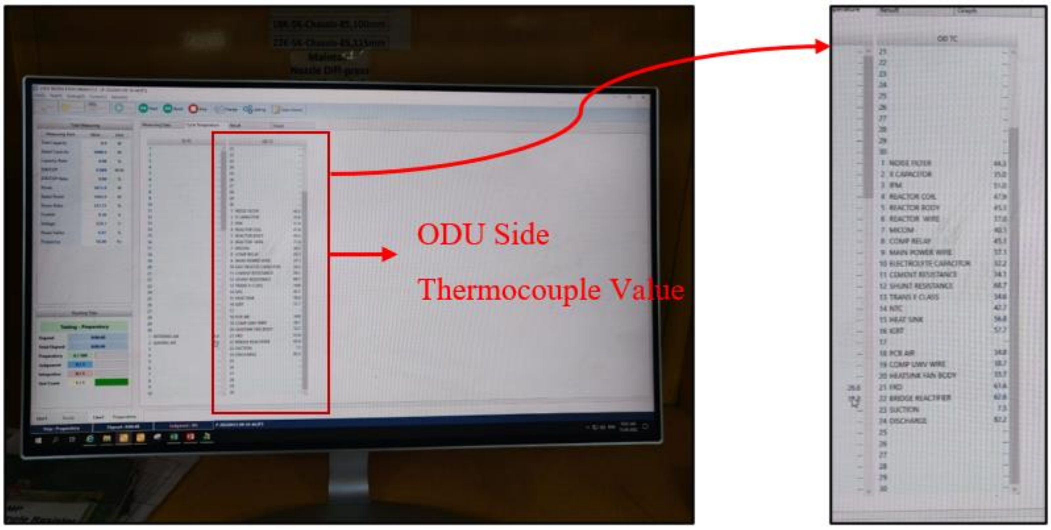
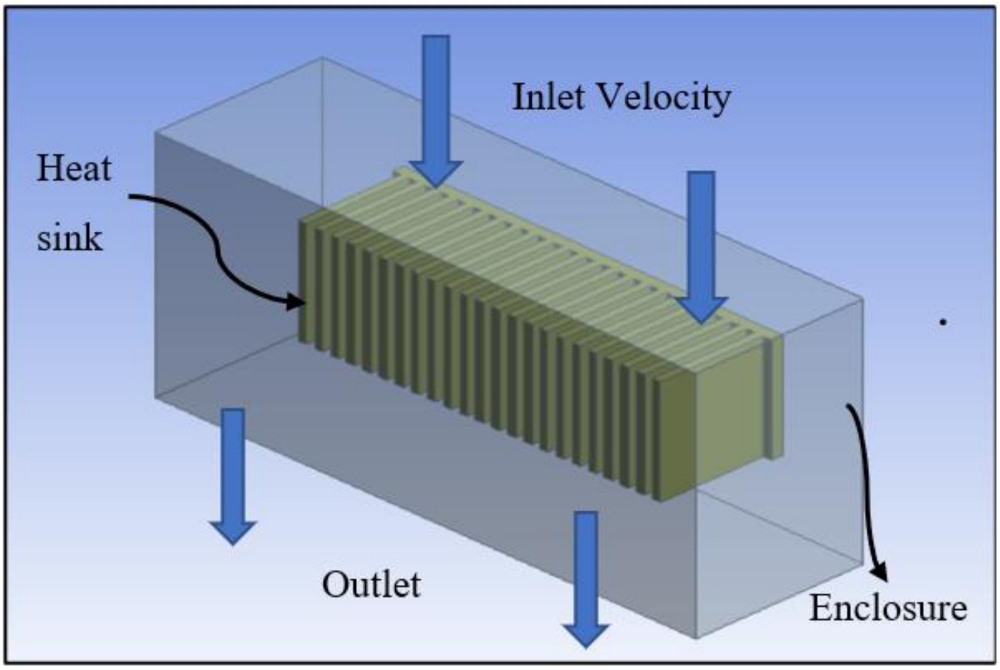


Fig.3.19. Thermocouple Value

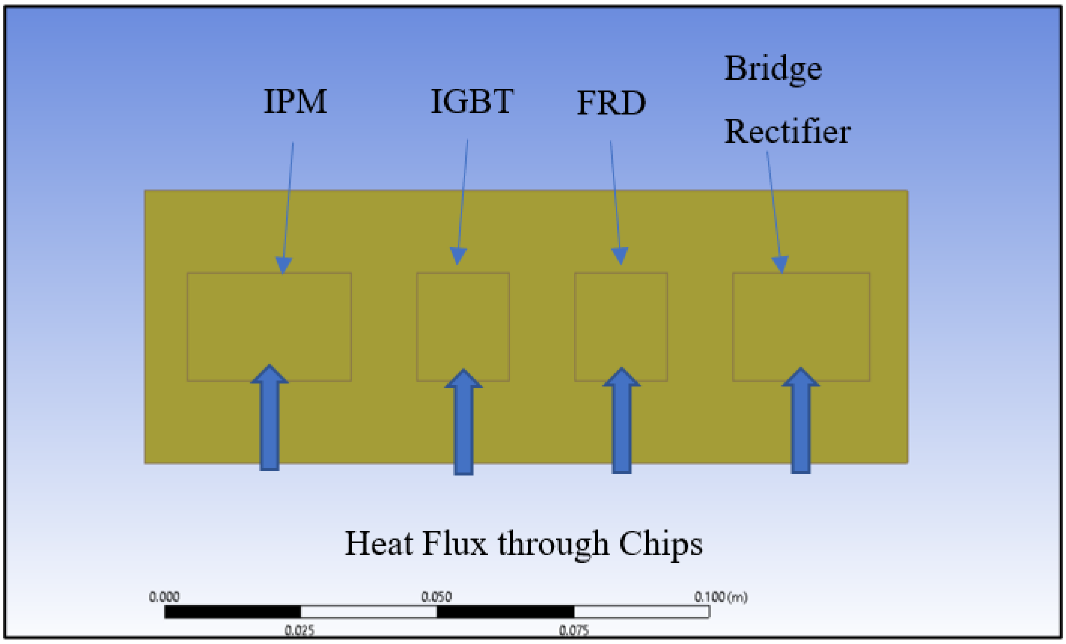
3.5 CFD MODELING

3.5.1 New Model Description

Version 22 of Ansys Workbench was used to create a geometric model. Schematics for the electronic package model, which included a chip and a top-mounted Heatsink, are shown in Fig. 3.17. The IPM chip measures 20 x 35 mm and is 1 mm thick and the details of all 4 chips are mentioned in table 6. In this study, a Heatsink with flat plates and rectangular fins is employed. The Heatsink measures 140 x 50 mm and has a 3.5 mm thick base. There are 23 rectangular fins, each measuring 50 x 3 mm, with a fin spacing of 2.95 mm and a height of 38 mm. The enclosure is also selected which acts as a PCB box. The velocity inlet is 4m/s.



(a) Isometric View



(b) Bottom View

Fig.3.20. Geometry Description of New Model

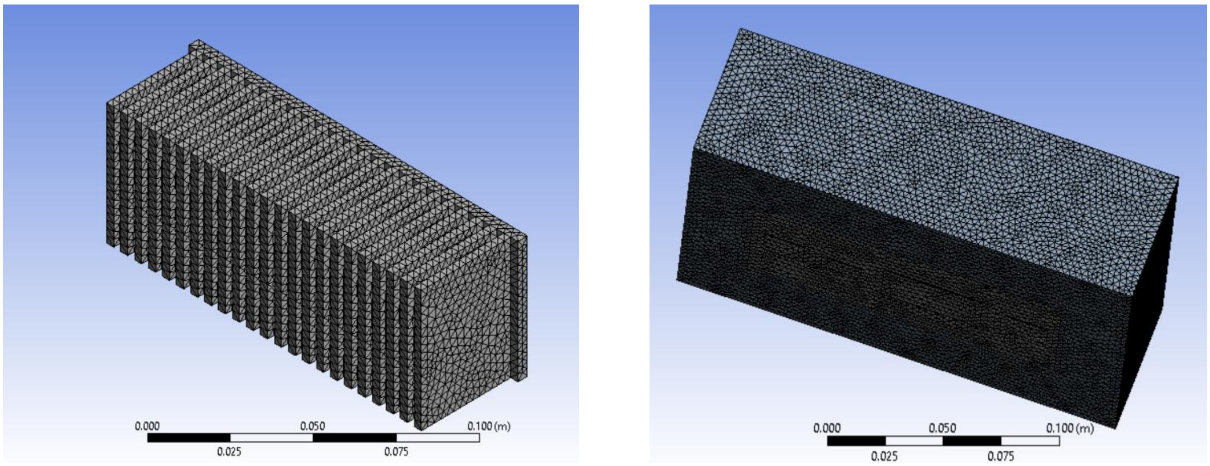
Table 11.
Chip Size description

Chip Name	Dimension
Intelligent Power Module (IPM)	20 x 25 mm^2
Insulated Gate Bipolar Transistor (IGBT)	20 x 16 mm^2
FRD	20 x 16 mm^2
Bridge Rectifier	20 x 30 mm^2

3.6.2 Meshing

The creation of the mesh is the second step in pre-processing. The model is then launched in the meshing module for mesh generation after being imported into Ansys Workbench.

There are different types of coarse, medium, and fine mesh. A high-quality solution must have mesh as its foundation. Tetrahedral CFD meshes are employed in our problem.



(a) (b)

Fig.3.21. (a) Meshing of Heatsink (b) Meshing of the whole domain

3.6.3 Load and Boundary Conditions

The steady-state thermal conduction of an aluminium Heatsink is analysed using the finite element method. To solve the model, the following presumptions were made:

1. The maximum case temperature of the chip is assumed to be no higher than 70℃ in for it to function properly.
2. The other chip surface that should be in contact with the printed circuit board is not taken into account by the study; it only takes into account the heat flow through the chip to the Heatsink (PCB).
3. The chip's and alleged printed circuit board's upper boundary temperature is assumed to be 110℃.
4. The electronic package is thought to be perfectly bonded.

The detailed description of new geometry dimensions and boundary condition are mentioned in the below table 10.

Table 12.
New model description and boundary Conditions used

Parameters	Values
Fin Height	38 mm
Fin Spacing	2.95 mm
Fin and Base material	Al-6063
Inlet Velocity	4 m/s
Heat Flux	68000 W/m^2
Number of fins	23
Fin thickness	3 mm
Base Area	140 x 50 mm^2
Enclosure Volume	200 x 100 x 65 mm^3
Atmospheric Temperature	293K
Thermal Conductivity	201 W/mK

3.6.3 Governing Equations

The laws of conservation of mass, momentum, and energy serve as the foundation for understanding heat transfer. It is assumed that all P-V-T thermodynamics properties are constant. The equation for continuity, momentum, and energy is shown below [21]. Together with the equation of state, the Navier-Stokes equations for direction, momentum, and energy also include x-y and z.

Law of Conservation of Mass-

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho \vec{v}) = 0 \tag{9}$$

Momentum Equation:

X momentum Equation-

$$\frac{\partial (\rho u)}{\partial t} + \nabla.\left(\rho u \vec{V}\right) = -\frac{\partial p}{\partial x} + \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z} + S_{Mx} \tag{10}$$

Y momentum Equation-

$$\frac{\partial(\rho v)}{\partial t} + \nabla.\left(\rho v \vec{V}\right) = -\frac{\partial p}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{zy}}{\partial z} + S_{My} \tag{11}$$

Z Momentum Equation-

$$\frac{\partial(\rho w)}{\partial t} + \nabla.\left(\rho w \vec{V}\right) = -\frac{\partial p}{\partial z} + \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} \tag{12}$$

Energy Equation-

$$\frac{\partial \rho}{\partial t} + \nabla.\left(\rho \vec{V}\right) = -p\nabla.\vec{V} + \nabla.(k\nabla T) + S_h \tag{13}$$

Equation of State-

$$p = \rho RT \tag{14}$$

where ρ is the density, u,v , and w are velocity components, $\vec{v}$ is the velocity vector, p is the pressure, S terms are the source terms and τ terms are the viscous stress components.

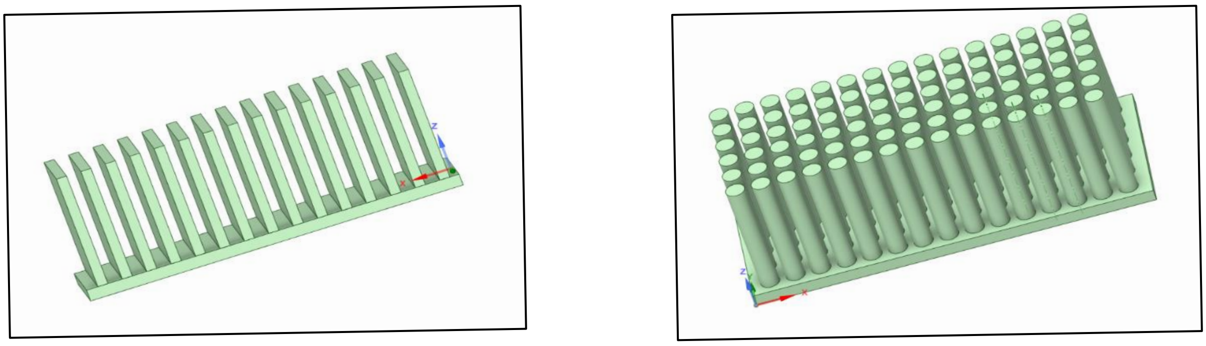
CHAPTER 4

RESULTS AND DISCUSSION

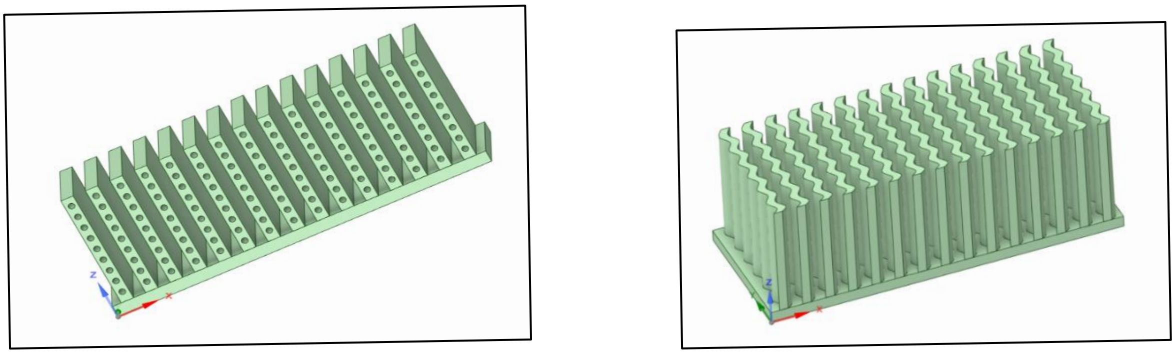
Numerical research is done on a steady-state convective heat transfer process. The following consequences of different heatsink parameters are examined and discussed:

4.1. THE EFFECT OF DIFFERENT SHAPES OF FIN

We have to improve the total heat transfer in the new Heatsink. So first what my mentor asked me to do is to compare different Heatsink geometries (like a rectangular fin, pin fin, perforated fin, and curve fin) and find out which is most suitable for our purpose. Our main motive is also not to increase the cost of the Heatsink. So, we have to choose accordingly. As illustrated in Fig. 4.1, construct a three-dimensional depiction of the Heatsink using rectangular fins, circular fins, perforated fins, and curve fins on ANSYS Spaceclaim. All of the fins are presumed to be the same size. The calculation for same total surface area for each shape is mentioned in the appendix section. Thermal conductivity, material, and base Temperature are all the same.



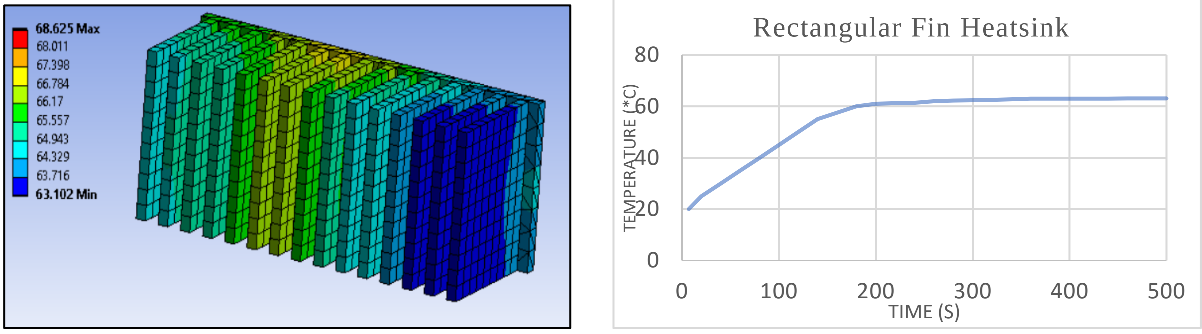
(a) Rectangular Fins (b) Pin Fin



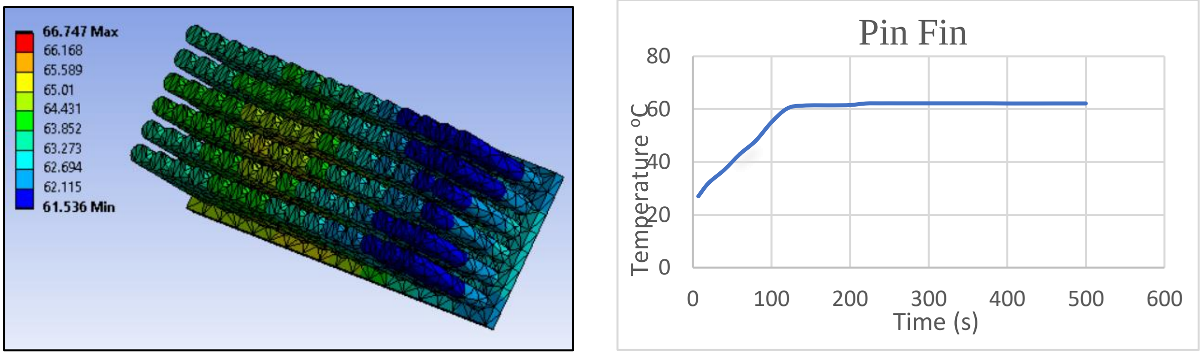
(c) Perforated Fins (d) Curved Fins

Fig 4.1 3-D Geometries of different shapes of fin

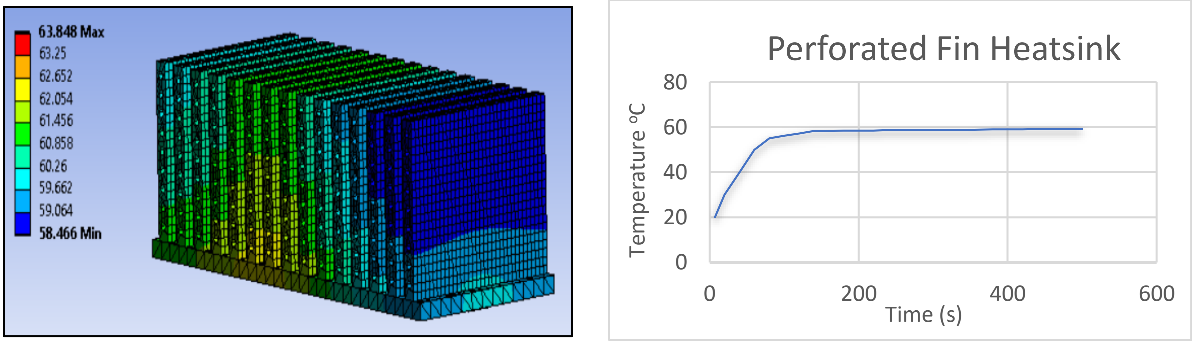
We perform transient thermal analysis using Ansys software to get the minimum temperature of the Heatsink so that we can compare each shape of the Heatsink. For doing this we have to make the geometries of equal volume so that we can compare them. The value of heat transfer coefficient, ambient temperature, and heat flow is the same for all cases. We perform this analysis for 500 seconds. As shown in fig 4.2 we saw that the perforated fin is the best of all of them because the minimum temperature gets constant after 90 seconds. A detailed description and comparison between all the shapes are shown below in fig 4.2 and fig 4.3 respectively.



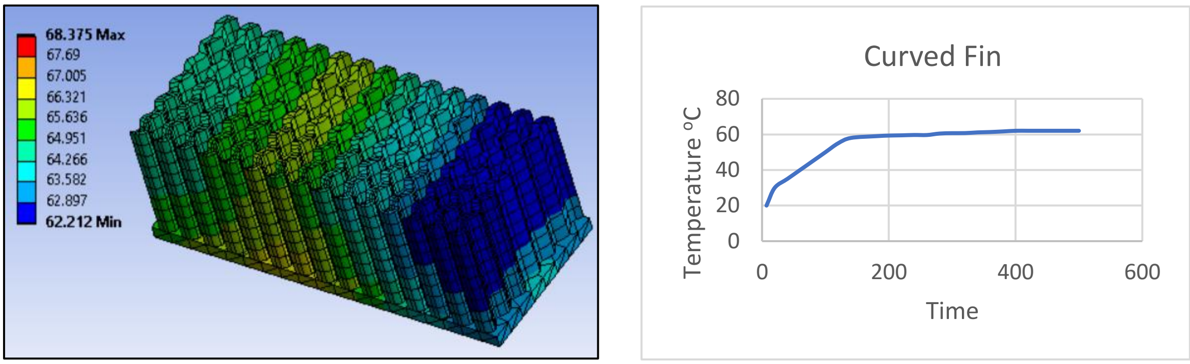
(a) Rectangular Fin



(b) Pin Fin



(c) Perforated Fin



(d) Curved Fin

Fig4.2 Steady-State Analysis of Different Geometry on Ansys Software

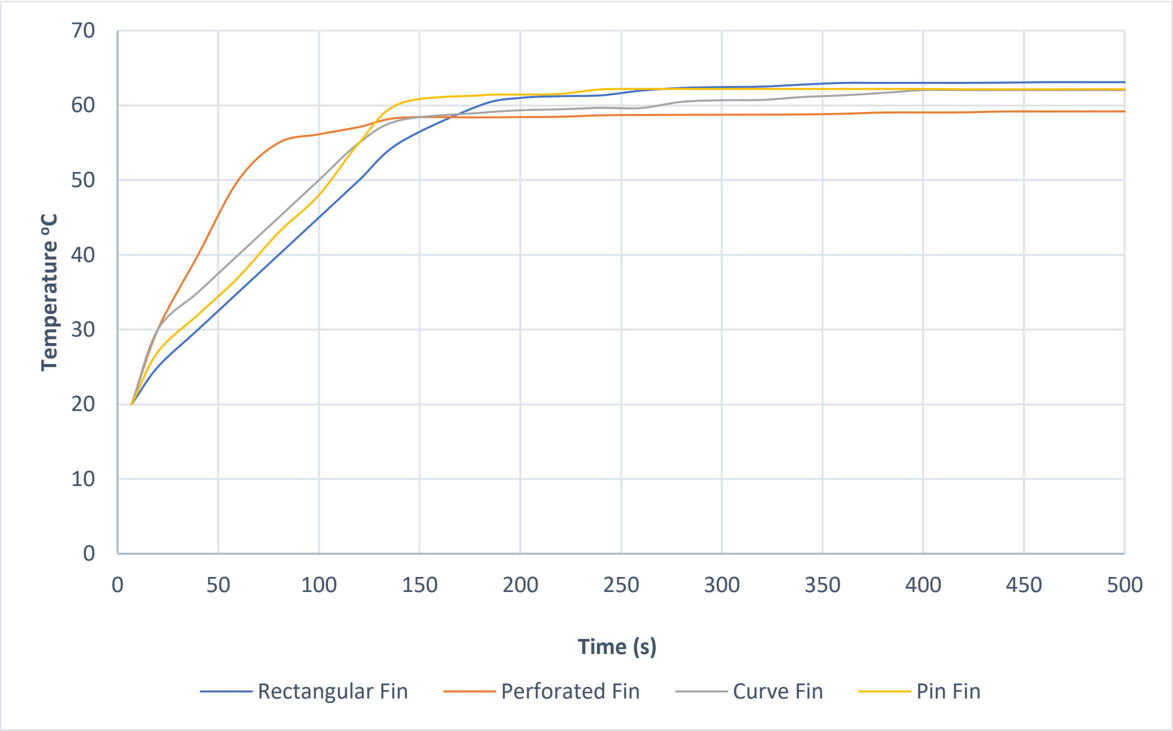


Fig4.3 Comparison of different Fin shapes with their minimum temperature

From the above result, we say that perforated fins show better results than others. But we have to consider its manufacturing cost also. So, for that, we have asked the manufacturing company and they give us approximate manufacturing costs for different shapes of the fin. As mentioned in table 11 and fig 4.4 we can conclude that for manufacturing cost of the perforated fin is much costlier than any other fin. So, for this reason, we rejected the idea of a perforated fin and in our case, we don't require that much amount of heat transfer. The fulfillment in our case is in the range of 50 to 58 kW/m^2. So, we chose the rectangular fin shape because its manufacturing cost is the least and its heat transfer rate is in our range. Therefore, we consider the rectangular fin for further analysis.

Table 13
Manufacturing Cost and total heat flux for different shapes

Geometry	**Minimum temperature (^{O}C)**	**Total Heat Flux (W/m^2)**	**Manufacturing Cost (Rs)**
Rectangular fin	63.102	53041	70
Pin Fin	61.536	58158	130
Perforated Fin	58.466	65794	180
Curved Fin	62.212	56524	110

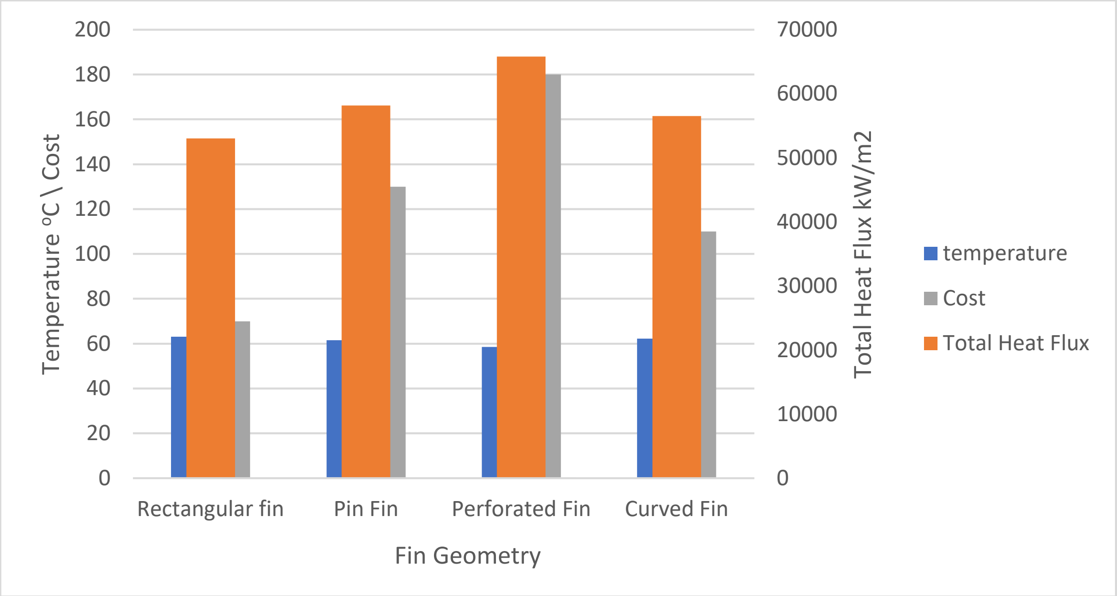


Fig.4.4 Variation of Temperature, Total Heat Flux, and Cost for different configurations of heatsinks

According to the analysis's findings, the order in which we arranged our Heatsink when manufacturing costs were considered (as in the industry we have to look at the cost optimization of the product also) was as follows for a particular choice of aluminum and a constant convective heat transfer coefficient:

Rectangular Fin > Pin Fin > Curved Fin > Perforated fin

4.2. THE EFFECT OF FIN QUANTITY

The ideal fin count is crucial for a Heatsink. A small quantity of fin takes up relatively less space. As a result, the heat transfer may not be as anticipated. On the other hand, having too many fins reduces the rate of convective heat transfer because the space between two adjacent fins may not always be large enough for fluid to flow freely. Additionally, if there are too many fins, more material is needed, which makes the item more expensive and heavier. Because of this, an ideal number of fins is required for a Heatsink to evacuate heat effectively [25]. Seven different 3-D models with 17 to 32 fins each are created to determine the ideal number of fins, and meshes are generated in accordance using the ideal mesh topology. In these cases, the Heatsink has a $5mm$ thick baseplate, $3mm$ fin width, and $40mm$ fin height. Table 12 and Figure 4.5 provide a summary of the outcomes from various fin quantities and their simulated outcomes. Figure 4.5 illustrates that after increasing fin quantity up to 23 fins, there was no discernible change in temperature. Therefore, it can be concluded that 23 fins with a fin space of 2.96 mm are adequate to effectively handle the PCB maximum temperature.

Table 14.
Maximum Heatsink surface temperature for different numbers of fins

Fin Quantity	Fin Spacing (mm)	Temperature (°C)
15	5.86	72.935
17	5.16	69.809
19	4.28	67.281
21	3.55	65.876
23	2.95	63.902
25	2.54	62.991
27	2.05	62.989

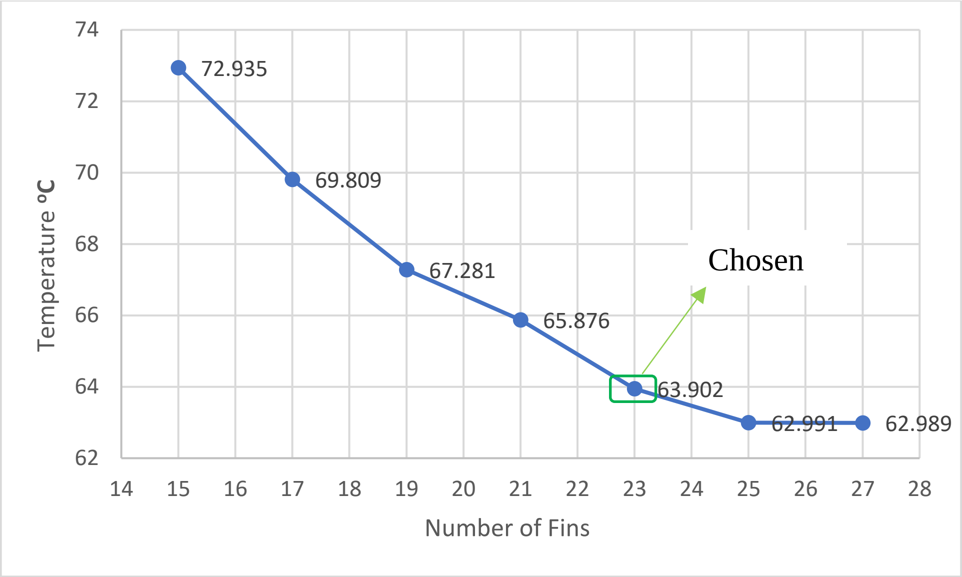
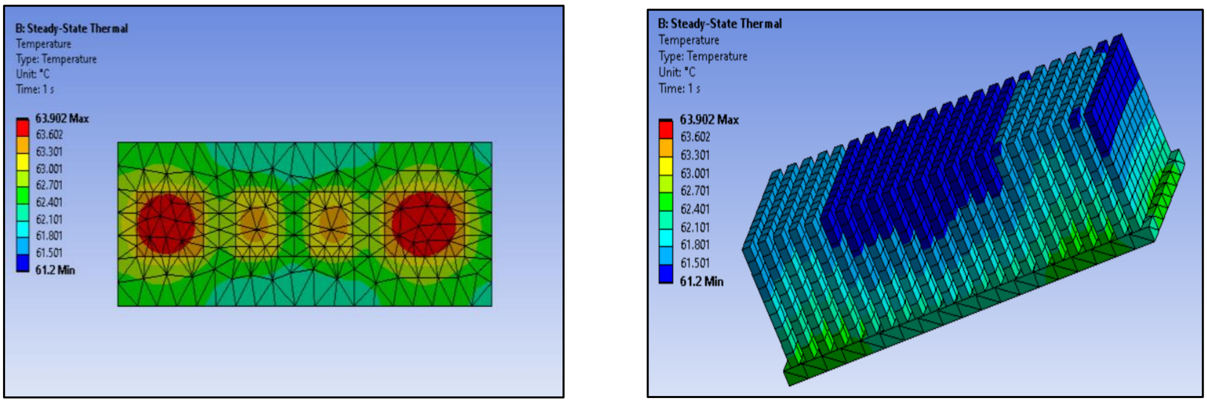


Fig.4.5 Maximum Heatsink surface temperature for different numbers of fins

The steady-state thermal analysis of the chosen fin quantity has been done on the Ansys software shown in figure 4.6. The value of heat transfer coefficient and heat flow have been taken as 28 W/m^{2}K and 35W respectively for all the cases. The ambient temperature is taken as 48^{o}C for the worst condition for the outdoor unit of the air conditioner.



(a) Bottom View *(b) Isometric View*

Fig.4.6 Steady-state thermal analysis of the chosen fin quantity

4.3. THE EFFECT OF BASEPLATE THICKNESS

A heatsinks baseplate thickness is another crucial factor. Meshes are created for baseplate thicknesses ranging from 2mm to 7mm using six different 3D models that are drawn. In every situation, the Heatsink has 23 fins with a 40mm fin height. Simulated results are gathered for various baseplate thicknesses using the optimal mesh topology. Results showed that the heatsink maximum temperature decreased as baseplate thickness increased from 2mm to 5mm.

The ideal baseplate thickness for future Heatsink geometry improvisation is 4mm, which is more suitable. Table 13 and Figure 4.7 provide a summary of the findings from various baseplate thickness and their simulated outcomes. A thicker plate can disperse heat over a larger region of the plate, decreasing thermal resistance. So, for this reason we go for the thicker plate. The maximum temperature was much the same whether the Heatsink base thickness was 5 mm or 7 mm. This might be due to a greater heat transfer in the main portion of the Heatsink base. So, we chose a 4mm thick plate for modelling.

Table 15.
Maximum Heatsink surface temperature for different baseplate thickness

Baseplate Thickness (mm)	Temperature (ºC)
2	66.302
3	65.638
4	64.115
5	63.827
6	63.771
7	63.721

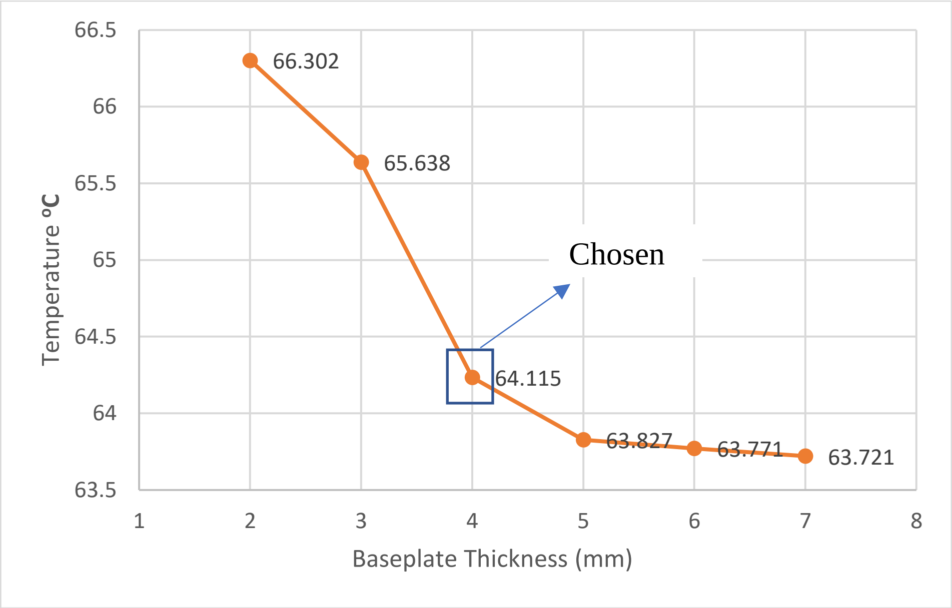
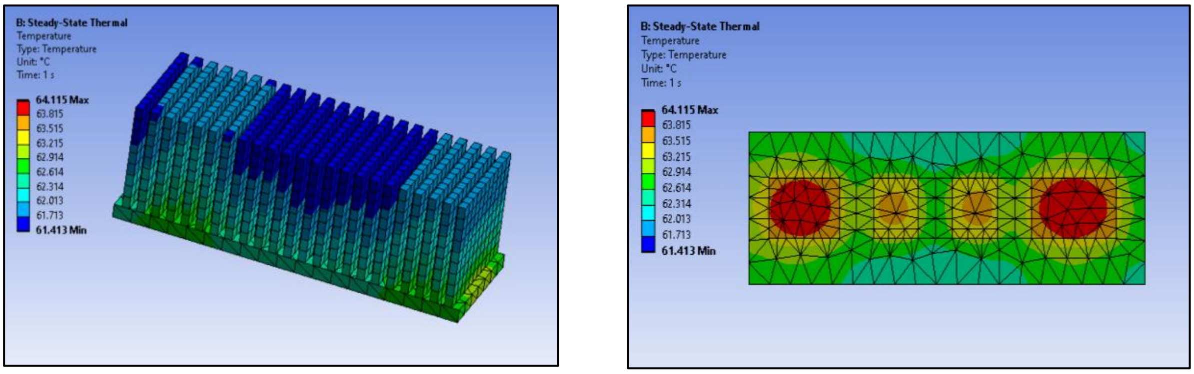


Fig.4.7 Maximum Heatsink surface temperature for different baseplate thickness

The steady-state thermal analysis of the chosen fin quantity has been done on the Ansys software which is shown in figure 4.8. The value of heat transfer coefficient and heat flow have been taken as 28 W/m^2K and 35W respectively for all the cases. The ambient temperature is taken as 48^oC for the worst condition for the outdoor unit of the air conditioner.



(a) Isometric View *(b) Bottom View*

Fig.4.8 Steady-state thermal analysis of the chosen baseplate thickness

4.4. THE EFFECT OF FIN HEIGHT

The next focus will be on optimizing the fins' height. Space is limited in the PCB chassis. As a result, fin height cannot be increased indefinitely. To deal with the Heatsinks space limitations and maximum temperature, optimal fin height is necessary [25]. Several 3D geometries with fin heights ranging from 30 to 60 mm are created to determine the ideal height. In these instances, the amount of fin 23, the thickness of the baseplate, and the mesh topology are all optimal. Table 14 displays the results of the simulations. As the fin height increases, it is discovered that the maximum Heatsink surface temperature decreases, as shown in Figure 4.9. For fin heights greater than 40mm, the temperature change is found to be less significant. The surface area close to the specified boundary condition may be the cause. The maximum temperature decreased when the fin height was 58.33 percent of the Heatsink base's length. The maximum temperature increased up to a fin height that is 75% of the length of the Heatsink base; after that, it decreased. The variation in maximum temperature may also have been influenced by the thickness of the Heatsink base and the proportion of the cross-sectional area to the height of the Heatsink fins.

Table 16.
Maximum Heatsink surface temperature for different fin height

Fin height (mm)	Temperature (ºC)
26	62.298
32	63.137
38	64.665
45	63.916
55	63.126
65	62.686

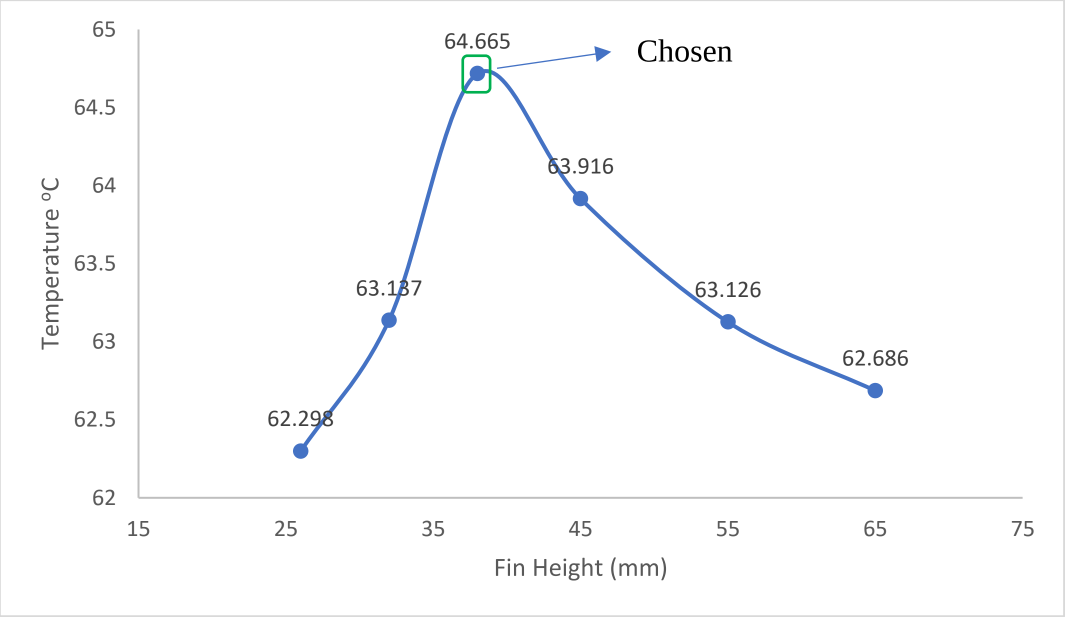
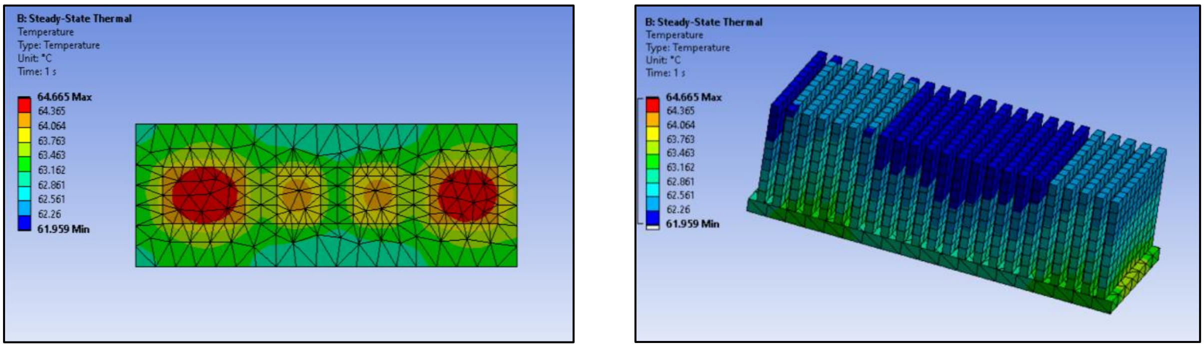


Fig4.9 Maximum Heatsink surface temperature for different baseplate thickness

The steady-state thermal analysis of the chosen fin height has been done on the Ansys software shown in figure 4.10. The heat transfer coefficient and heat flow values have been taken as 28 W/m^{2}K and 35W respectively for all the cases. The ambient temperature is taken as 48°C for the worst condition for the outdoor unit of the air conditioner.



(a) Bottom View *(b) Isometric View*

Fig.4.10 Steady-state thermal analysis of the chosen fin height

4.5 EXPERIMENTAL RESULTS

The PCB overload test performed gave the following results mentioned in table 15. The maximum temperature we achieved from this test is 63.4℃ which is acceptable. The test result for all the thermocouples attached to the PCB surface comes under the specification of IS-1391. The test voltage and IDU fan speed are 230V and high speed 4 m/s respectively. The following test results are for a 2-ton Air conditioner. This time we have taken the factor of safety 2[19]. As you can see from table 15 the previously used IPM maximum temperature is just below the specification that’s why the short-circuiting takes place in the PCB. As you go to the appendix section for the results for

Table 17.
PCB Temperature comparison with previously used and new heatsink

Location	Temp. Spec. (FOS- 2)	Previously Used	Newly	Judgment On The basis of Spec	Judgment On the basis of FOS
IPM	Below 80℃	78. 6℃	61.3 ºC	PASS	NG (Previously used)
Heatsink	Below 105℃	77℃	68.0 ºC	PASS	PASS
IGBT	Below 105℃	85℃	60.2 ºC	PASS	PASS
FRD	Below 105℃	73℃	55.7 ºC	PASS	PASS
Bridge Rectifier	Below 105℃	82℃	61.5 ºC	PASS	PASS

The main results that we get from the thermocouples attached through the hole are mentioned in table 15. The temperature of IPM in the previously used Heatsink just touches the specification line i.e., 80°C. When we ran the air conditioner continuously for 5 hours then this value of previously used IPM damages itself as the time interval of cooling increases which makes the short-circuiting the IPM section of PCB. But this type of behavior didn't show in the new model of the Heatsink as we succeed in lowering the maximum temperature of the Heatsink which automatically lowered the IPM's maximum temperature. The overall temperature values we get through the test are mentioned in table 16.

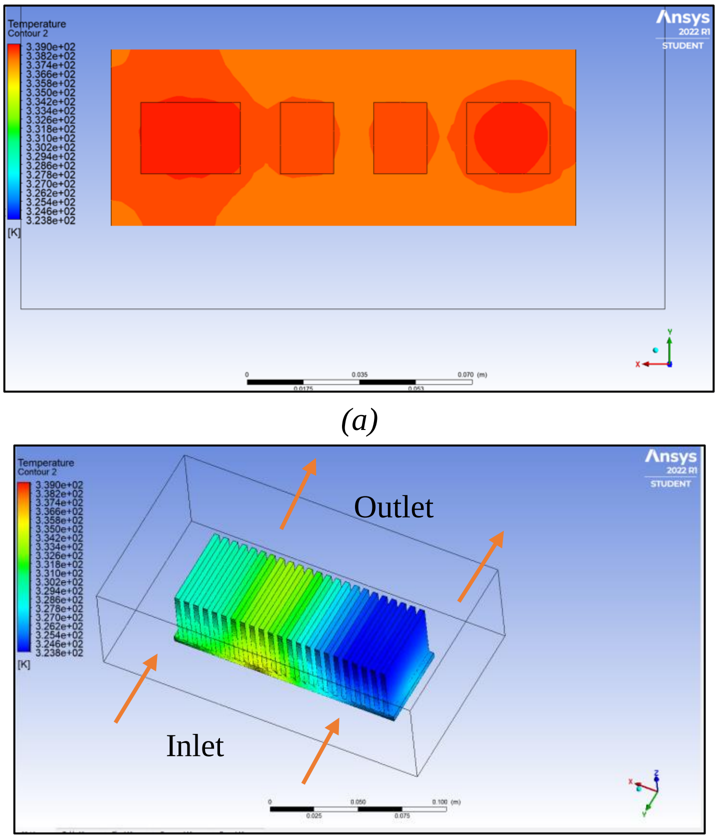
Table 18.

PCB Overload Test Result of newly Heatsink

S.NO.	Location	Extended Pipe(20m)	Standard Pipe (5m)	Judgment	Temp. SPEC.
1	IPM	62.1°C	61.3 °C	OK	Max 80 °C or less
2	Heatsink	68.0 °C	67.8 °C	OK	Max 105 °C or less
3	PCB Air Temp	53.3 °C	55.2 °C	OK	Max 105 °C or less
4	X- Capacitor Body	54.2 °C	51.3 °C	OK	Max 105 °C or less
5	Reactor Coil	96.6 °C	87.4 °C	OK	Max 100 °C or less
6	MICOM	64.4 °C	61.2 °C	OK	Max 80 °C or less
7	Capacitor	61.0 °C	59.2 °C	OK	Max 85 °C or less
8	Control Box Surface	55.5 °C	53.7 °C	OK	Max 80 °C or less (Check Deformation of plastic parts)
9	Shunt Resistance	99.9 °C	90.7 °C	OK	Max 105 °C or less
10	COMP Relay	72.9 °C	71.4 °C	OK	Max 95 °C or less
11	Noise Filter	101.2 °C	81.0 °C	OK	Max 105 °C or less
12	IGBT	62.4 °C	60.2 °C	OK	Max 105 °C or less
13	FRD	57.8 °C	55.7 °C	OK	Max 105 °C or less
14	Bridge Rectifier	61.9 °C	61.5 °C	OK	Max 105 °C or less

4.6 CFD FLUENT APPROACH RESULTS

The simulations were performed using the ANSYS FLUENT CFD code. The fin height, number of fins, and baseplate thickness are 38mm, 23, and 4mm respectively for the 3D geometry of the heatsink. The meshing was very fine. The flow and temperature behaviour of the air entering the Heatsink from the inlet section is depicted in Figure 4.11. The Heatsink's lower side in Fig. 4.11 (a) displays a higher temperature of about 339 K.



(a)

(b)

Fig.4.11. The contour of maximum temperature distribution in rectangular Heatsink at 4 m/s velocity (a) Bottom view of heatsink (b) Isometric view of a Heatsink with inlet/outlet section

Fig.4.12 shows the Velocity contour in the section where the Heatsink is placed in the PCB box. It shows the velocity distributions in the Heatsink region. In some region, the magnitude of the velocity in the side section of fins are highest and inside the fin, the velocity magnitude is around 4.748 m/s. Only at the time of entering the Heatsink, the velocity magnitude is maximum i.e., 8.201 m/s. From this, we can understand that at the time of velocity entering the heatsink an increase in temperature causes an increase in velocity which makes it easier for taking heat from the heatsink.

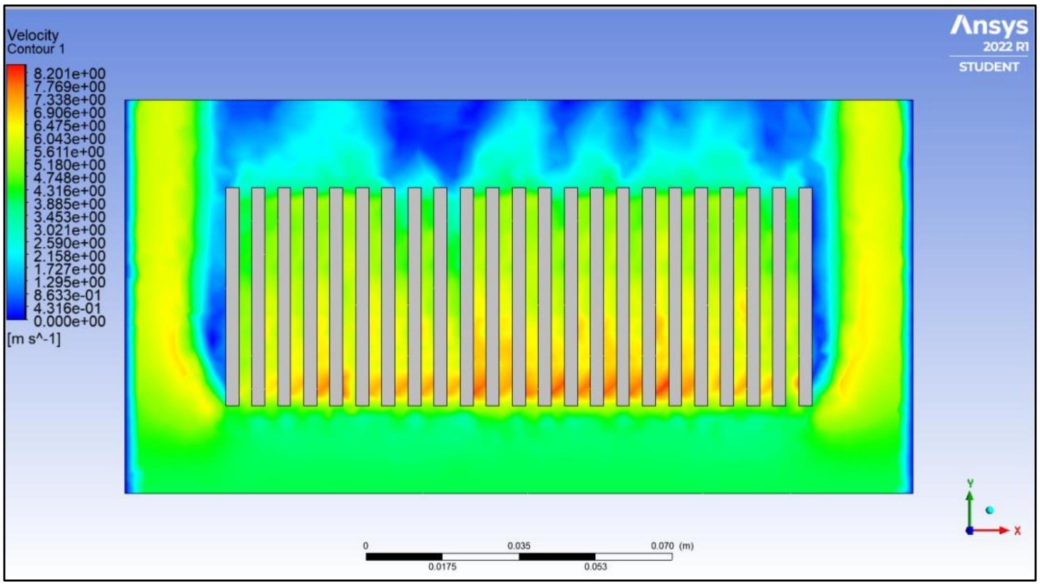


Fig.4.12. Velocity Contour

The maximum pressure drop is shown at the outlet as 1.848 Pa. It became clear if we see Fig.4.13. In the section where velocity is higher the pressure drop behavior is lesser and vice versa.

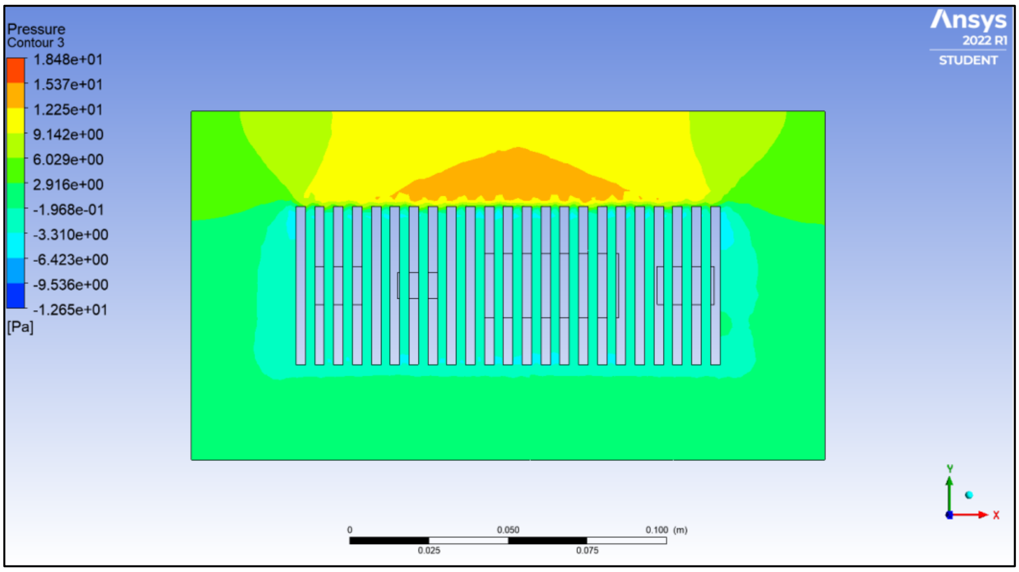


Fig.4.13 Pressure Contour

4.7 VALIDATION

As shown in Fig. 4.14, the maximum temperature of a Heatsink that we determine using the numerical approach, the experimental approach, and the numerical modelling approach is compared to each other. As can be seen, the experimental method's maximum temperature value is 68°C. This is due to the fact that in other methods, the calculation's underlying assumption is taken into account.

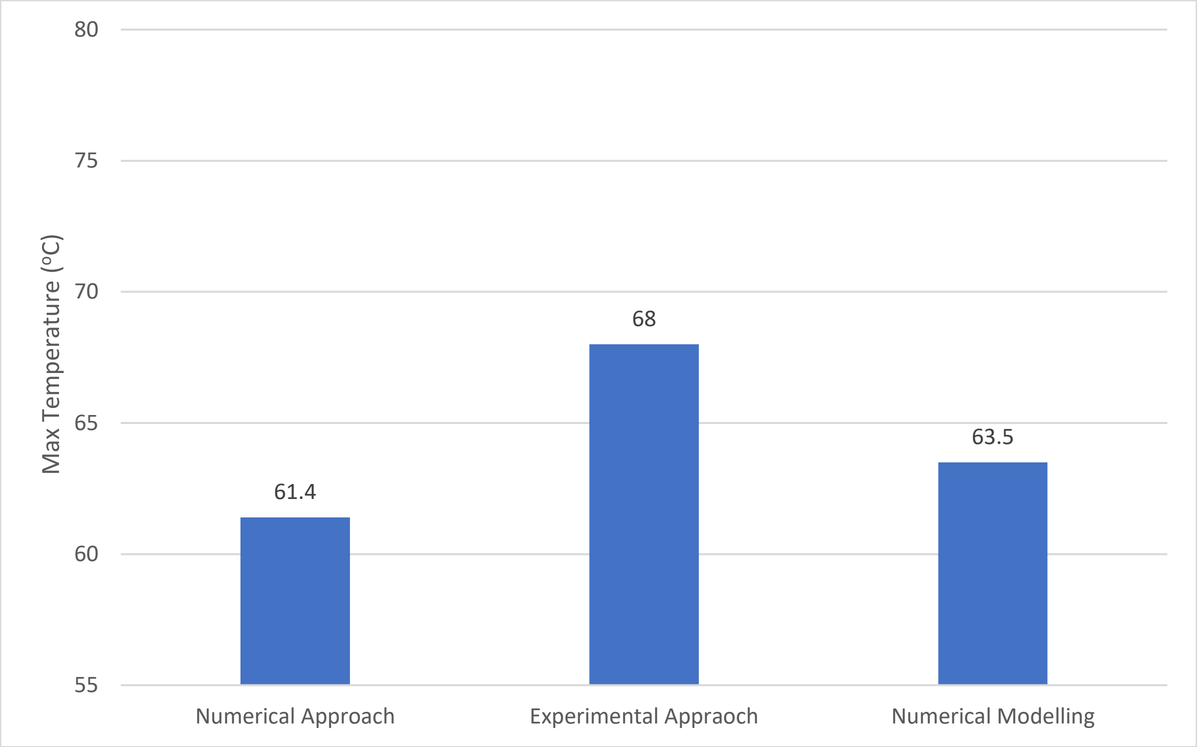


Fig.4.14. Comparison between Numerical Approach, Experimental Approach, and CFD Modelling

We had prepared a comparison table 18 which gives a detailed description of the previously used heatsink and newly heatsink:

Table 18.
Comparison of Heatsink

Parameters	Previously Heatsink	Newly Heatsink
Weight	746gm	755gm
Cost of Mfg.	Rs. 67	Rs. 70
Heatsink Max. Temp.	77℃	68℃

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION

The results of an experimental study on plate fin Heatsinks were compared with those from numerical analysis and numerical modelling to determine how accurate they were. The thermal properties of Heatsinks were examined using a variety of fin shapes, and we then investigated the effects of height in fin, numbers of fin, and base thickness on the heatsink while keeping the very same parameters in every case constant. The experimental study and the numerical analysis have been validated. Based on the study results, the below conclusion has been summarized.

- Based on the findings, when we compare the heatsink by keeping every parameter constant only the fin shape changes. We observe that as we increase the contact area of the heatsink, the total heat transfer value increases. So that’s why the perforated heatsink shows better results from pin fin, rectangular fin, and curved fins.

- For manufacturing, plate-fin heatsinks are easily available in the market. And by comparing with manufacturing costs, we found that plate fin heatsinks are much cheaper and more reliable than others.

- Based on the findings, the maximum temperature of the heatsink is reduced by changing its physical form as follows:
  1. By increasing the number of fins from 19 to 23 but after that, there was no discernible change in temperature.
  2. By decreasing the Baseplate thickness from 6 to 4 mm. The maximum temperature was much the same whether the heatsink base thickness was 5 mm or 7 mm. This might be due to a greater heat transfer in the main portion of the Heatsink base.
  3. Decreasing the fin height, the maximum heatsinks surface temperature decreases. So, we reduce the fin height from 45 to 38 mm.

- The difference of maximum temperature of the heatsink between the experimental study and CFD analysis is around 4.75%.

5.2 FUTURE SCOPE

The results of this study show that rectangular heatsink designs with holes achieve the best cooling, but we were unable to employ perforated heatsinks because of their high manufacturing costs. But in the future, if some advancement in the manufacturing field takes place and the cost of perforated fin decreases then it might be considered for use in HVAC heatsinks. The threaded pitch dimensions in Pin FHS and the slight changes to the fin dimensions in PFHS may further enhance Heatsink performance.

APPENDIX

A1. TEMPERATURE MEASUREMENTS WHILE CHANGING ROOM CONDITION

Table A1.1
Temperature values when WBT and DBT are 24°C and 35°C respectively

Location	Newly
IPM	52.1°C
Heatsink	24°C
IGBT	51.4 °C
FRD	52.8 °C
Bridge Rectifier	49.6 °C

Table A1.2
Temperature values when WBT and DBT are 25°C and 38°C respectively

Location	Newly
IPM	52.8°C
Heatsink	27°C
IGBT	51.8 °C
FRD	53.5 °C
Bridge Rectifier	50.4 °C

Table A1.3
Temperature values when WBT and DBT are 26°C and 41°C respectively

Location	Newly
IPM	53.2°C
Heatsink	28°C
IGBT	52.2 °C
FRD	53.7 °C
Bridge Rectifier	50.7 °C

Table A1.4
Temperature values when WBT and DBT are 27°C and 44°C respectively

Location	Newly
IPM	53.6°C
Heatsink	31°C
IGBT	52.5 °C
FRD	53.9 °C
Bridge Rectifier	51.1 °C

Table A1.5
Temperature values when WBT and DBT are 28°C and 47°C respectively

Location	Newly
IPM	54.2°C
Heatsink	37.4°C
IGBT	52.8 °C
FRD	53.9 °C
Bridge Rectifier	51.1 °C

Table A1.6
Temperature values when WBT and DBT are 29°C and 50°C respectively

Location	Newly
IPM	54.4°C
Heatsink	39.1°C
IGBT	53.2 °C
FRD	54.0 °C
Bridge Rectifier	52.7 °C

Table A1.7
Temperature values when WBT and DBT are 30°C and 51°C respectively

Location	Newly
IPM	54.7°C
Heatsink	41.3°C
IGBT	53.5 °C
FRD	54.0 °C
Bridge Rectifier	52.8 °C

Table A1.8
Temperature values when WBT and DBT are 31°C and 52°C respectively

Location	Newly
IPM	55.9°C
Heatsink	45.4°C
IGBT	54.8 °C
FRD	54.4 °C
Bridge Rectifier	53.7 °C

A2. CALCULATION FOR EACH FIN SHAPE HAS SAME TOTAL SURFACE AREA

To compare each fin i.e., rectangular, pin, perforated, and curved we have done some calculations so that each has the same total surface area. So, for that the dimensions taken are shown in below table:

Table A2.1
Dimensions and Volume

Fin Shape	Dimensions (mm)					Volume (mm^3)
Rectangular	L=40	W=50	t=4	n=15		8000
Pin	L=40	r = 2.95		n=90		7478.287
Perforated	L=40	W=50	t=3.239	n=15	Holes=135 r= 1.24	6586.28
Curved	L=40	c.r=1.5	t=3.000	n=15		7679.149

Dimension Calculation-

Volume of cuboid=L*W*t= 8000mm^3

Now Volume for perforated = Volume of cuboid – (number of holes in one fin* volume of cylinder) = 6586.28 mm^3

Volume of pin fin = 3.14*r^2*h * no. of pin fin in 1 row = 7478.287mm^3

REFERENCES

1. I. T'Jollyn, T. Pujol, M. De Paepe, A. Massaguer, L. Montoro 2017 'Plate fin Heatsink modelling and design considerations for thermoelectric generators' International Conference on Renewable Energies and Power Quality, Vol 1 No. 15, pp. 551-556.

2. Santosh Kansal, Piyush Laad 2015 'Performance & Thermal Analysis of Heatsink with Fins of Different Configuration Using CFD' in International Journal of Scientific & Engineering Research, Vol. 6 No. 6, pp. 1487-1495.

3. Akshendra Soni 2016 'Study of Thermal Performance between Plate-fin, Pin-fin and Elliptical Fin Heatsinks in Closed Enclosure under Natural Convection' in International Advanced Research Journal in Science, Engineering and Technology, Vol. 3 No. 11, pp. 133-139.

4. Mohamed H.A. Elnaggar 2015 'Heat Transfer Enhancement by Heatsink Fin Arrangement in Electronic Cooling' in Journal of Multidisciplinary Engineering Science and Technology, vol. 2 no. 3, pp. 457-460.

5. Channamallikarjun 2014 'Thermal analysis of CPU with variable baseplate heat-sink using CFD' International Journal of Research in Engineering and Technology, Vol. 3 No. 3, pp. 510-515.

6. G. Naresh, G. Akhil Sai, G. Abhiram, K. Sai Sandeep G. Aditya Vardhan, K. Balaram Krishna 2020 'Steady State Thermal Analysis on Heatsinks by Varying Fin Configuration Using ANSYS' Mukt Shabd Journal, Vol. 9 No. 4, pp. 2113-2124.

7. Pawar S.P, Prof. Ghuge N.C, Prof. Palande D.D 2015 'Review-Design and Analysis of Heatsink Optimization and its Comparison with Commercially Available Heatsink' International Journal of Application or Innovation in Engineering & Management, Vol.4 No. 8, pp. 101-104.

8. Numan HABIB, Muftooh Ur Rehman SIDDIQI, and Muhammad TAHIR 2022 'THERMAL ANALYSIS OF PROPOSED HEATSINK DESIGN UNDER

NATURAL CONVECTION FOR THE THERMAL MANAGEMENT OF ELECTRONICS' Thermal Science, Vol. 26 No. 2B, pp. 1487-1501.

9. Nilesh Khamkar, Avinash Waghmode, Atul Joshi, Pramod Supekar ,Dr. Ashwini Kumar, Prof. Kiran Londhe, Prof. Vipul R. Kaushik 2019 'Heatsink design for optimal performance of compact electronic appliances - A Review' Adalya Journal, Vol.8 no. 4, pp. 57-65.

10. Prakash.T, Sabarinathan.R 2016 'DESIGN AND ANALYSIS OF HEATSINK IN CPU BY USING CFD' IJARIIE, vol. 2 no. 6, pp. 1463-1470.

11. Hari Raghavan.J, Rangu.P 2017 'A Study and Analysis on the Thermal Performance of a Pin Fin Heatsink for Natural Convection using CFD' International Journal of Engineering Research & Technology, Vol. 6 No. 05, pp. 882-888.

12. Kota LeelaSaiBharath,V Pradeep Kumar 2021 'Design and Analysis of a Rectangular Fin with Comparing by Varying Its Geometry and Material, with Perforation and Extension' Turkish Journal of Computer and Mathematics Education, Vol. 12 No. 2, PP. 3039-3050.

13. M. Praveen Kumar, A. C. Uma Maheshwar Rao 2018 'CFD Analysis on Electronic Heatsink of Al and Cu Metals'International Journal of Research in Engineering, Science and Management, Vol. 1 No. 10, PP. 644-648.

14. M. Prashanth Reddy, C. Labesh kumar and T. Vanaja 2017 'THERMAL MODELING AND MANUFACTURING OF HEATSINK FOR COOLING CPU' International Journal of Mechanical Engineering and Technology, Vol. 8 No. 9, PP. 502-509.

15. Poojitha Madupu, T.Swetha, N.Chandra Kanth 2017 'Thermal analysis to estimate heat transfer from Heatsink by natural convection through closed enclosure' IJARIIE, Vol. 2 No. 2, PP. 42-47.

16. Suabsakul Gururatana and Xianchang Lit, "Study of a Small-Scale Heatsink with Interrupted and Staggered Elliptic Fins," Canadian Journal on Mechanical Sciences & Engineering Vol. 3 No. 2, February 2012.

17. R. L. Webb, "Next Generation Devices for Electronic Cooling With Heat Rejection to

Air," Journal of Heat Transfer, vol. 127, pp. 2-10, 2005.

18. Knight, R. W., Goodling, J .S., and Hall, D, J., “Optimal Thermal Design of Forced Convection Heatsinks- Analytical’ ASME Journal of Electronic Packaging, Vol. 113, pp. 313-321, 1991.

19. Benyamin Naranjani, Ehsan Roohi, Amin Ebrahimi 2020 ‘Thermal Design on the Basis of FOS and hydraulic performance analysis of a Heatsink with corrugated channels and nanofluids’ Journal of Thermal Analysis and Calorimetry, available from: https://doi.org/10.1007/s10973-020-10225-9.

20. S Sushma, T K Chandrashekar 2021 ‘An Experimental Investigation on Performance of Heat Transfer Using Heatsink of Different Shape for Electronic Applications’ Indian Journal of Science and Technology, available from: https://doi.org/10.17485/IJST/v14i35.1179.

21. Takeshi hirasawa, Kenya Kawabata and Masaru Oomi, 2005, “Evolution of Heatsink technology”, Furukawa Review No.27, pp. 25-29.

22. M. Chandra Sekhar Reddy 2015 ‘Thermal analysis of a heatsink for Electronics Cooling’ International Journal of Mechanical Engineering and Technology, Vol. 6 No. 11, pp. 145-153.

23. Lockhart, F.J., 1976. HEAT AND MASS TRANSFER DATA BOOK, by CP Kothandaraman and S. Subramanyan. Chemical Engineering Education, 10(4), pp.154-154.

24. Arularasan, R. and Velraj, R., 2008. CFD analysis in a heat sink for cooling of electronic devices. International Journal of the computer, the internet and management, 16(3), pp.1-11.

ME Thesis

ORIGINALITY REPORT

12%	11%	5%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	tudr.thapar.edu:8080 Internet Source	1%
2	etheses.whiterose.ac.uk Internet Source	1%
3	akademiabaru.com Internet Source	1%
4	en.wikipedia.org Internet Source	1%
5	Mathias Ekpu, Raj Bhatti, Ndy Ekere, Sabuj Mallik, Emeka Amalu, Kenny Otiaba. "Investigation of effects of heat sinks on thermal performance of microelectronic package", 3rd IEEE International Conference on Adaptive Science and Technology (ICAST 2011), 2011 Publication	1%
6	www.i-scholar.in Internet Source	1%
7	law.resource.org Internet Source	1%