

**STEADY STATE THERMAL ANALYSIS ON RECTANGULAR FLAT-  
PLATE HEAT SINKS WITH DIFFERENT PERFORATION GEOMETRY**

**A project report submitted in partial fulfillment of the requirements for the  
award of the degree of**

**BACHELOR OF TECHNOLOGY  
IN  
MECHANICAL ENGINEERING**

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**CERTIFICATE**

This is to certify that the Project Report entitled “**STEADY STATE THERMAL ANALYSIS ON RECTANGULAR FLAT-PLATE HEAT SINKS WITH DIFFERENT PERFORATION GEOMETRY**” being submitted by DASIKA VENKATA SAI SHASHIDHAR (317126520013), RAPETI MOHANA RAO (317126520044), BUDDHA THEEKSHITH (317126520011), PALLI PAVAN KUMAR (317126520036), KANDREGULA OOHASHREE (317126520025) in partial fulfillments for the award of degree of **BACHELOR OF TECHNOLOGY** in **MECHANICAL ENGINEERING**. It is the work of bona-fide, carried out under the guidance and supervision of **MR.G.NARESH**, Assistant Professor, Department Of Mechanical Engineering, ANITS during the academic year of 2017-2021.

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## NOMENCLATURE

$Q_i$	=	Heat transfer, $W/mm^2$
$K$	=	Thermal conductivity, $W/mK$
$dt/dx$	=	Temperature gradient, $K/m$
$\dot{m}$	=	Mass flow rate, $kg/s$
$C_p$	=	Specific heat at constant pressure, $J/kgK$
$P_r$	=	Prandtl number
$G_r$	=	Grashof number
$R_a$	=	Rayleigh number
$A_s$	=	Surface area, $m^2$
$T_s$	=	Surface temperature, $K$
$T_a$	=	Ambient temperature, $K$

## Latin symbols

$\beta$	=	Coefficient of thermal expansion, $1/K$
$\eta$	=	Efficiency
$\rho$	=	Density, $kg/m^3$
$\mu$	=	<b>Absolute viscosity, <math>Ns/m^2</math></b>
$\nu$	=	kinematic viscosity, $m^2/s$

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## **ABSTRACT**

A heat sink is a passive heat exchanger that is designed in such a way that a large surface area is in contact with surrounding medium (like air). Heat generated by every element of an electronic circuit or a system must be dissipated for improving its reliability and to prevent the premature failure of component. Heat sinks provide heat dissipation there by increasing the life of the component or system. Surface area plays important role in dissipating heat to the surrounding through fins. To increase rate of heat transfer and fin efficiency, various perforations are provided on the fin surface so as to expose more area to surrounding which ultimately increases the heat transfer. So, in this study we concentrated on comparative analysis on perforated heat sinks of different configurations and geometry. The optimal design for a heat sink with maximum possible natural convection was determined. The heat sinks were designed using CATIA software. The Steady state Thermal analysis of these designed models were done using ANSYS software. The results obtained suggested the optimum heat sink designed among the considered perforated heat sink models. It is concluded that as the perforations increase the rate of heat dissipation also increased and among the considered geometries of perforations triangular perforation gives more effective heat dissipation than the other two.

# CHAPTER 1

## INTRODUCTION

### 1.1 Necessity of Electronic Cooling System

With the increase in heat dissipation from microelectronics devices and the reduction in overall form factors, thermal management becomes a more important element of electronic product design.

Heat sinks are devices that enhance heat dissipation from a hot surface, usually the case of a heat generating component, to a cooler ambient, usually air which is assumed to be the cooling fluid. In most situations, heat transfer across the interface between the solid surface and the coolant air is the least efficient within the system, and the solid-air interface represents the greatest barrier for heat dissipation. A heat sink lowers this barrier mainly by increasing the surface area that is in direct contact with the coolant. This allows more heat to be dissipated and/or lowers the device operating temperature. The primary purpose of a heat sink is to maintain the device temperature below the maximum allowable temperature specified by the device manufacturers.

Both the performance reliability and life expectancy of electronic equipment are inversely related to the component temperature of the equipment. The relationship between the reliability and the operating temperature of a typical silicon semi-conductor device shows that a reduction in the temperature corresponds to an exponential increase in the reliability and life expectancy of the device. Therefore, long life and reliable

performance of a component may be achieved by effectively controlling the device operating temperature within the limits set by the device design engineers.

Reduction of temperature at the device will reduce stress in the component internal surface both the performance and reliability of electronic circuitry are strongly influenced by the temperature. Exposure to temperature beyond which the circuit is designed to withstand may result in failure of the circuit to perform to specification or in failure together. The maximum temperature to which the circuit will meet the electrical specification with power applied, and the maximum storage temperature is defined as maximum temperature when the power is off, to which circuit may be exposed for a given period of time without the detrimental effects. The detrimental effects of excessive temperature may be divided into three categories as shown in the table 1.

Failure modes	Characteristics
Soft failures	Circuit continues to operate but does not meet specifications when the temperature is elevated beyond the maximum operating temperature. Circuit returns to normal operation when the temperature is lowered. Failure is due to change in component parameters with temperature.
Hard failures (Short Term)	Circuit does not operate. Circuit may or may not return to normal operation when the temperature is lowered. Failure is likely due to component but also may be due to change in component parameters with temperature.

Hard failures (Long Term)	Circuit does not operate at any temperature. Failures are irreversible. Failure may be caused by corrosion or inter metallic formation or similar phenomenon. Failures may also be caused by mechanical stress due to difference in temperature coefficient of expansion between a component and substrate.
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**Table 1: Characteristics**

Soft failures happen as a result of the tendency of the parameters of both active and passive components to exhibit a degree of sensitivity to temperature.

As the temperature increases, the cumulative effects of component parameters drift may eventually cause the circuit output variables to deviate from the specification. Hard failures in the short term may occur as a result of component overload as a result of excessive heat or as a result of the breakdown of component attach or packaging materials.

Hard failures in the long term may occur for a variety of reasons such as corrosion, chemical reactions, and inter-metallic compound formation all of which are accelerated by elevated temperature. Hard failures may occur as a result of mechanical stress due to differences in the temperature coefficient of expansion between two materials joined together such as a component mounted on a circuit board.

In order to maximize circuit performance and reliability, it's important to be able to predict the maximum operating and storage temperatures and to design and package electronic circuits, to minimize heat generated during operation and to minimize circuit temperature by employing adequate thermal management methods.

In selecting an appropriate heat sink that meets the required thermal criteria, one needs to examine various parameters that affect not only the heat sink performance itself, but also the overall performance of the system. The choice of a particular type of heat sink depends largely to the thermal budget allowed for the heat sink and external conditions surrounding the heat sink. It is to be emphasized that there can never be a single value of thermal resistance assigned to a given heat sink, since the thermal resistance varies with external cooling conditions.

When selecting a heat sink, it is necessary to classify the air flow as natural, low flow mixed, or high flow forced convection. Natural convection occurs when there is no externally induced flow and heat transfer release slowly on the free buoyant flow of air surrounding the heat sink. Forced convection occurs when the flow of air is induced by mechanical means, usually a fan or blower. There is no clear distinction on the flow velocity that separates the mixed and forced flow regimes. It is generally accepted in applications that the effect of buoyant force on the overall heat transfer diminishes to negligible level (under 5%) when the induced air flow velocity excess 1 to 2 m/s.



## 1.2 Determination of Volume of Heat Sink:

Table 2 shows approximate ranges of volumetric thermal resistance of a typical heat sink under different flow conditions.

<b>Flow condition m/s</b>	<b>Volumetric Resistance</b> $\text{cm}^3 \text{ }^\circ\text{C/W}$ ( $\text{in}^3 \text{ }^\circ\text{C/W}$ )	
natural convection	500-800	(30-50)
1.0 (200)	150-250	(10-15)
2.5 (500)	80-150	(5-10)
5.0 (1000)	50-80	(3-5)

**Table 2: Range of volumetric thermal resistance**

The volume of a heat sink for a given low condition can be obtained by dividing the volumetric thermal resistance by the required thermal resistance. Table 2 is to be used only as a guide for estimation purposes in the beginning of the selection process. The actual resistance values may vary outside the above range depending on many additional parameters, such as actual dimensions of the heat sink, type of the heat sink, flow configuration, orientation, surface finish, altitude, etc. The smaller values shown above correspond to a heat sink volume of approximately 100 to 200  $\text{cm}^3$  (5 to 10  $\text{in}^3$ ) and the larger ones to roughly 1000  $\text{cm}^3$  (60 $\text{in}^3$ ).

Although there are many parameters to be considered in optimizing a heat sink, one of the most critical parameters is the fin density. In a planar fin heat sink, optimum fin spacing is strongly related to two parameters: flow velocity and fin length in the direction of the flow. The average performance of a typical heat sink is linearly proportional to the width of a heat sink in the direction perpendicular to the flow and approximately proportional to the square root of the fin length in the direction parallel to the flow. For example, an increase in the width of a heat sink by a factor of two would increase the heat dissipation capability by a factor of two, whereas an increase in the fin length in the direction parallel to the flow would increase the heat dissipation capability by a factor of 1.4. Therefore, if the choice is available, it is beneficial to increase the width of a heat sink rather than the length of the heat sink. Also, the effect of radiation heat transfer is very important in natural convection, as it can be responsible for up to 25% of the total heat dissipation. Unless the component is facing a hotter surface nearby, it is imperative to have the heat sink surfaces painted or anodized to enhance radiation.

If the cooler is insufficient and the temperature exceeds the maximum operating temperature, then this does not mean that the CPU is automatically damaged. With CPUs, we will usually encounter crashes if the CPU is overheated; but these go away as soon as the CPU is cooler again. In the long term, running the CPU at a temperature that is too high may reduce the CPU life, since an overheated CPU is more prone to electromigration - even if it runs stable. With P4 CPUs, the CPU will turn its speed down automatically when it overheats. No damage to the CPU is possible, but the system will get slower while it's hot (which, in some cases, users might not even notice).

## **1.3 Heat Transfer Enhancers**

### **1.3.1 Heat sink**

A heat sink is an environment or object that absorbs and dissipates heat from another object using thermal contact (either direct or radiant). Heat sinks are used in a wide range of applications wherever efficient heat dissipation is required; major examples include refrigeration, heat engines, cooling electronic devices and lasers.

A heat sink without a fan is called a passive heat sink; a heat sink with a fan is called an active heat sink. Heat sinks are generally made of an aluminum alloy and often have fins.

Heat is generated in many ways. Systems performing work give up their energy in the form of heat. Chemical reactions release potential energy in the form of heat. Electron flow through materials generates heat. Compression of gases generates heat. Radiation exciting matter creates heat. Heat is an energy associated with the random motion of atoms and molecules.

The amount of sensible heat present in a body manifests itself as the temperature of the body. As heat is added to a body, the temperature rises. More sensible heat per unit volume means a higher temperature.

The first law of thermodynamics states that the total heat input must equal the total heat output plus any heat energy stored or converted to other forms of energy in the system. The second law of thermodynamics further states that heat flows from a hotter to a colder body and never the other way around. These two laws are the foundation of heat transfer.

Although the basic laws of heat transfer are analogous to the fundamental equations of electricity, the transmission of heat in actual situations becomes rather complex. The three basic mechanisms of heat transfer are: Radiation, Conduction & Convection. In actual situations all three of these are taking place simultaneously.

It is apparent however that in each of the above process, heat is transformed from one area to another because of temperature difference. Heat always flows from hot to cooler area. The amount of heat flow is determined by the difference in temperature of a second area. This leads to the obvious conclusion that the low temperature area limits the cooling and the component temperatures must be calculated relative to the ambient temperatures. It is also important to note that the amount of heat flow is proportional to the amount of exposed surface of the heated area as well as the heat conductivity of the transfer path. The fundamental heat transfer problem in electronics is the removal of internally developed heat by increasing heat conductivity between the heat sources and the ultimate sink. One of the most economical and satisfactory methods is the use of a metal heat sink, which by conduction, radiation and convection increases the dissipation of heat.

A heat sink is a structure that facilitates the drain of heat from a hotter body in contact with it. It is essential a thermal short circuit from the hot body to any readily available cooling fluid. The mechanical heat sink has this ability because it can transfer heat to the surroundings better than the hotter body alone can transfer the heat at the same temperature.

A good heat sink design tends to minimize temperature gradients in the heat sink and maximize surface area per unit volume consistent with the heat transported throughout the heat sink to the exposed surface.

Cooling technique employed heat generated at one point is readily transported throughout the heat sink to the exposed surface. The smaller the temperature drop

is to the heat transfer surface, the more efficient the heat sink. The shape of the conduction path in the material affects the performance. A large cross section aids heat flow while a thin cross section offers a great resistance to flow. The plane normal to the flow of heat ideally offers the greater cross-sectional area at points of heat input.

Heat sinks materials are selected for their ability to perform as extended surfaces. The material must be a good thermal conductor. Silver is the best metal conductor, but is much too expensive for most applications.

Copper is an excellent thermal conductor and find many applications where high conductivity is required. Copper has twice the conductivity of aluminum but has thrice the specific gravity.

Aluminum is another material widely used in heat transfer work. Its ease of fabrication and light weight make it excellent material for forming long individual fins.

## **1.4 Principle**

Heat sinks function by efficiently transferring thermal energy ("heat") from an object at high temperature to a second object at a lower temperature with a much greater heat capacity. This rapid transfer of thermal energy quickly brings the first object into thermal equilibrium with the second, lowering the temperature of the first object, fulfilling the heat sink's role as a cooling device. Efficient function of a heat sink relies on rapid transfer of thermal energy from the first object to the heat sink, and the heat sink to the second object [18].

The most common design of a heat sink is a metal device with many fins. The high thermal conductivity of the metal combined with its large surface area result in the rapid transfer of thermal energy to the surrounding, cooler, air. This

cools the heat sink and whatever it is in direct thermal contact with. Use of fluids (for example coolants in refrigeration) and thermal interface material (in cooling electronic devices) ensures good transfer of thermal energy to the heat sink. Similarly, a fan may improve the transfer of thermal energy from the heat sink to the air.

## 1.5 Characteristics

**High heat sink surface** It's at the surface of the heat sink where the thermal transfer takes place. Therefore, heat sinks should be designed to have a large surface; this goal can be reached by using many fine fins, or by increasing the size of the heat sink itself.

**Good aerodynamics** Heat sinks must be designed in a way that air can easily and quickly flow through the cooler and reach all cooling fins. Especially heat sinks having a very large number of fine fins, with small distances between the fins may not allow good air flow. A compromise between high surface (many fins with small gaps between them) and good aerodynamics must be found. This also depends on the fan the heat sink is used with: A powerful fan can force air even through a heat sink with lots of fine fins with only small gaps for air flow - whereas on a passive heat sink, there should be fewer cooling fins with more space between them. Therefore, simply adding a fan to a large heat sink designed for fan less usage doesn't necessarily result in a good cooler.

**Good thermal transfer within the heat sinks** large cooling fins are pointless if the heat can't reach them, so the heat sink must be designed to allow good thermal transfer from the heat source to the fins. Thicker fins have better thermal conductivity; so again, a compromise between high surface (many thin fins) and

good thermal transfer (thicker fins) must be found. Of course, the material used has a major influence on thermal transfer within the heat sink. Sometimes, heat pipes are used to lead the heat from the heat source to the parts of the fins that are further away from the heat source.

**Perfect flatness of the contact area** the part of the heat sink that is in contact with the heat source must be perfectly flat. A flat contact area allows you to use a thinner layer of thermal compound, which will reduce the thermal resistance between heat sink and heat source.

## **1.6 Performance**

Heat sink performance (including free convection, forced convection, liquid cooled, and any combination thereof) is a function of material, geometry, and overall surface heat transfer coefficient. Generally, forced convection heat sink thermal performance is improved by increasing the thermal conductivity of the heat sink materials, increasing the surface area (usually by adding extended surfaces, such as fins or foam metal) and by increasing the overall area heat transfer coefficient (usually by increase fluid velocity, such as adding fans, pumps, etc.)

For more complex heat sink geometries, and/or heat sinks with multiple materials, and/or heat sinks with multiple fluids, computation fluid dynamics (CFD) analysis is recommended.

## **1.7 Components of Heat Sinks Are**

- Base Plate
- Fins or Extendable surfaces

### **1.7.1 Base plate**

Base plate is part of heat sink on which the component is mounted. The base plate should be a good conductor of heat. It can be made of material, which has good thermal conductivity.

The base plate should have minimum thickness so that riveting of screwing of the component on to the base plate is possible.

If fins are machined as integral part of the base plate from which they are extend, there is no contact resistance at the base. However, more commonly, fins are manufactured separately and are attached to the base plate by a metallurgical or adhesive joint.

Alternatively, the attachment may involve press fit, for which the fins are forced into slot machines on the base plate material. In such cases, there a thermal contact resistance, which may adhesively affect the overall performance.

### **1.7.2 Fins**

In any application, selection of a particular fin configuration may depend on space, weight, manufacturing difficulties and cost considerations as well as the extent to which the fins reduce the surface convection coefficient and increase pressure drop associated with flow of the fins.

Sometimes it is necessary to enhance the overall surface heat transfer rate. In general terms this may be achieved by lowering the convective resistance (by increasing the convection heat transfer coefficient) or by lowering the conductive resistance (by increasing the surface area. Fins and extended surfaces are used in transformer shields, integrated circuits heat sinks, heat exchanger tubes engine, electronic motor and gearbox casings.

In many engineering situations, means are often sought to improve heat dissipation from a surface to its surroundings. The surface area exposed to the surroundings is requisitely increased by the attachment of protrusions, and the arrangement provides a means by which heat transfer can be substantially improved. The



protrusions are called fins or spines and these extensions can take a variety of forms.

## **1.8 Different Types of Fin Configurations**

1. Straight fin
2. Annular fin
3. Pin fin or spine

### **1.8.1 Straight fin**

It is an extended surface attached to the plane wall. The cross-sectional area of the fin may be uniform or it may vary with the distance from the wall.

### **1.8.2 Annular fin**

Fins are attached circumferentially to a cylindrical surface and their cross-sectional area varies with radius from the centerline of the cylinder. However, both straight and annular fins are of rectangular cross section, whose area can be expressed as a product of fin thickness and width.

### **1.8.3 Pin fin**

It is an extended surface of circular cross section material must have relatively high thermal conductivity

## **1.9 Importance of Fin Spacing**

If two surfaces are too close together the airflow from the surface interfaces, and the design curve no longer applies. Fins should not be spaced too close together on the surface of a box, because this may result in pinching and choking of the natural flow of air cooling. Close spaced fins may increase the flow resistance and reduce the effective cooling available from the fins. When several fins are stacked together there should be sufficient space to permit two convection films to develop.

## 1.10 Heat Sink Materials

The thermal conductivity of the heatsink material has a major impact on cooling performance. Thermal conductivity is measured in W/m-K; higher values mean better conductivity.

As a rule of thumb, materials with a high electrical conductivity also have a high thermal conductivity. Alloys have lower thermal conductivity than pure metals but may have better mechanical or chemical (corrosion) properties.

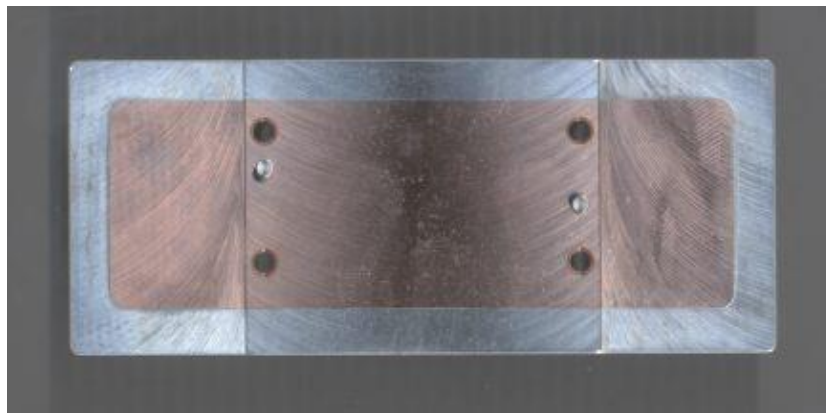
The following materials are commonly used for heatsinks:

**Aluminum.** It has a thermal conductivity of 205W/m-K, which is good (as a comparison: steel has about 50W/m-K). The production of aluminum heatsinks is inexpensive; they can be made using extrusion. Due to its softness, aluminum can also be milled quickly; die-casting and even cold forging are also possible (see part 2 of this guide for more information about production methods). Aluminum is also very light (thus, an aluminum heatsink will put less stress on its mounting when the unit is moved around).

**Copper's** thermal conductivity is about twice as high as aluminum - almost 400W/m-K. This makes it an excellent material for heatsinks; but its disadvantages include high weight, high price, and less choice as far as production methods are concerned. Copper heatsinks can be milled, die-cast, or made of copper plates bonded together; extrusion is not possible.

To combine the advantages of aluminum and copper, heatsinks can be made of **aluminum and copper bonded together**. Here, the area in contact with the heat source is made of copper, which helps lead the heat away to the outer parts of the heatsink. The first heatsink for PC CPUs with an embedded copper piece was the

Alpha P7125 (for first-generation Slot A Athlon CPUs). Keep in mind that a copper embedding is only useful if it is tightly bonded to the aluminum part for good thermal transfer. This is not always the case, especially not with inexpensive coolers. If the thermal transfer between the copper and the aluminum is poor, the copper embedding may do more harm than good. The copper plate helps spread heat across the base plate.



**Fig:1Alpha P7125 base plate**

### **1.11 Enhancement of Heat Transfer Quotient**

Inspection of heat transfer rate equation shows that for a fixed rate of heat dissipation  $q$  the magnitude of the temperature difference is governed by the product  $(h \cdot A)$  to obtain high heat dissipation at a relatively low temperature difference. One requires superior heat transfer properties.

The trend in components design for air born and space applications have been and will continue to be towards micro miniaturization. Ordinarily miniaturized electronic equipment is also quite small.

#### **Heat transfer coefficient can be improved in two ways**

**1. Use of better fluid:** This is often impossible because of weight and installation requirement. Use of a liquid coolant for e.g., requires a pump, heat exchanges

pipings, valves and possibly an expansion tank for handling the ultimate heat sink fluid.

**2. Use of available coolant fluid at a higher velocity:** This is often impractical because of the increased power required to force the fluid through the system. Inspection of several correlations will show that a two-fold increase in heat transfer coefficient requires a two-fold increase in velocity. At the same time two-fold increase in fluid velocity results in almost a fourfold increase in pressure loss and possibly as much as eight -fold increase in the power required.

Increase of the  $h \cdot A$  product is not easily achieved by increasing the heat transfer coefficient. Considerably a more effective method accomplishing this increase is by augmenting surface by employing fins.

Such augmentation can result in as much as an order of magnitude increase in the  $h \cdot A$  product without officially altering the heat transfer coefficient. In electronic cooling applications the designers strive to use a type of fin that lends itself readily to analysis and to easy manufacture. In this category they are the longitudinal fin of rectangular profile, the radial fin of rectangular profile and the cylindrical spine (pinfin). The longitudinal fin of triangular profile is more difficult to analyze and to manufacture but it is often used because its installation weight is about one half that of the fin of rectangular profile.

## **1.12 Applications of Heat Sinks**

In common use, it is a metal object brought into contact with an electronic component's hot surface. In most cases, a thin thermal interface material mediates between the two surfaces. Microprocessors and power handling semiconductors are examples of electronics that need a heat sink to reduce their temperature through increased thermal mass and heat dissipation (primarily by conduction and convection and to a lesser extent by radiation). Heat sinks are widely used in

electronics, and have become almost essential to modern integrated circuits like microprocessors, DSPs, GPUs, and more. The following equipment also uses heat sinks to transfer more heat Audio/Video Equipment, Consumer Appliances , Data Centers, Fuel cells, Heat exchangers, IC packages,Lighting/Lamps, Mobile/Portable equipment, Networking systems, Ovens & Furnaces, PCB Design ,Rack mounted systems,Radar, Satellites, servers.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Literature Review

**Akshendrasoni et al [17]** performed a comparative analysis on heat sinks based on total heat dissipation using Ansys. The study involves comparison of plate, circular and elliptical fin. It is concluded from analysis that plate fin dissipated larger amount of heat compared to others.

**Amit Md. Estiaque Arefin et al [13]** modified the pin design where the pins are expanded outward. Thermal analysis of the conventional model and the modified model was conducted and compared successfully. It is clear from the numerical analysis of the paper that in the practical environment the modified pin fin heat sink will perform better than the conventional one.

**Arularasan R. et al [4]** worked out to select an optimal heat sink design, based on preliminary studies on the fluid flow and heat transfer characteristics of a parallel plate heat sink through modeling and simulations. This paper explains the choice of selecting various parameters in optimizing by considering various constraints in the heat sink design, with optimum geometric parameters such as optimum fin thickness, optimum fin height, and optimum base height and optimum gap between the fins, etc.

**R. Sam Sukumar et al [18]** designed an optimal heat sink by considering heat sinks which contain continuous rectangular fins, interrupted rectangular fins and above models with through holes. Based on the result obtained it was concluded

that the interrupted fins are more efficient than the continuous. The paper also explains that the through holes for the interrupted fins has better performance than the interrupted rectangular fins with an advantage of reduction in weight due to material removal from the standard.

**V.Himachandra Raju et al [1]** conducted steady state thermal analysis to extract the temperature and heat flux distribution for a given heat input. Further, using CFD analysis, dynamic pressure variation, turbulence kinetic variation and Nusselt number at the tip of fin for varying velocities have been calculated.

**Ahmed F. Khudheyer et al [6]** conducted natural convection heat transfer for heat sink with rectangular fins for five different geometries (continuous fins, 1-interrupted fins, 4-interrupted fins, inclined fins and V-fins) at different heat flux values experimentally. This paper provides information that validates the facts that the average heat transfer coefficient increases with the increase in the value of the fins height, heat transfer coefficient increases by increasing spacing up to certain limit and it starts to decrease with the increasing in spacing more than the limit, increased length of fins (continuous case) causes a decrease in heat transfer coefficient.

**Christian Alvin et al [19]** held experimental tests and numerical simulations to investigate the thermal management of LED lamps with a variety of geometrical configurations of extruded-fin heat sinks. This paper also includes the usage of two kinds of interface heat transfer materials to determine their effectiveness in dissipating heat. The paper also deals with the effect of thermal conductivity of thermal interface material on the overall heat transfer rate of a heat sink.

**Varun R Yadav et al [16]** carried out steady state thermal analysis of fins by modifying its certain parameters such as geometry. In this study it is observed that triangular fins allow a great temperature distribution when compared to pin fin or rectangular fins.

## **2.2 Scope of The Work from Literature Review**

The gist of the above papers is the comparison of heat dissipation from a heat sink in two different external conditions of natural convection and forced convection. It is observed that the heat dissipation in forced convection occurred better than that in the natural convection. Thus, experiment would be performed and results and discussions would be concluded to justify the geometric configuration that yields a better heat transfer in the case of natural convection [6].



## CHAPTER3

### MODELING OF HEAT SINKS USING CATIA

This chapter gives the basic idea about a CAD package called CATIA, its features and tools and step by step procedure to design the profile of a heat sink (fin) using CATIA package.

#### 3.1 Introduction to CATIA

CATIA is a robust application that enables you to create rich and complex designs. The goals of the CATIA course are to teach you how to build parts and assemblies in CATIA, and how to make simple drawings of those parts and assemblies. This course focuses on the fundamental skills and concepts that enable you to create a solid foundation for your designs.



#### What is CATIA?

CATIA is mechanical design software. It is a *feature-based, parametric solid modeling* design tool that takes advantage of the easy-to-learn Windows graphical user interface. You can create *fully associative* 3-D solid models with or without *constraints* while utilizing automatic or user-defined relations to

capture *design intent*. To further clarify this definition, the *italic* terms above will be further defined:

### **Feature-based**

Like an assembly is made up of a number of individual parts, a CATIA document is made up of individual elements. These elements are called features. When creating a document, you can add features such as pads, pockets, holes, ribs, fillets, chamfers, and drafts. As the features are created, they are applied directly to the work piece.

Features can be classified as sketched-based or dress-up:

1. Sketched-based features are based on a 2D sketch. Generally, the sketch is transformed into a 3D solid by extruding, rotating, sweeping, or lofting.
2. Dress-up features are features that are created directly on the solid model. Fillets and chamfers are examples of this type of feature.

The dimensions and relations used to create a feature are stored in the model. This enables you to capture design intent, and to easily make changes to the model through these parameters.

- Driving dimensions are the dimensions used when creating a feature. They include the dimensions associated with the sketch geometry, as well as those associated with the feature itself. Consider, for example, a cylindrical pad. The diameter of the pad is controlled by the diameter of the sketched circle, and the height of the pad is controlled by the depth to which the circle is extruded.
- Relations include information such as parallelism, tangency and concentricity. This type of information is typically communicated on

drawings using feature control symbols. By capturing this information in the sketch, CATIA enables you to fully capture your design intent up front.

### **Solid Modeling:**

A solid model is the most complete type of geometric model used in CAD systems. It contains all the wireframe and surface geometry necessary to fully describe the edges and faces of the model. In addition to geometric information, solid models also convey their —topology, which relates the geometry together. For example, topology might include identifying which faces (surfaces) meet at which edges (curves). This intelligence makes adding features easier. For example, if a model requires a fillet, you simply select an edge and specify a radius to create it.

### **Fully Associative:**

A CATIA model is fully associative with the drawings and parts or assemblies that reference it. Changes to the model are automatically reflected in the associated drawings, parts, and/or assemblies. Likewise, changes in the context of the drawing or assembly are reflected back in the model.

### **Constraints:**

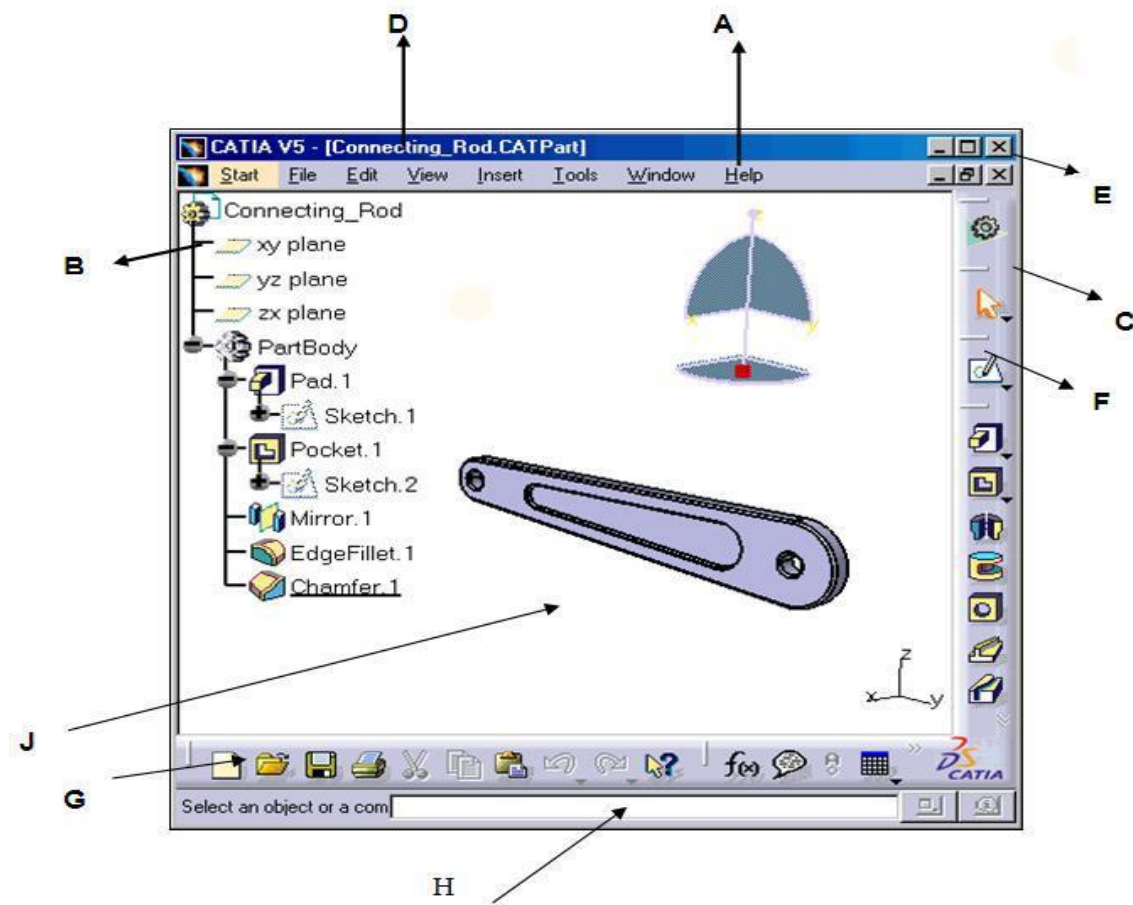
Geometric constraints (such as parallel, perpendicular, horizontal, vertical, concentric, and coincident) establish relationships between features in your model by fixing their positions with respect to one another. In addition, equations can be used to establish mathematical relationships between parameters. By using constraints and equations, you can guarantee that

design concepts such as through holes and equal radii are captured and maintained.

### 3.2 CATIA User Interface:

Below is the layout of the elements of the standard CATIA application.

1. Menu Commands
2. Specification Tree
3. Window of Active document
4. Filename and extension of current document
5. Icons to maximize/minimize and close window
6. Icon of the active workbench
7. Toolbars specific to the active workbench
8. Standard toolbar
9. Compass
10. Geometry area



**Fig.2.1**

Different types of engineering drawings, construction of solid models, assemblies of solid parts can be done using inventor.

Different types of files used are:

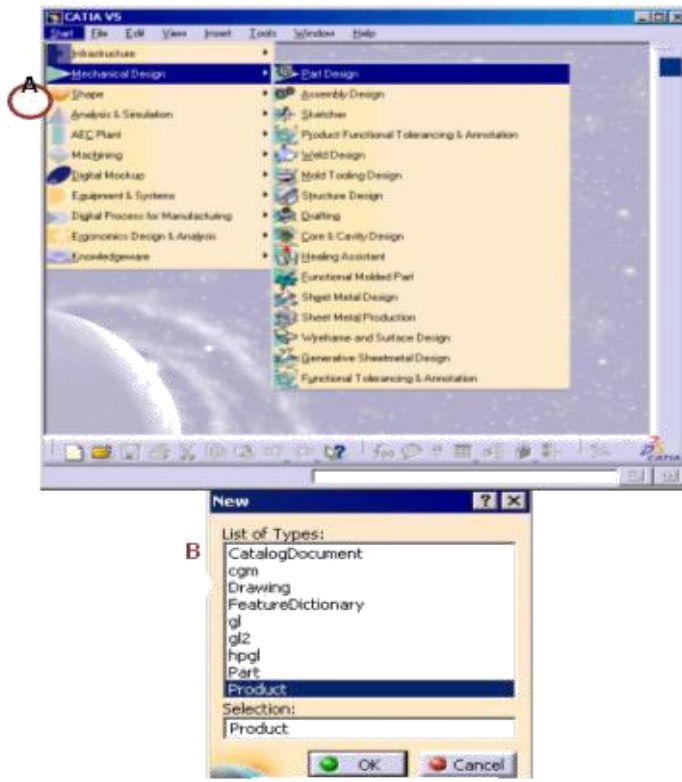
1. Part files: CATPart
2. Assembly files: CATProduct

### 3.3 CATIA components

#### Workbenches

Workbenches contain various tools that you may need to access during your part creation.

You can switch between any primary workbenches using the following two ways:



You can tell what workbench you are currently in by the icon displayed in the upper right corner of the window.

The icon's background image will also denote what Solution this workbench is found within. For example, the Green Triangle icon indicates the Mechanical Design Solution.




**Figure No. 2.2**

A. Use the Start Menu.

- B. Click File >New to create a new document with a particular file type.  
The associated workbench automatically launches.

The parts of the major assembly is treated as individual geometric model , which is modeled individually in separate file .All the parts are previously planned & generated feature by feature to construct full model

Generally all CAD models are generated in the same passion given bellow :

-  : Enter CAD environment by clicking, later into part designing mode to construct model.
-  : Select plane as basic reference.
-  : Enter sketcher mode.

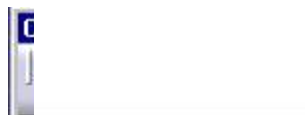
In sketcher mode:



: Tool used to create 2-d basic structure of part using line, circle etc,.



: Tool used for editing of created geometry termed as operation



:Tool used for Dimensioning, referencing. This helps creating parametric relation.



: Its external feature to view geometry



: Tool used to exit sketcher mode after creating geometry.

- **Sketch Based Feature :**



**Pad** :On exit of sketcher mode the feature is to be padded .( adding material )



**Pocket**:On creation of basic structure further pocket has to be created(removing material)



**Revolve**:Around axis the material is revolved, the structure should has same profile around axis.



**Rib**: sweeping uniform profile along trajectory (adding material)

**Slot**: sweeping uniform profile along trajectory (removing material)



**Loft**: Sweeping non-uniform/uniform profile on different plane alonglinear/non-linear trajectory



Its 3d creation of features creates chamfer,radius, draft, shell...



: Its tool used to move geometry, mirror, pattern, scaling in 3d environment On creation of individual parts in separate files,



**Assembly environment:**In assembly environment the parts are recalled & constrained.



**Product structure tool:** To recall existing components already modeled.



**Constraints:** Assembling respective parts by mean of constraints



**Update:** updating the made constrains.

- Additional features are: Exploded View, snap shots, clash analyzing numbering, bill of material, etc.
- Finally creating draft for individual parts & assembly with possible details

The parts of the major assembly is treated as individual geometric model, which is modeled individually in separate file .All the parts are previously planned & generated feature by feature to construct full model

Generally all CAD models are generated in the same passion given bellow :



**Enter CAD environment by clicking, later into part designing mode to construct model.**



**:Select plane as basic reference.**



**: Enter sketcher mode.**

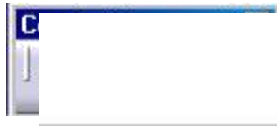
In sketcher mode:



**: Tool used to create 2-d basic structure of part using line, circle etc**



Tool used for editing of created geometry termed as operation



: Tool used for Dimensioning, referencing. This helps creating parametric relation.

: Its external feature to view geometry in & out



: Tool used to exit sketcher mode after creating geometry.

### Sketch Based Feature :



**Pad:**On exit of sketcher mode the feature is to be padded. (Adding material)



**Pocket:**On creation of basic structure further pocket has to be created (removing material)



**Revolve:**Around axis the material is revolved, the structure should have same profile around axis.



**Rib:**sweeping uniform profile along trajectory (adding material)

**Slot:**sweeping uniform profile along trajectory (removing material)



**Loft:**Sweeping non-uniform/uniform profile on different plane along linear/non-linear trajectory



: Its 3d creation of features creates chamfer, radius, draft, shell, thread...



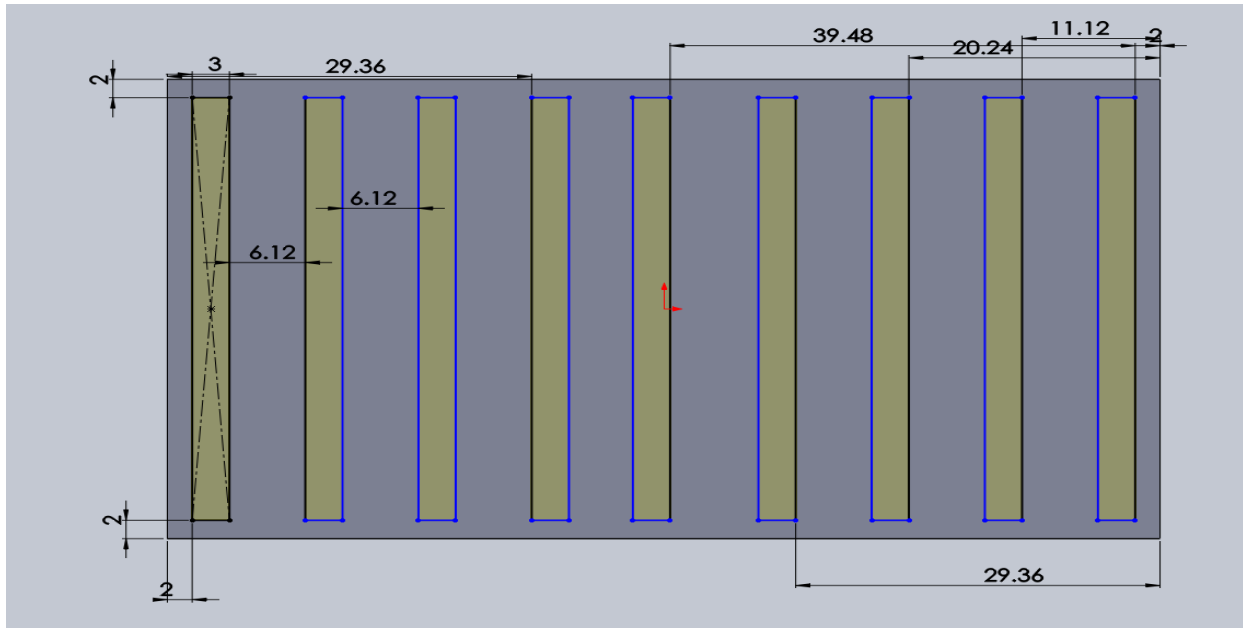
: Its tool used to move geometry, mirror, pattern, scaling in 3denvironment

### **3.4 Design of rectangular flat plate using CATIA:**

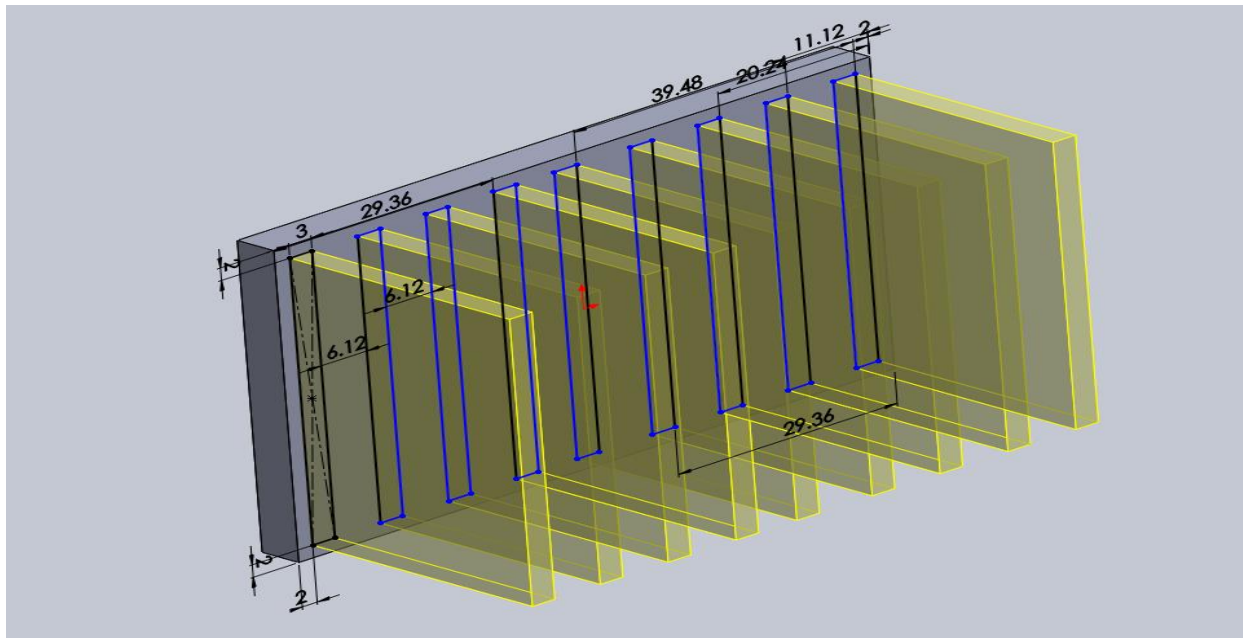
- Create a point in geometrical set as an origin point.
- Making the point as origin create an axis inside geometrical set.
- Choosing part body as the working bench select x-y plane in the sketcher.
- Now draw a rectangle with dimension 80 x 50 mm.
- Exit from the sketcher and choose the rectangular sketch drawn. Now, using pad option extrude it to 5mm thickness along +Z direction.
- Now, insert separate body and create a plane on the surface of rectangular base.
- Select sketch option and choose the created plane a reference or base plane.
- Draw a rectangle at the left corner of the base plate with dimensions as shown in the figure.
- Exit the sketcher and pad the drawn fin base to 30mm.
- Now using duplicate option create fins all over the surface of rectangular base created.

#### **Design of perforations to the fin:**

- Now to the created rectangular fins perforations are to be inserted with different shapes.
- Create a side of rectangular fin and create a plane parallel to it.
- Now select that plane as the sketcher plane and draw respective geometry(Square(3 x 3mm), circle(D 3.384mm), Triangle(4.559 x 4.559 x 4.559mm)) perforations.
- Exit sketcher and using pocket option make a through hole till the end of last fin such that every fin is perforated.

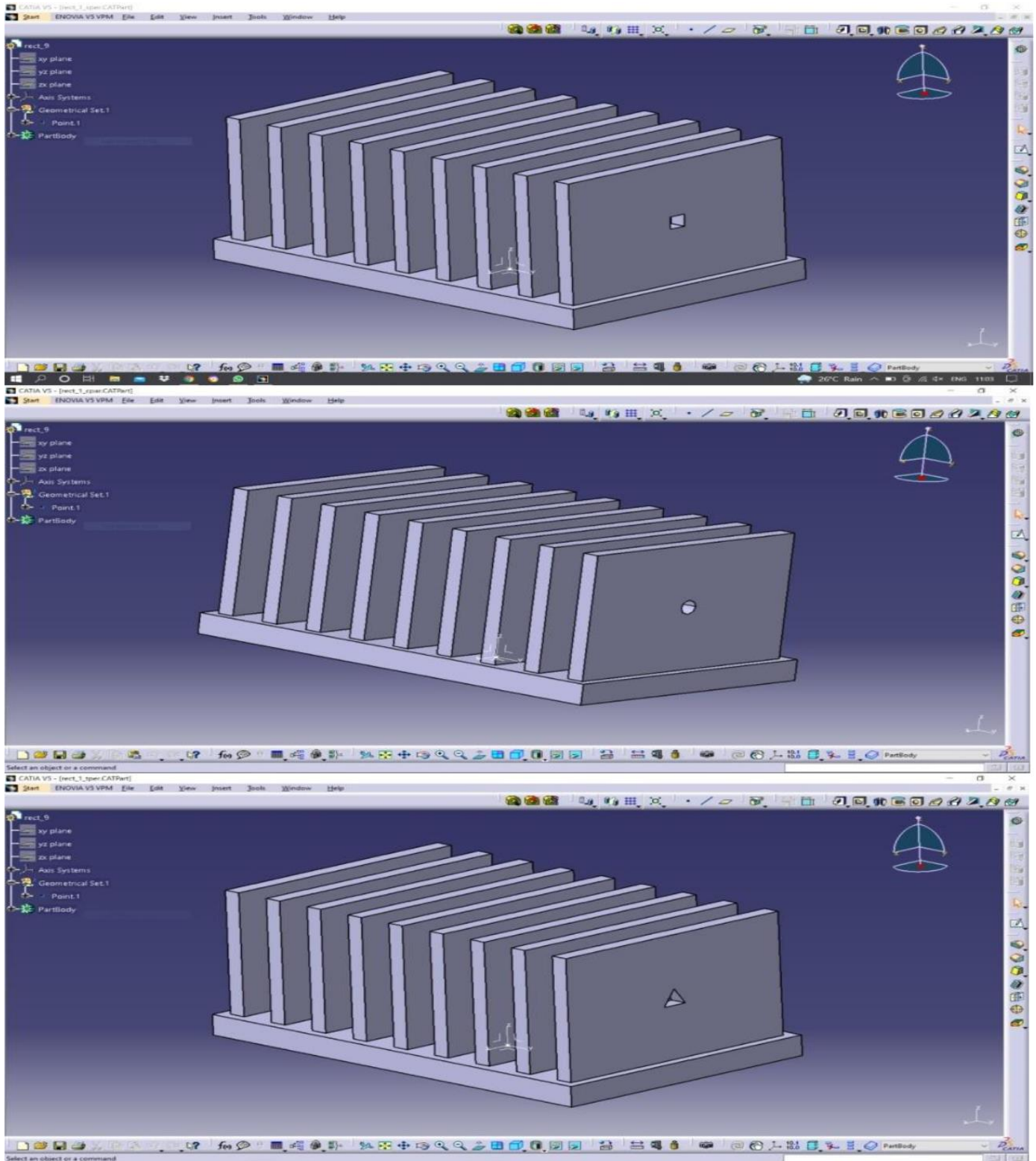


**Fig. 2.3 Top view of rectangular flat plate pin fin**

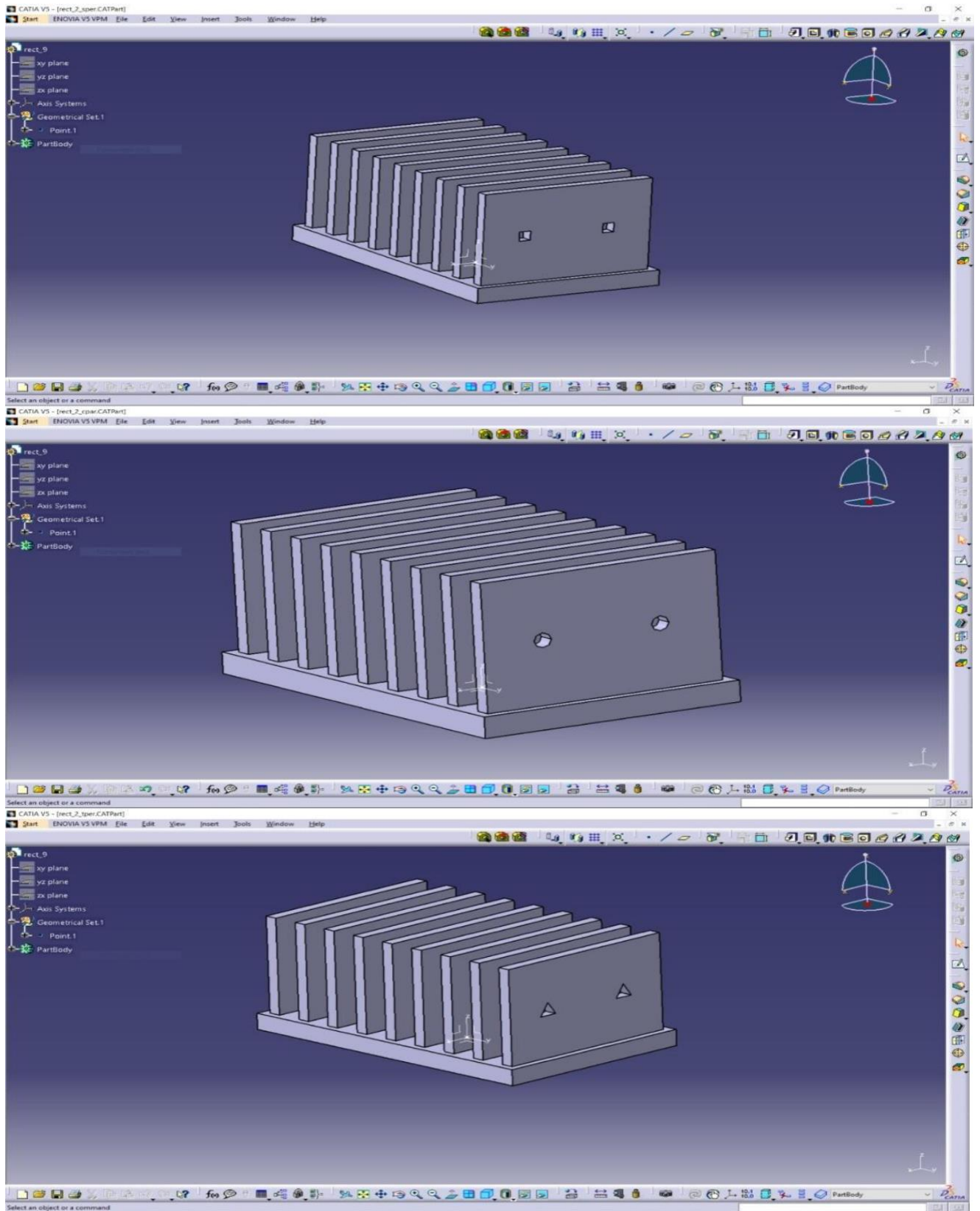


**Fig. 2.4 Isometric view of rectangular flat plate pin fin**

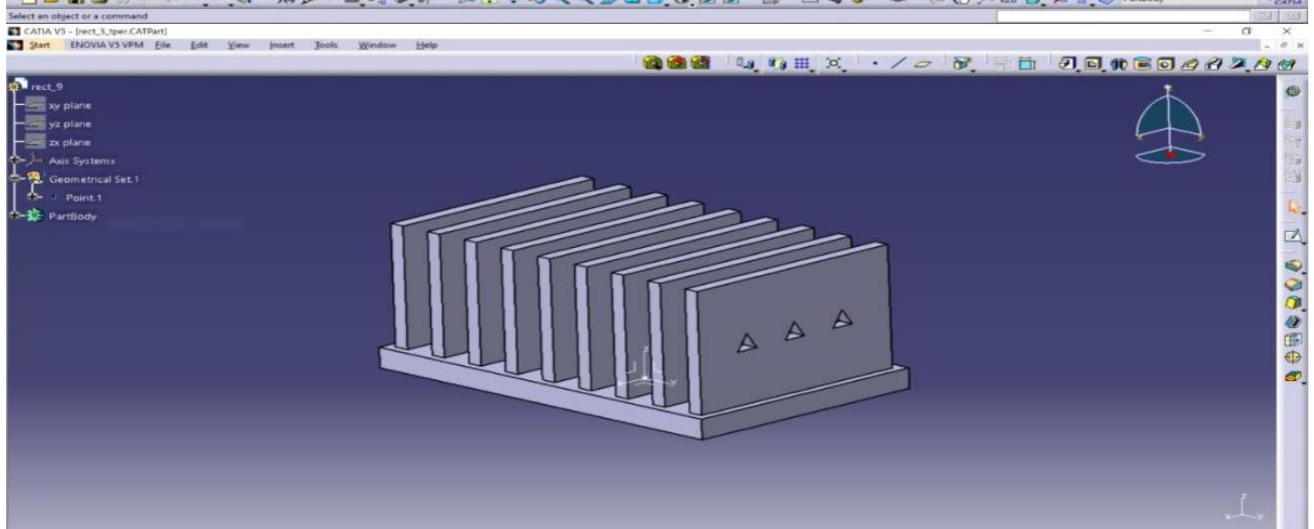
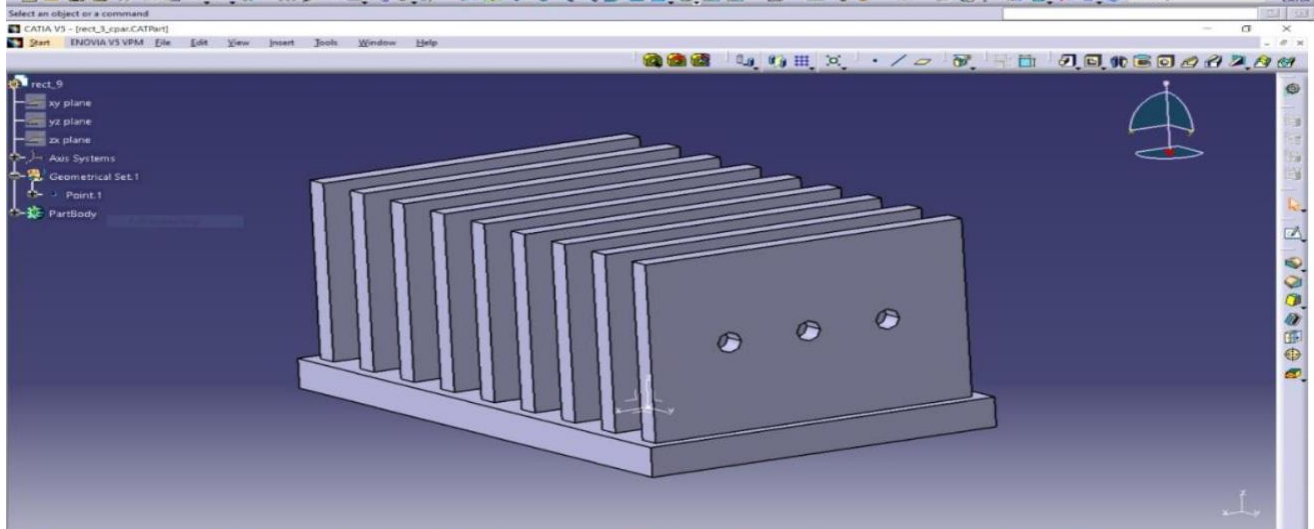
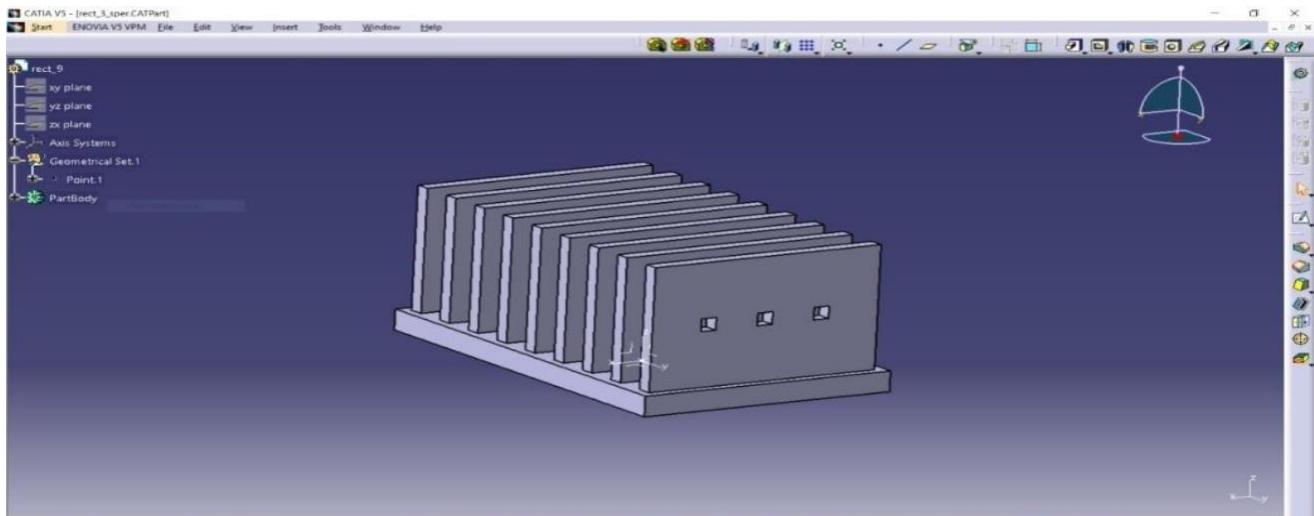
### 3.4.1 Designs considered for analysis:



Design of Single perforated circular, triangular and square perforations



Design of double perforated circular, triangular and square perforations



Design of triple perforated circular, triangular and square perforations

## **CHAPTER 4**

### **ANALYSIS OF HEAT SINKS USING ANSYS**

#### **4.1 INTRODUCTION TO ANSYS**

ANSYS was founded in 1970 by John Swanson. Swanson sold his interest in the company to venture capitalists in 1993. ANSYS went public on NASDAQ in 1996. In the 2000s, ANSYS made numerous acquisitions of other engineering design companies, acquiring additional technology for fluid dynamics, electronics design, and other physics analysis.

##### **4.1.1 Software**

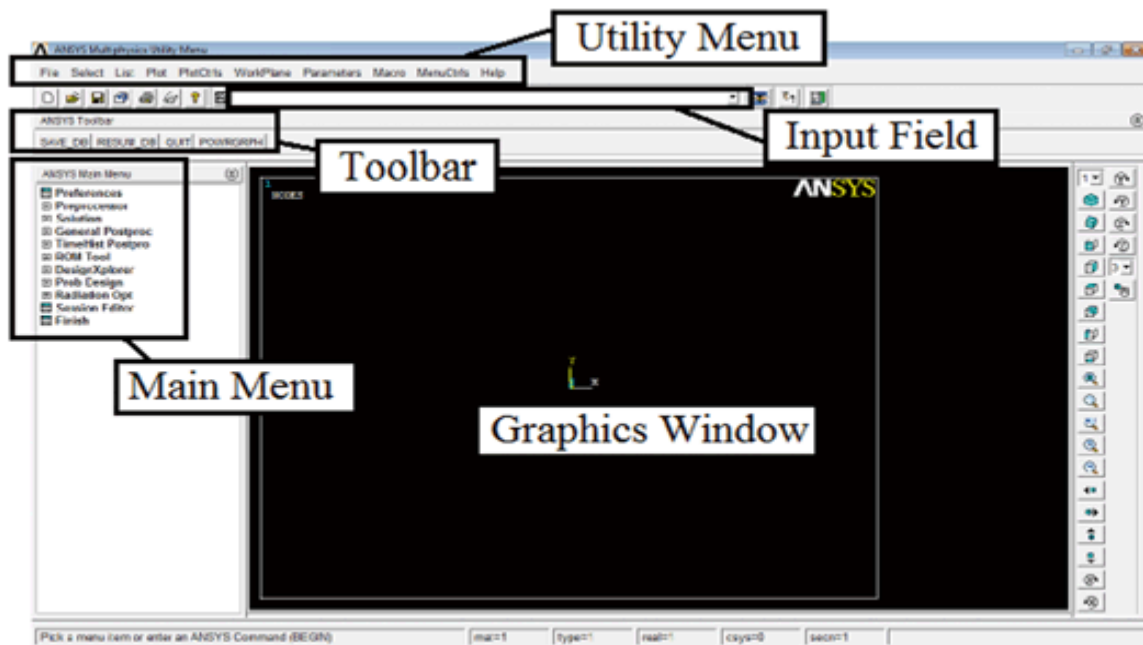
ANSYS develops and markets finite element analysis software used to simulate engineering problems. The software creates simulated computer models of structures, electronics, or machine components to simulate strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. ANSYS is used to determine how a product will function with different specifications, without building test products or conducting crash tests. For example, ANSYS software may simulate how a bridge will hold up after years of traffic, how to best process salmon in a cannery to reduce waste, or how to design a slide that uses less material without sacrificing safety[17].

Most Ansys simulations are performed using the ANSYS Workbench software, which is one of the company's main products. Typically, ANSYS users break down larger structures into small components that are each modeled and tested individually. A user may start by defining the

dimensions of an object, and then adding weight, pressure, temperature and other physical properties. Finally, the ANSYS software simulates and analyzes movement, fatigue, fractures, fluid flow, temperature distribution, electromagnetic efficiency, and other effects over time.

#### 4.1.2 Basic program structure of ANSYS software

Treatment of engineering problems basically contains three main parts: create a model, solve the problem, analyses the results. ANSYS, like many other FE-programs, is also divided into three main parts (processors) which are called preprocessor, solution processor, post processor. Other software may contain only the preprocessing part or only the post processing part. During the analysis you will communicate with ANSYS via a Graphical User Interface (GUI), which is described below and seen in Figure.



**Fig 4.1 Graphical user Interface**

- 1. Utility menu** Here you can access and adjust properties about your session, such as file controls, listing and graphic controls.
- 2. Toolbar** Push buttons to commonly used commands.



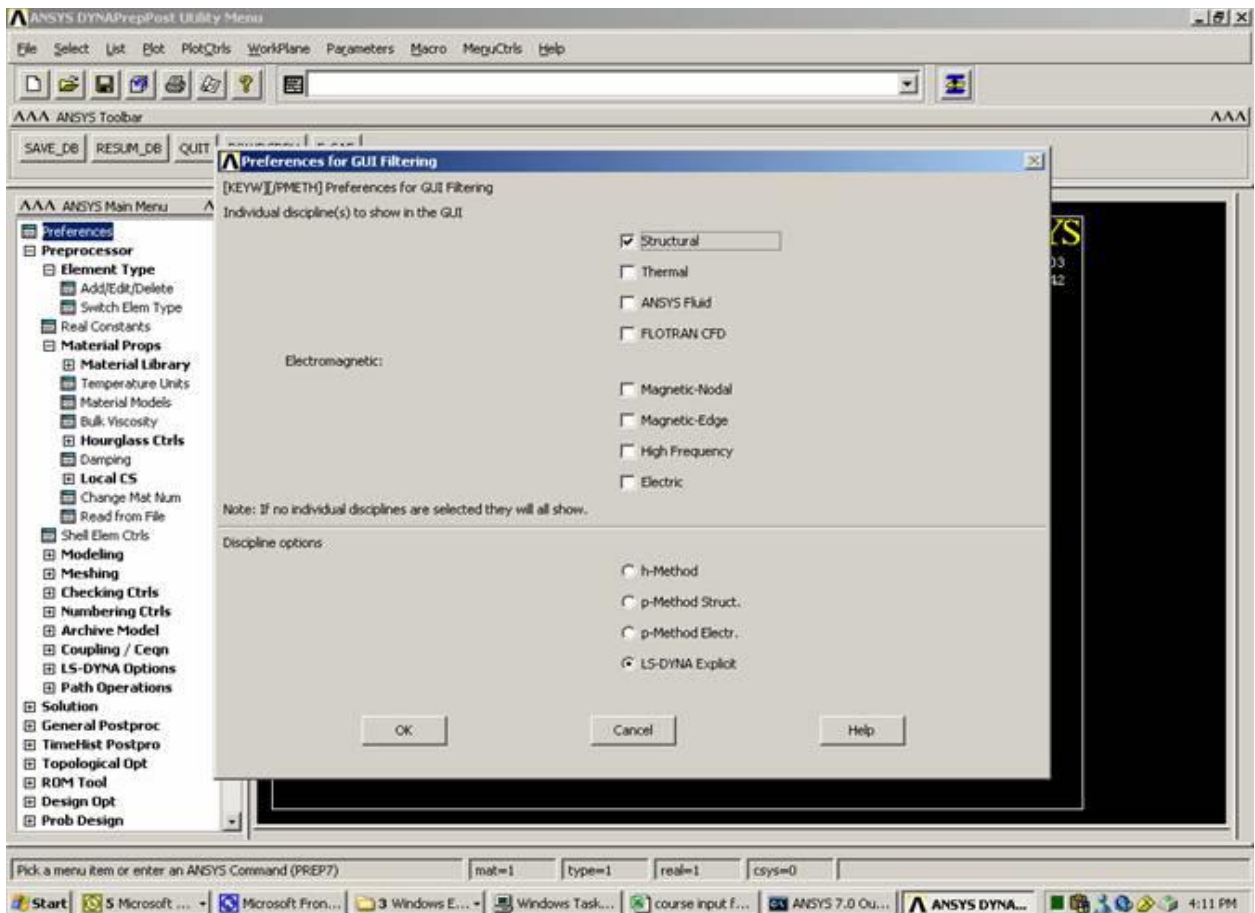
**3. Main menu** Here you can find the processors used when analyzing, your problem.

**4. Graphics window** in the graphics window your model is displayed: geometry, elements, visualization of results and so forth.

**5. Input window** You can type commands in the input window

### 4.1.3 Preferences

The starting step to define which analysis of a problem.



**Fig 4.1.1 Basic window**

### 4.1.4 Pre-processor

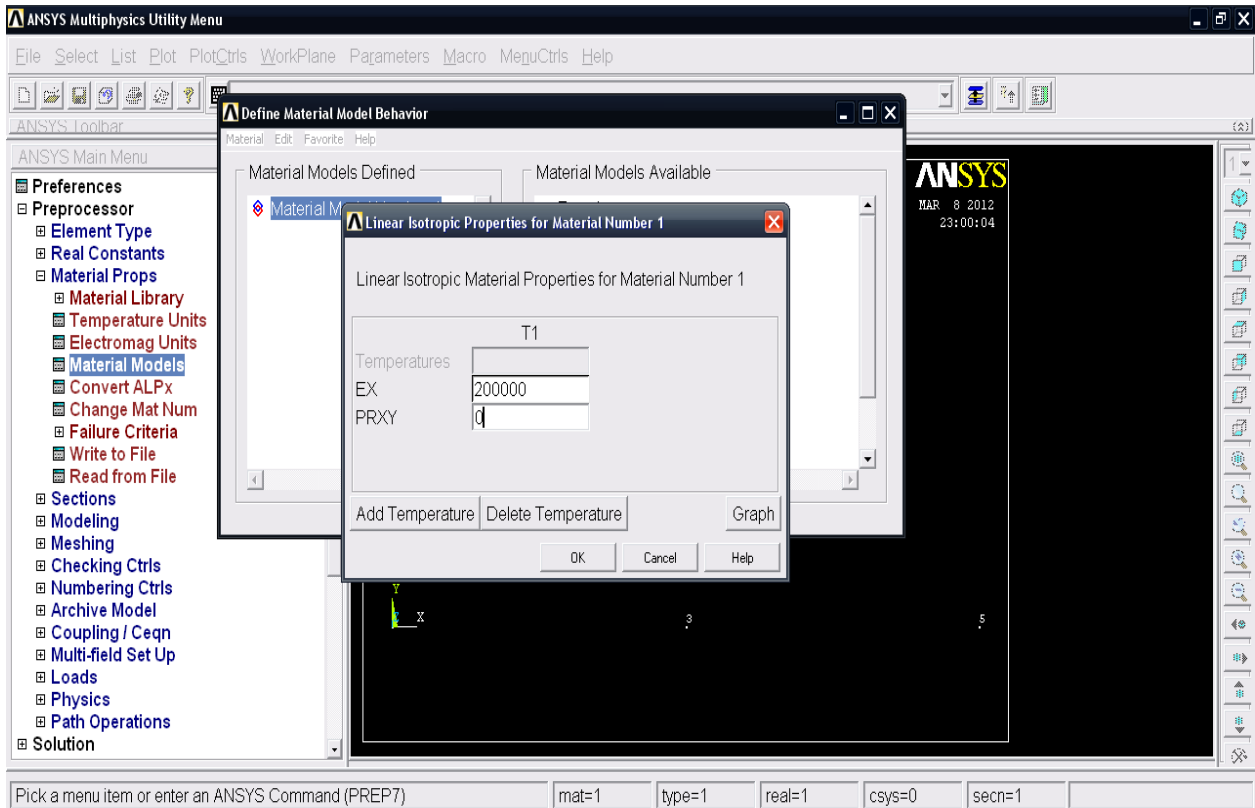
Within the preprocessor the model is set up. It includes a number of steps and usually in the following order:

**Build geometry:** Depending on whether the problem geometry is one, two or three dimensional, the geometry consists of creating lines, areas or volumes. These geometries can then, if necessary, be used to create other geometries by the use of Boolean operations. The key idea when building the geometry like this is to simplify the generation of the element mesh. Hence, this step is optional, but most often used. Nodes and elements can however be created from coordinates only.

**Define materials:** A material is defined by its material constants. Every element has to be assigned a particular material.

**Generate element mesh:** The problem is discretized with nodal points. The nodes are connected to form finite elements, which together form the material volume. Depending on the problem and the assumptions that are made, the element type has to be determined. Common element types are truss, beam, plate, shell and solid elements. Each element type may contain several subtypes, e.g., 2D 4-noded solid, 3D 20-noded solid elements. Therefore, care has to be taken when the element type is chosen.

The element mesh can in ANSYS be created in several ways. The most common way is that it is automatically created, however more or less controlled. For example, you can specify a certain number of elements in a specific area, or you can force the mesh generator to maintain a specific element size within an area. Certain element shapes or sizes are not recommended and if these limits are violated, a warning will be generated in ANSYS. It is up to the user to create a mesh which is able to generate results with a sufficient degree of accuracy.



**Fig 4.1.2 APDL Material properties window**

**Solution processor:**

Here you solve the problem by gathering all specified information about the problem:

**Apply loads:** Boundary conditions are usually applied on nodes or elements. The prescribed quantity can for example be force, traction, displacement, moment, rotation. The loads may in ANSYS also be edited from the preprocessor.

**Obtain solution:** The solution to the problem can be obtained if the whole problem is defined

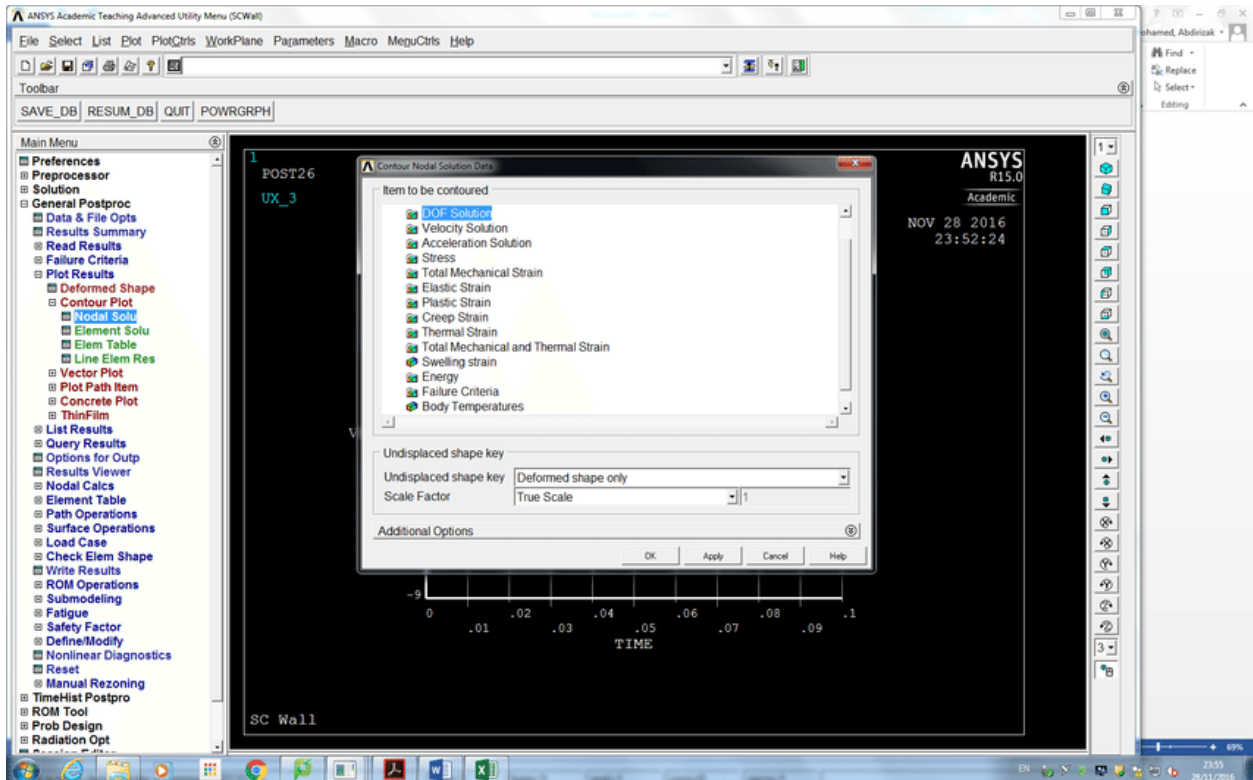


Fig 4.1.3 Solution window of APDL

#### 4.1.5 Post-processor:

Within this part of the analysis you can for example:

**Visualize the results:** For example, plot the deformed shape of the geometry or stresses.

**List the results:** If you prefer tabular listings or file printouts, it is possible.

### 4.2 ANSYS Work Bench

ANSYS Workbench is the framework upon which the industry's broadest suite of advanced engineering simulation technology is built. An innovative project schematic view ties together the entire simulation process, guiding the user every step of the way. Even complex multi physics analyses can be performed with drag-and-drop simplicity.

The ANSYS Workbench platform automatically forms a connection to share the geometry for both the fluid and structural analysis, minimizing data storage and making it easy to study the effects of geometry changes on both Analysis. In addition, a connection is formed to automatically transfer pressure loads from the fluid analysis to the structural analysis.

The ANSYS Workbench interface is arranged into two primary areas: The toolbox and the project Schematic. The toolbox contains the system templates that you can use to build a project. The project Schematic is the area if the interface where you will manage your project. The new project schematic view shows an overall view of the entire simulation project. Engineering intent, data relationships and the state of the entire project are visible at a glance, even for complex analysis involving multiple physics. In addition to this, you will see a menu bar and a toolbar with frequently used functions. You can also use context menus, accessible via a right-mouse click, on schematic items and cells. Context menus provide capabilities to add to and modify projects. The entire process is persistent. Changes can be made to any portion of the analysis and the ANSYS Workbench platform will manage the execution of the required applications to update the project automatically, dramatically reducing the cost of performing design iterations.

ANSYS Workbench is a project-management tool. It can be considered as the top-level interface linking all our software tools. Workbench handles the passing of data between ANSYS Geometry/Mesh/Post processing tools. This greatly helps project management. You do not worry about the individual files in disk (geometry, mesh etc.). Graphically, you can see at-a-glance how a project has been built. Because

Workbench can manage the individual applications and pass data between them, it is easy to automatically perform design studies (parametric analyses) for design optimization.

#### **4.2.1 ANSYS Workbench features**

- Bidirectional, parametric links with all major CAD systems.
- Integrated, analysis-focused geometry modelling, repair, and simplification via ANSYS Design Modeller.
- Highly automated, physics-aware meshing.
- Automatic contact detection.
- Unequalled depth of capabilities within individual physics disciplines.
- Unparalleled breadth of simulation technologies.
- Complete analysis systems that guide the user start-to-finish through an analysis.
- Comprehensive multi physics simulation with drag-and-drop ease of use.
- Flexible components enable tools to be deployed to best suit engineering intent.
- Innovative project schematic view allows engineering intent, data relationships, and the state of the project to be comprehended at a glance.
- Complex project schematics can be saved for re-use.
- Pervasive, project-level parameter management across all physics.
- Automated what-if analysis with integrated design point capability.

- Adaptive architecture with scripting and journaling capabilities and API's enabling rapid integration of new and third-party solutions.

## **4.3 Introduction to Steady State Thermal Analysis**

### **4.3.1 Definition of steady state analysis**

The ANSYS/Multiphysics, ANSYS/Mechanical, ANSYS/FLOTRAN, and ANSYS/Thermal products support steady-state thermal analysis. A steady-state thermal analysis calculates the effects of steady thermal loads on a system or component. Engineer/analysts often perform a steady-state analysis before doing a transient thermal analysis, to help establish initial conditions. A steady state analysis also can be the last step of a transient thermal analysis, performed after all transient effects have diminished.

You can use steady-state thermal analysis to determine temperatures, thermal gradients, heat flow rates, and heat fluxes in an object that are caused by thermal loads that do not vary over time. Such loads include the following:

- Convections
- Radiation
- Heat flow rates
- Heat fluxes (heat flow per unit area)
- Heat generation rates (heat flow per unit volume)
- Constant temperature boundaries.

A steady state thermal analysis may be either linear, with constant material properties; or nonlinear, with material properties that depend on temperature. The thermal properties of most material do vary with temperature, so the analysis usually is nonlinear. Including radiation effects also makes the analysis nonlinear.

### **4.3.2 Available elements for thermal analysis**

1. Two-Dimensional Solid Elements
2. Three-Dimensional Solid Elements
3. Radiation Link Elements
4. Conducting Bar Elements
5. Convection Link Elements
6. Shell Elements
7. Coupled-Field Elements
8. Specialty Elements

### **4.3.3 Tasks in a thermal analysis**

The procedure for doing a thermal analysis involves three main tasks:

- Build the model.
- Apply loads and obtain the solution and review the result

#### **4.3.3.1. Creating model geometry/Build the mode**

There is no single procedure for building model geometry; the tasks you must perform to create it vary greatly, depending on the size and shape of



the structure you wish to model. Therefore, the next few paragraphs provide only a generic overview of the tasks typically required to build model geometry.

The first step in creating geometry is to build a solid model of the item you are analyzing. You can use either predefined geometric shapes such as circles and rectangles (known within ANSYS as primitives), or you can manually define nodes and elements for your model. Two-dimensional primitives are called areas, and 3-D primitives are called volumes.

Model dimensions are based on a global coordinate system. By default, the global coordinate system is Cartesian, with X, Y, and Z axes; however, you can choose a different coordinate system if you wish. Modelling also uses a working plane—a movable reference plane used to locate and orient modelling entities. You can turn on the working plane grid to serve as a "drawing tablet" for your model.

You can tie together, or sculpt, the modelling entities you create via Boolean operations. For example, you can add two areas together to create a new, single area that includes all parts of the original areas. Similarly, you can overlay an area with a second area, then subtract the second area from the first; doing so creates a new, single area with the overlapping portion of area.

Once you finish building your solid model, you use meshing to "fill" the model with nodes and elements.

#### **4.3.3.2. Applying loads and obtaining the solution**

You must define the analysis type and options, apply loads to the model, specify load step options, and initiate the finite element solution.

### **Applying Loads**

You can apply loads either on the solid model (key points, lines, and areas) or on the finite element model (nodes and elements). You can specify loads using the conventional method of applying a single load individually to the appropriate entity, or you can apply complex boundary conditions via TABLE type array parameters.

You can specify five types of thermal loads:

#### **Constant Temperatures (TEMP)**

These are DOF constraints usually specified at model boundaries to impose a known, fixed temperature.

#### **Heat Flow Rate (HEAT)**

These are concentrated nodal loads. Use them mainly in line-element models (conducting bars, convection links, etc.) where you cannot specify convections and heat fluxes. A positive value of heat flow rate indicates heat flowing into the node (that is, the element gains heat). If both TEMP and HEAT are specified at a node, the temperature constraint prevails.

*Note:* If you use nodal heat flow rate for solid elements, you should refine the mesh around the point where you apply the heat flow rate as a load, especially if the elements containing the node where the load is applied have widely different thermal conductivities otherwise you may get an unphysical

range of temperature. Whenever possible, use the alternative option of using the heat generation rate load or the heat flux rate load. These options are more accurate, even for a reasonably coarse mesh.

### **Convections (CONV)**

Convections are surface loads applied on exterior surfaces of the model to account for heat lost to (or gained from) a surrounding fluid medium. They are available only for solids and shells. In line-element models, you can specify convections through the convection link element (LINK34), or the thermal-fluid link element (FLUID66).

### **Heat Fluxes (HEAT)**

Heat fluxes are also surface loads. Use them when the amount of heat transfer across a surface (heat flow rate per area) is known or is calculated through a FLOTRAN CFD analysis. A positive value of heat flux indicates heat flowing into the element. Heat flux is used only with solids and shells. An element face may have either CONV or HFLUX (but not both) specified as a surface load. If you specify both on the same element face, ANSYS uses what was specified *last*.

#### **4.3.3.3. Reviewing analysis results**

ANSYS writes the results from a thermal analysis. Results contain the following data:

#### **Primary data**

- Nodal temperatures (TEMP)

### **Derived data**

- Nodal and element thermal fluxes (TFX, TFY, TFZ, TFSUM)
- Nodal and element thermal gradients (TGX, TGY, TGZ, TGSUM)
- Element heat flow rates
- Nodal reaction heat flow rates

*Note:* To review results in the general postprocessor, the ANSYS database must contain the same model for which the solution was calculated. (If necessary, use the resume operation or issue the **RESUME** command to retrieve the model.) In addition, the results file, Jobname.RTH, must be available.

### **Reviewing Results**

Once you have read results into memory, you can use the ANSYS graphics displays and tables to review them. To display your results, use the following menu paths. Equivalent commands are shown in parentheses.

For contour displays:

Command(s):

**PLESOL**  
**PLETAB**  
**PLNSOL**

## 4.4 Analytical Modelling

### 4.4.1 Heat transfer principle

Heat sink works on the principle of Fourier's law of heat conduction, simplified to a one-dimensional form in the X-direction, shows that when there is a temperature gradient in a body, heat will be transferred from the higher temperature region to the lower temperature region. The rate at which heat is transferred by conduction, is proportional to the product of the temperature gradient and the cross-sectional area through which heat is transferred

$$Q_i = -kA \times (dT/dx) \quad (4.1)$$

Consider a heat sink in a duct, where air flows through the duct. It is assumed that the heat sink base is higher in temperature than the air. Applying the conservation of energy, for steady-state conditions, and Newton's law of cooling to the temperature nodes shown in the diagram gives the following set of equations:

$$Q = mc_{p,in}(T_{air,out} - T_{air,in}) \quad (4.2)$$

Where

$$T_{air,av} = (T_{air,in} + T_{air,out})/2 \quad (4.3)$$

### 4.4.2 Assumptions for thermal analysis of heat sink

The performance of the heat sink is determined by the various parameters like the heat transfer coefficient, Fin efficiency, etc.

#### Heat Transfer Coefficient (h)

To define the heat transfer coefficient, consider the Newton's law of convection given by the equation

$$Q=hA_s(T_s-T_a) \quad h=Q/ A_s(T_s-T_a) \quad (4.4)$$

Fin Efficiency

$$\eta=\tanh(mL)/ mL \quad (4.5)$$

Where,

$h$  = heat transfer coefficient of fin,

$P$  = Perimeter of fin =  $2(B+D)$ ,

$L$  = Length of pin fin.

$k$  = thermal conductivity of Aluminum fin = 202.4 W/mK

$A$ = Area of fin =  $B \times D$

$T_a$ =Ambient temperature= $30^0$  C

$T_s$ = Surface temperature =  $80^0$  C

This analysis is based on the following assumptions:

- 1.The fins are with adiabatic tip.
2. The fluid, air is assumed to be incompressible throughout the process.
3. Air properties are taken at film temperature.
4. There are no heat sources within the fin itself.
5. The radiation heat transfer is negligible.
6. The temperature at the base of the fin is uniform.

#### **4.4.3 FEM of a heat sink**

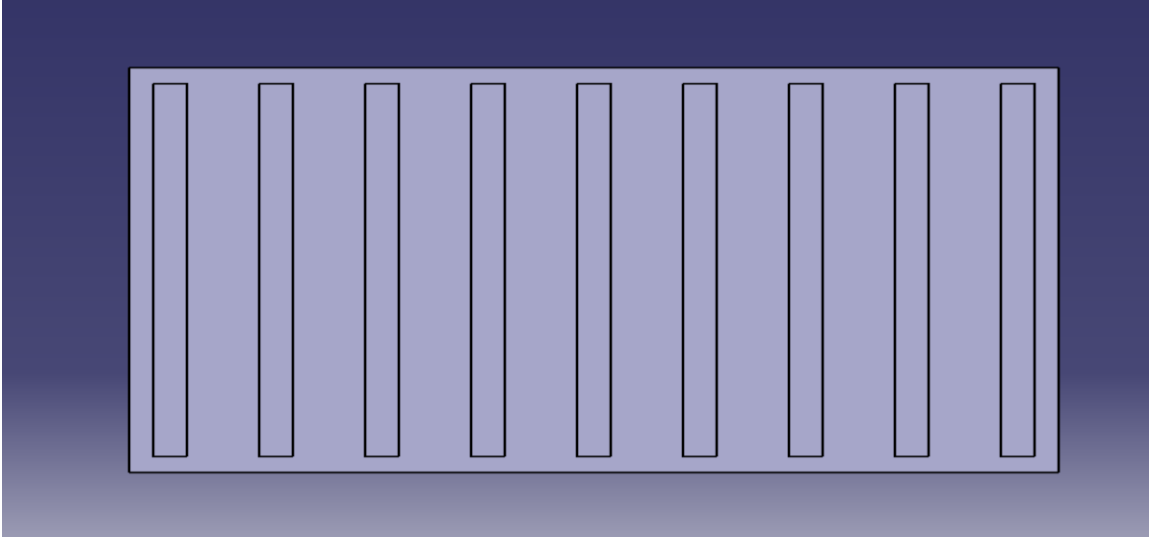
In the present work, the software ANSYS 19.2 has been used to model and simulate Heat transfer and steady state analysis of heat sink with rectangular pin fin.

##### **4.4.3.1 Preparation of the design model**

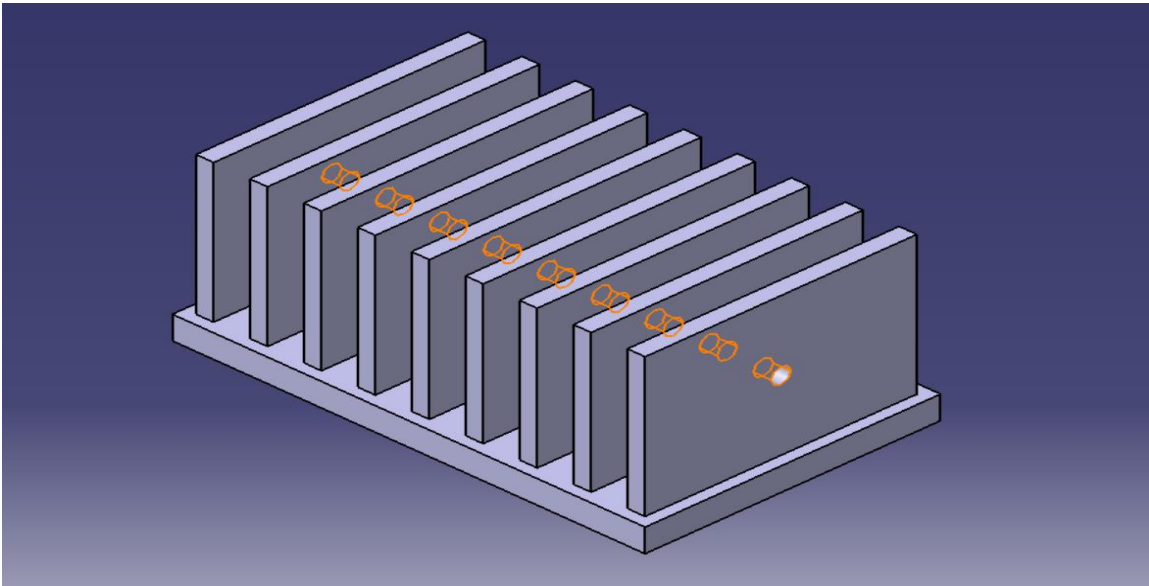
The designs of heat Sink with rectangular pin fins with inline Staggered arrangements is done in ANSYS Workbench 19.2 in IGES format. A flat platform of 80x50x5mm is common in all designs. Fin height for all models is 30 mm. There are a total number 81 pin fins in line arrangement with 9 pin fins in each column with fin spacing of 6.12 mm between them.

#### 4.4.3.2. Geometry

The top view and 3D model are shown in Fig 3.1 & 3.2 respectively. The material properties for modelling of the heat sink with rectangular plate fin are shown in the Table3 and properties of air are tabulated and shown.



**Fig 4.4.1 Top view of rectangular plate fin**



**Fig 4.4.2 Isometric view of rectangular plate fin**

S.No	Properties	Value
1.	Density ( $\rho$ )	2719 kg/m <sup>3</sup>
2.	Specific heat ( $C_p$ )	871 J/KgK
3.	Thermal conductivity(k)	202.4 W/mK

**Table 3. Properties of aluminum**

#### 4.4.3.3 Calculations

$$T_s=80^\circ\text{C}, T_a=30^\circ\text{C}$$

$$T=(T_s+T_a)/2= 110/2=55^\circ\text{C}$$

At 55°C, properties of dry air

$$\rho= 1.0765 \text{ kg/m}^3$$

$$\mu=19.855 \times 10^{-6} \text{ Ns/m}^2$$

$$\nu=18.46 \times 10^{-6} \text{ m}^2/\text{s}$$

$$\beta=1/T$$

$$\text{Pr}= 0.697 \text{ (where Pr is Prandtl number)}$$

$$k=0.02861 \text{ W/m-k}$$

$$\text{Gr}= (g\beta(T_s-T_a)L^3) / \nu^2 \text{ ( where Grashof number)}$$

$$(9.81 \times (1/ (55+273)) \times 50 \times (50 \times 10^{-3})^3)$$

$$= \frac{\quad}{\quad}$$



$$(18.46 \times 10^{-6})^2$$

$$Gr = 548544.4023$$

$$Ra = Gr \times Pr = 382335.4484 \text{ (where Ra is Rayleigh number)}$$

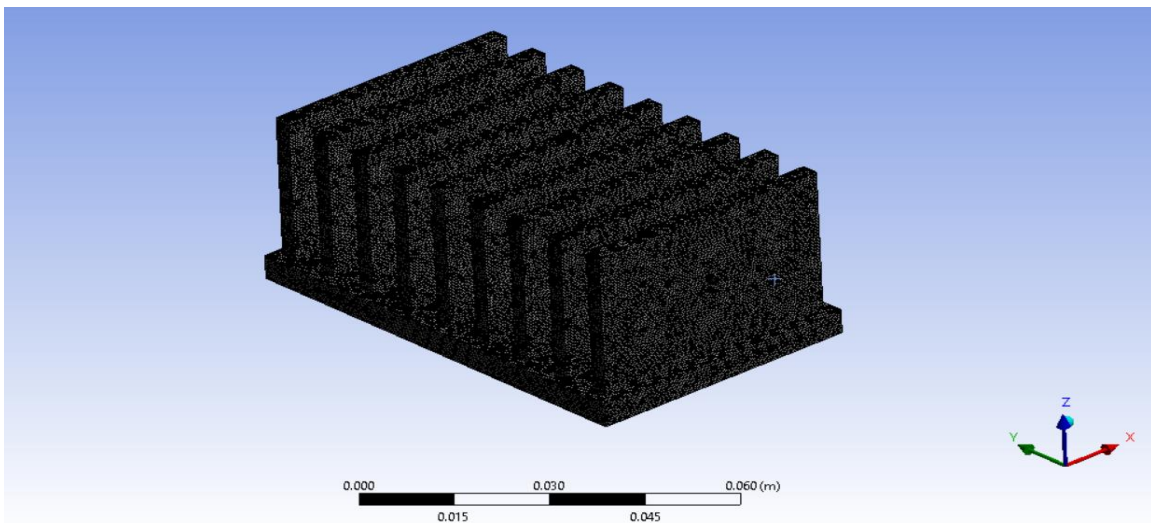
$$S_{opt} [14] = 2.714 \times L \frac{1}{(Ra)^{1/4}}$$

$$= 6.12 \text{ mm}$$

$$h = 1.31 \times k = 6 \text{ w/m}^2\text{K}$$

#### 4.4.3.4 Mesh generation

The heat sink model is imported in to the work bench design modeler and meshed with a four node three dimensional tetrahedron element. The meshed model of the heat sink is shown in the Fig 4.4.3 and the mechanical Ansys workbench is used to mesh the heat sink.

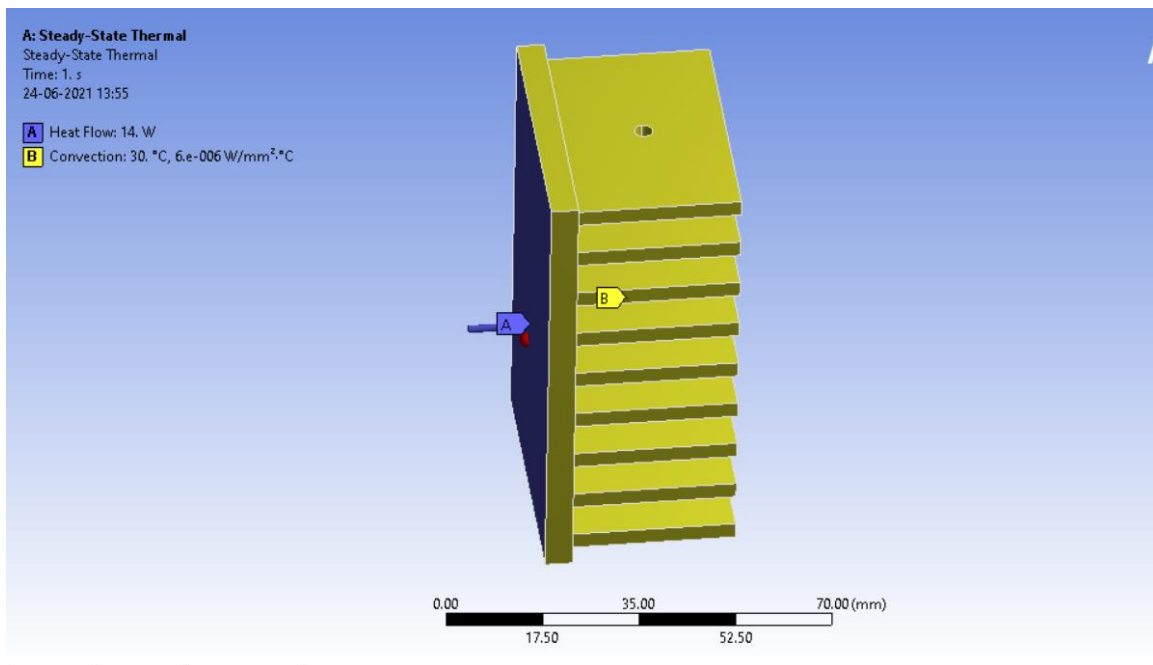


**Fig4.4.3.4 Meshing of heat sink model**

The selected fins from the geometry then follows for the meshing. The meshing includes the coarse and fine meshing. Here the fine meshing has been selected for the aluminum heat sink. The meshing summarizes the all nodes in to the consideration for applying the principle of heat transfer convection process. The fine meshing discretizes the fins into very small no. of area so that the proper flowing of the temperature and the heat flux can be observed accurately.

#### 4.4.3.5 Boundary Conditions

Heat sink is given a heat flow of 14 Watt the bottom surface, and convection of  $6 \times 10^{-6} \text{ W/mm}^2\text{C}$  to the remaining faces shown in figure-4.4.4.



**Fig 4.4.3.5. Loading boundary conditions**

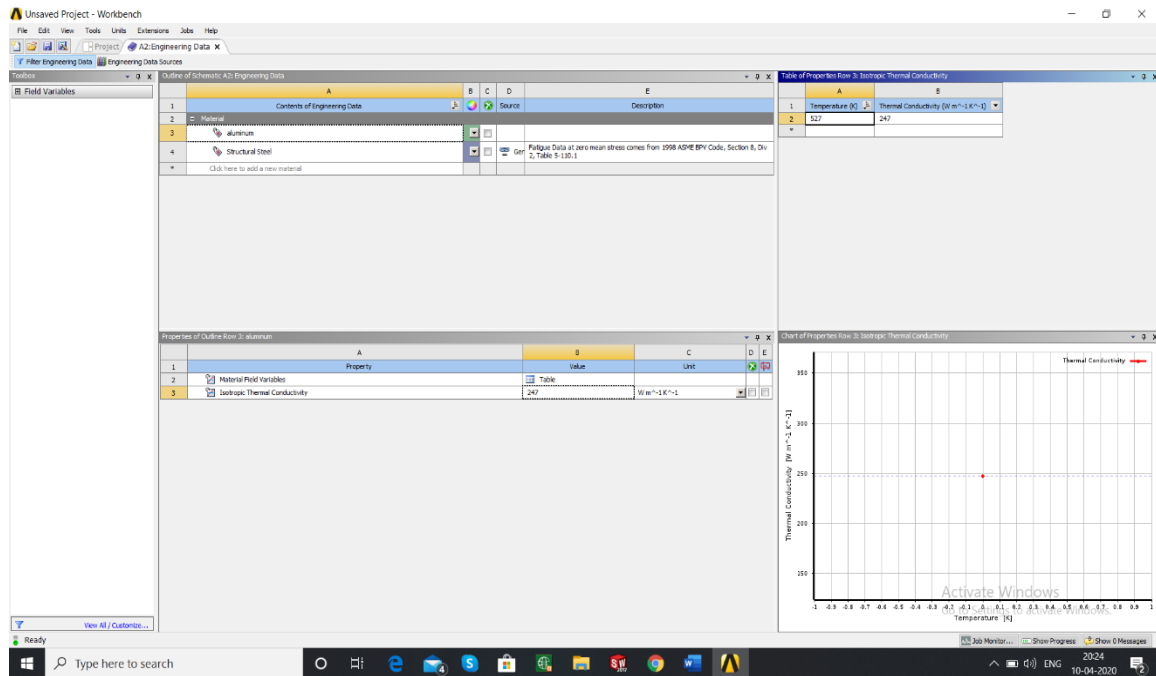
After applying the boundary conditions, run the simulation for some time and then we will obtain the results of temperature distribution and total heat flux contours with maximum and minimum values.

## 4.5 Steady state thermal analysis on heat sink

### 4.5.1 Rectangular plate Fin

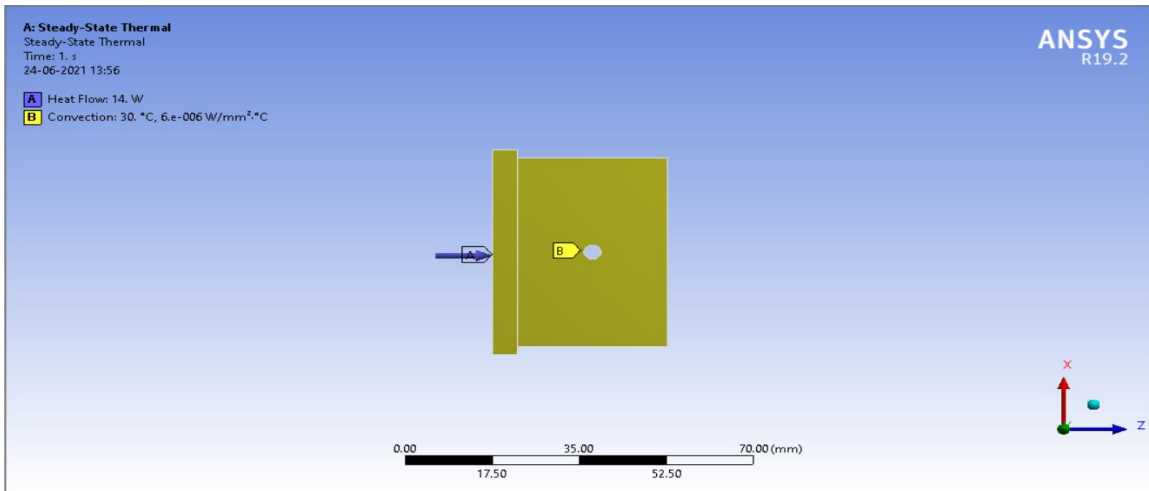
The 3d assembly model designed in Catia is saved as IGES format to do the analysis in ANSYS work bench. The work bench extracts the information of dimensions of the model and open to select the type of analysis that is required [1].

The engineering data is modified aluminum material is added to component with thermal conductivity of 247 W/m-k and 527 k temperature at peak.



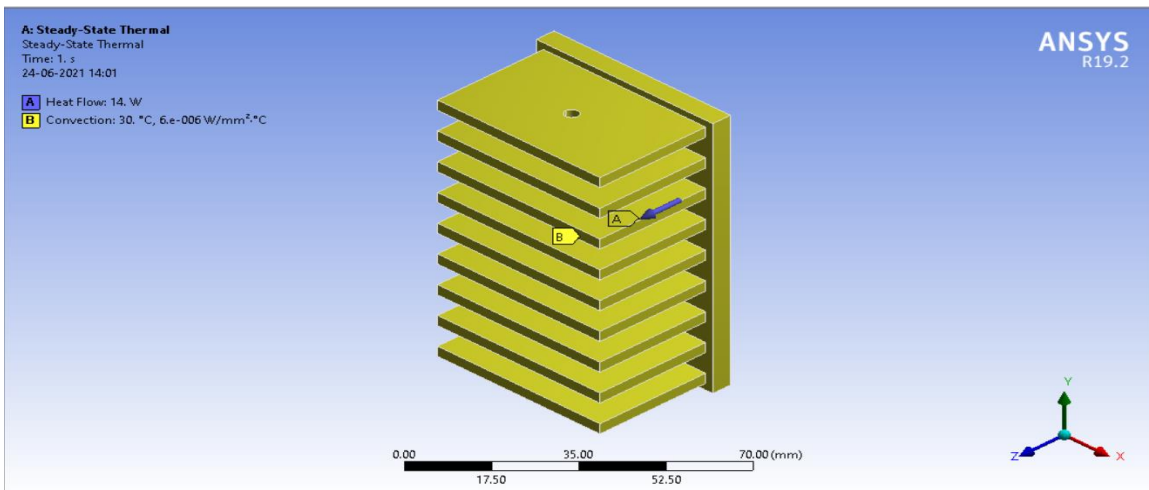
**Fig 4.5.1 Material selection in Ansys workbench**

The material is assigned to the heat sink and then the preprocessing of FEA i.e. meshing is given to the heat sink with the element size of 1mm in order to get fine meshing and appropriate results.



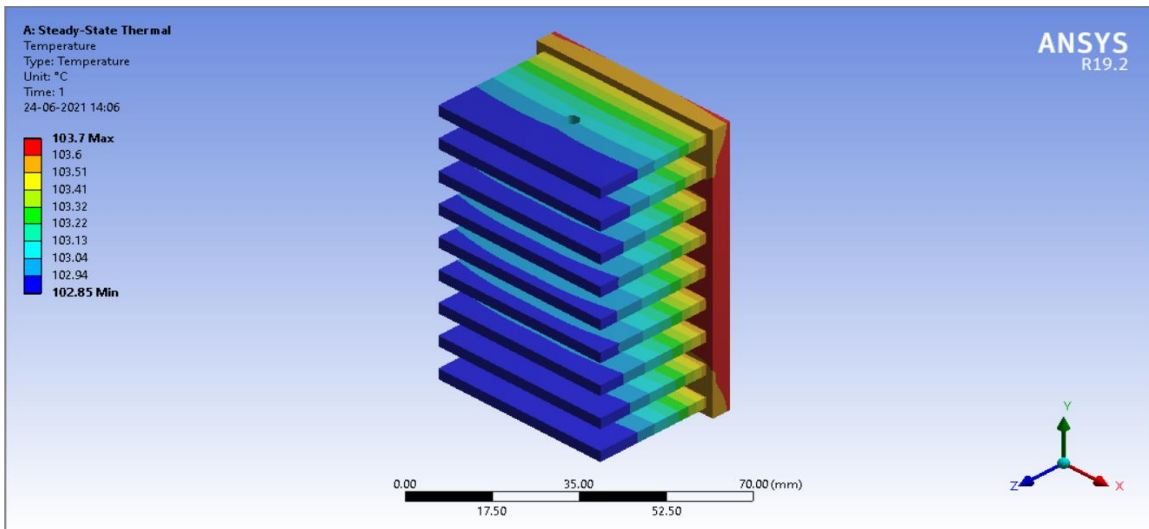
**Fig4.5.2 Side view of applied heat flux and convection**

The heat flow of 14W is given to the fin base as initial condition followed by the convective heat transfer coefficient to the remaining part of the sink with a value of  $6e-6 \text{ W/mm}^2 \text{ } ^\circ\text{C}$ .



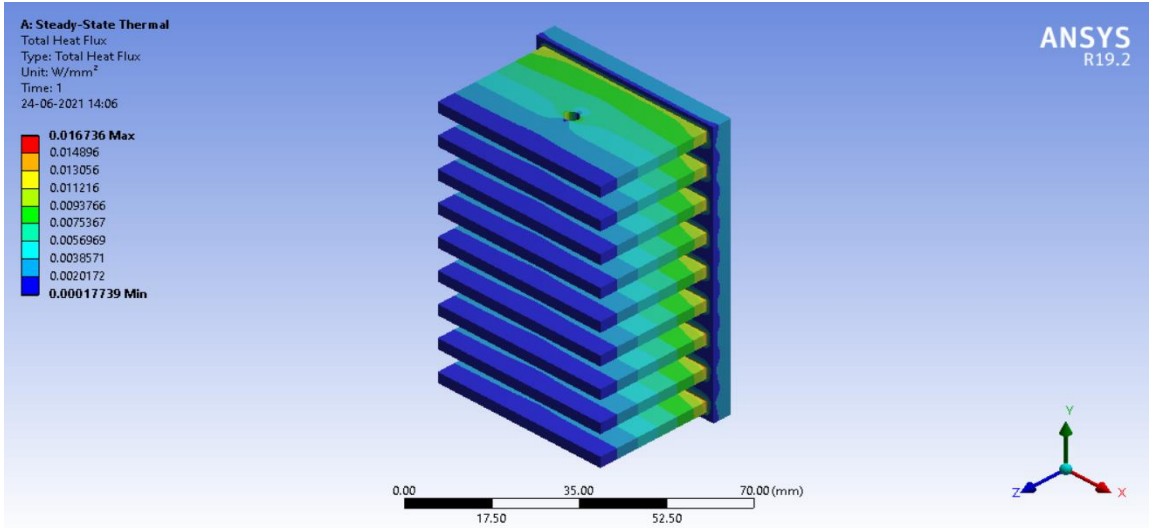
**Fig 4.5.3 Isometric view of applied heat flux and convection**

The conditions such as temperature and total heat flux are obtained by assigning them to Solution part. Thereafter the whole process is solved by using Ansys workbench.



**Fig 4.5.4 Expected result (Temperature distribution) after simulation**

The first procedure is repeated for different types of heat sinks (varying fin geometrical configuration) for comparative analysis.



**Fig 4.5.5 Expected result (Total Heat Flux) after simulation**

The adhoc boundary conditions are taken compare to determine the fin geometry with better performance among the listed fins.

## CHAPTER 5

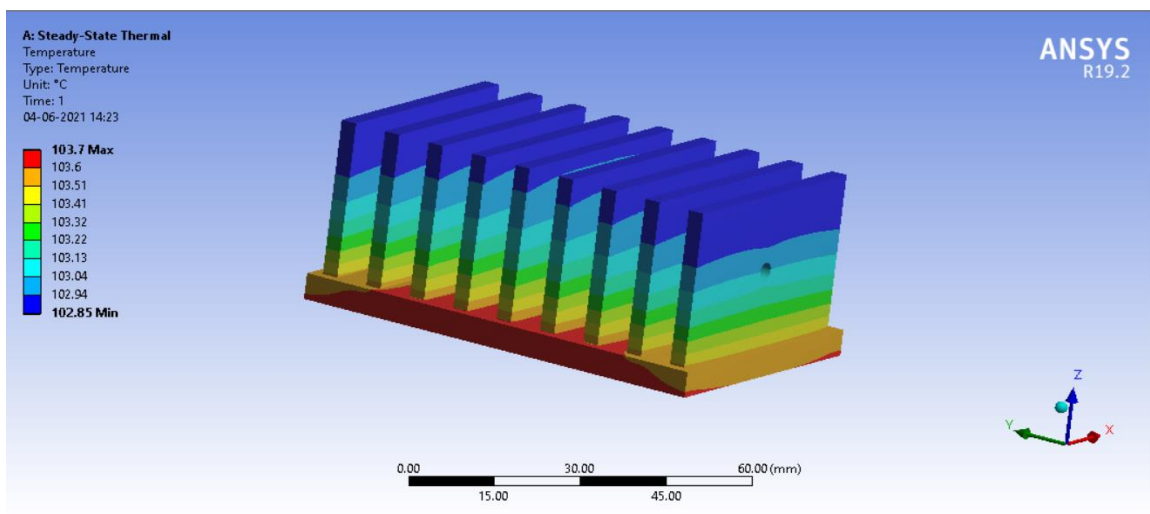
### RESULTS AND DISCUSSIONS

For a steady state thermal analysis, an amount of heat flow is given as input to the base plate of each heat sink considered in the analysis. A constant convection heat transfer coefficient of  $6 \times 10^{-6} \text{ W/mm}^2 \text{ } ^\circ\text{C}$  and ambient temperature  $30^\circ \text{ C}$  have been applied to the remaining surface of all heat sinks considered in the analysis. Using Ansys workbench, the maximum and minimum temperature, heat flux of heat sinks has been estimated. The result pertaining to the steady state thermal analysis involves temperature & heat flux contours as explained and shown below.

### 5.1 Temperature Distribution

#### 5.1.1 Rectangular flat plate fin with circular perforations:

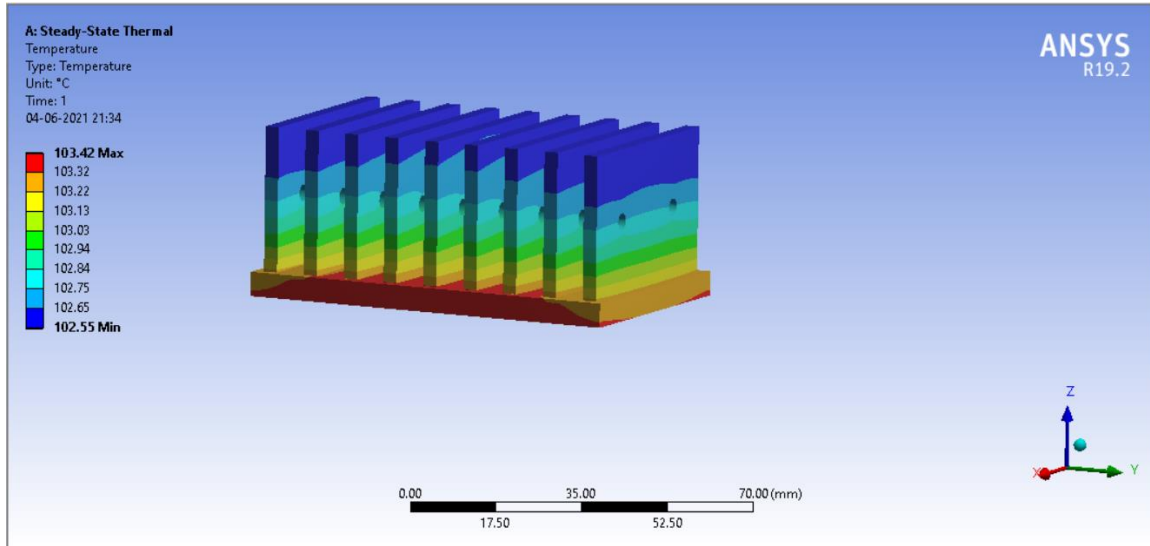
##### a). single perforation:



**Fig.5.1.1(a) Rectangular flat-plate fin with single circular perforation**

The temperature distribution is obtained with  $103.7^\circ\text{C}$  of maximum temperature at the centre of base plate and the minimum temperature of  $102.85^\circ\text{C}$  at the tip of fins. The simulated result is shown in fig 5.1.1(a)

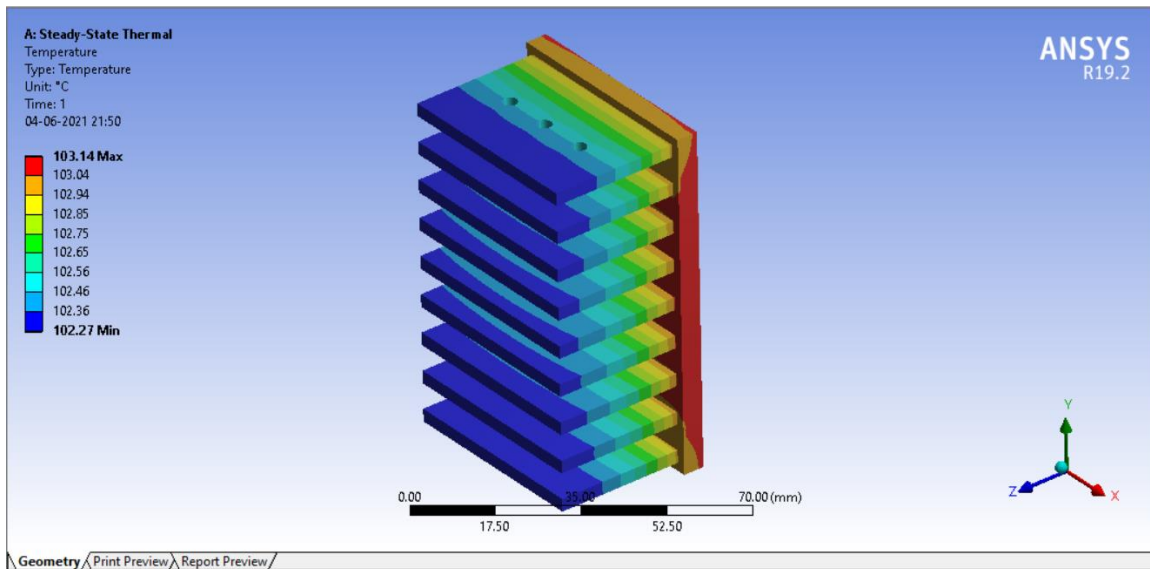
## b). Double perforation:



**Fig.5.1.1(b) Rectangular flat-plate fin with double circular perforation**

The temperature distribution is obtained with 103.42°C of maximum temperature at the centre of base plate and the minimum temperature of 102.55°C at the tip of fins. The simulated result is shown in fig 5.1.1(b)

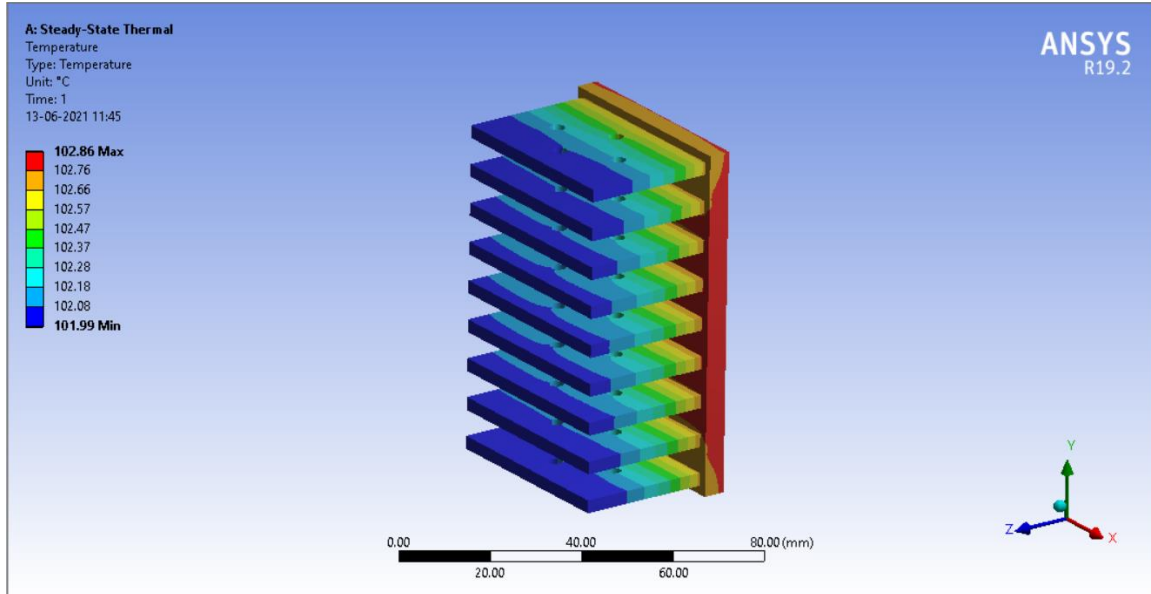
## c). Triple perforation:



**Fig.5.1.1(c) Rectangular flat-plate fin with triple circular perforation**

The temperature distribution is obtained with 103.14°C of maximum temperature at the centre of base plate and the minimum temperature of 102.27°C at the tip of fins. The simulated result is shown in fig 5.1.1(c)

### d). Four perforations:

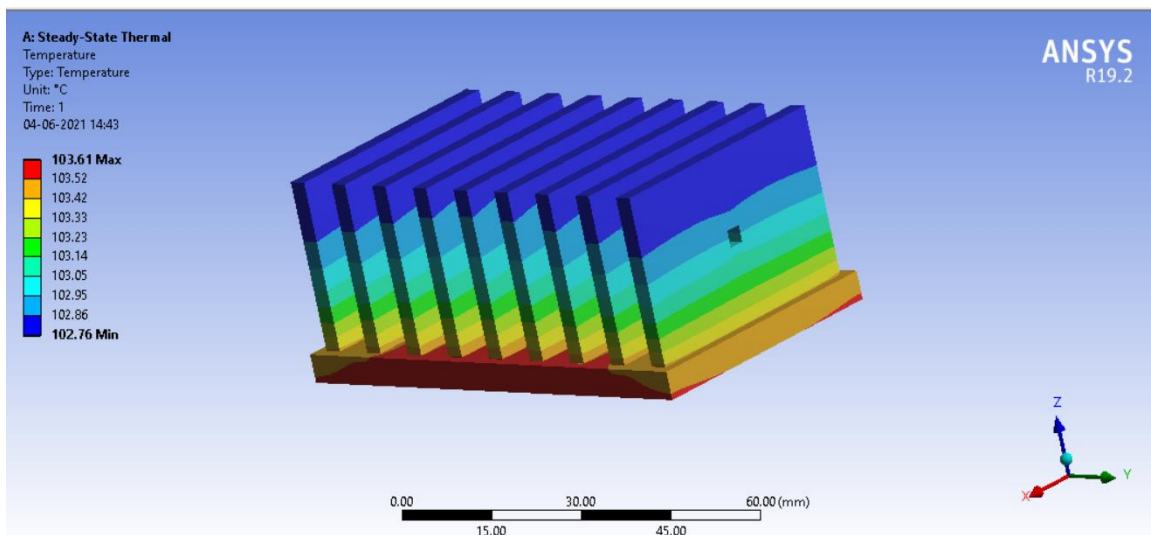


**Fig.5.1.1(d) Rectangular flat-plate fin with four circular perforations**

The temperature distribution is obtained with 102.86°C of maximum temperature at the centre of base plate and the minimum temperature of 101.99°C at the tip of fins. The simulated result is shown in fig 5.1.1(d)

### 5.1.2 Rectangular flat plate fin with square perforations:

#### a). single perforation:

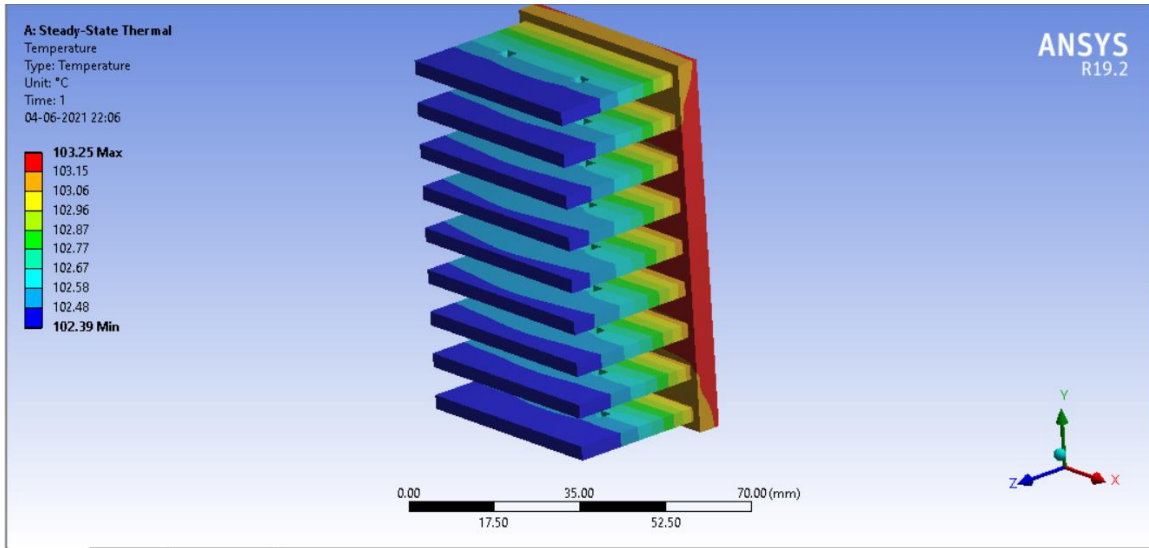


**Fig.5.1.2(a) Rectangular flat-plate fin with single square perforation**



The temperature distribution is obtained with 103.61°C of maximum temperature at the centre of base plate and the minimum temperature of 102.76°C at the tip of fins. The simulated result is shown in fig 5.1.2(a).

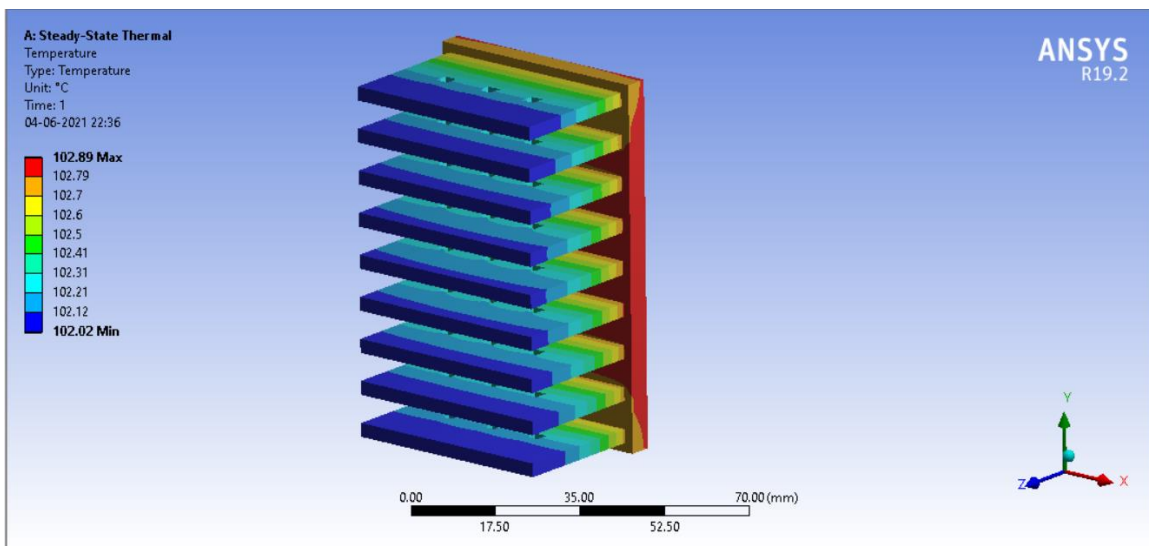
**b). Double perforation:**



**Fig.5.1.2(b) Rectangular flat-plate fin with double square perforation**

The temperature distribution is obtained with 103.25°C of maximum temperature at the centre of base plate and the minimum temperature of 102.39°C at the tip of fins. The simulated result is shown in fig 5.1.2(b).

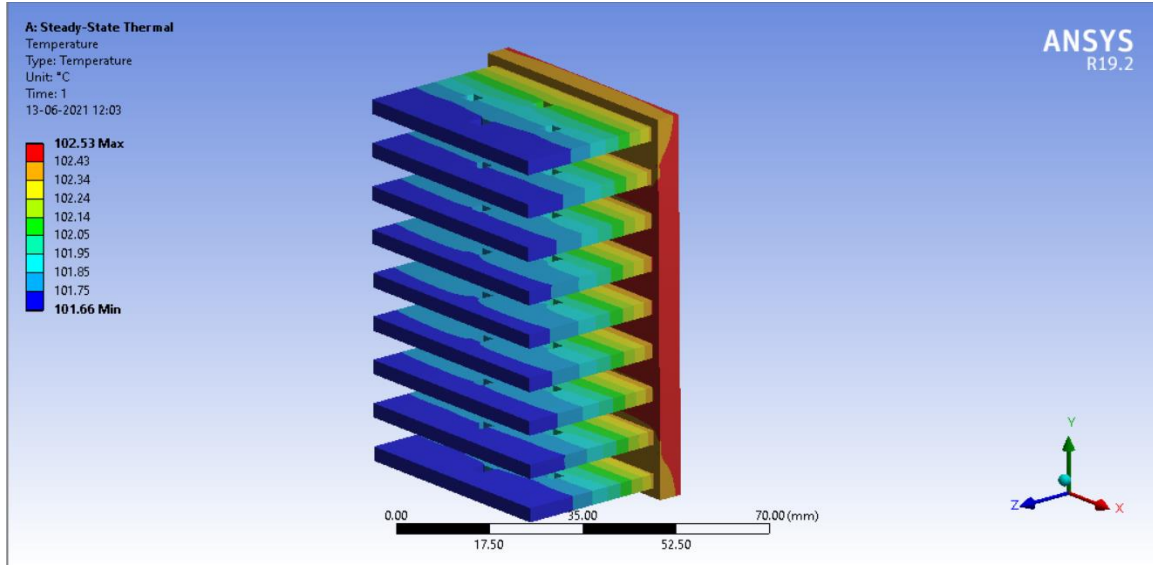
**c). Triple perforation:**



**Fig.5.1.2(c) Rectangular flat-plate fin with triple square perforation**

The temperature distribution is obtained with 102.89°C of maximum temperature at the centre of base plate and the minimum temperature of 102.02°C at the tip of fins. The simulated result is shown in fig 5.1.2(c).

**d). Four perforations:**

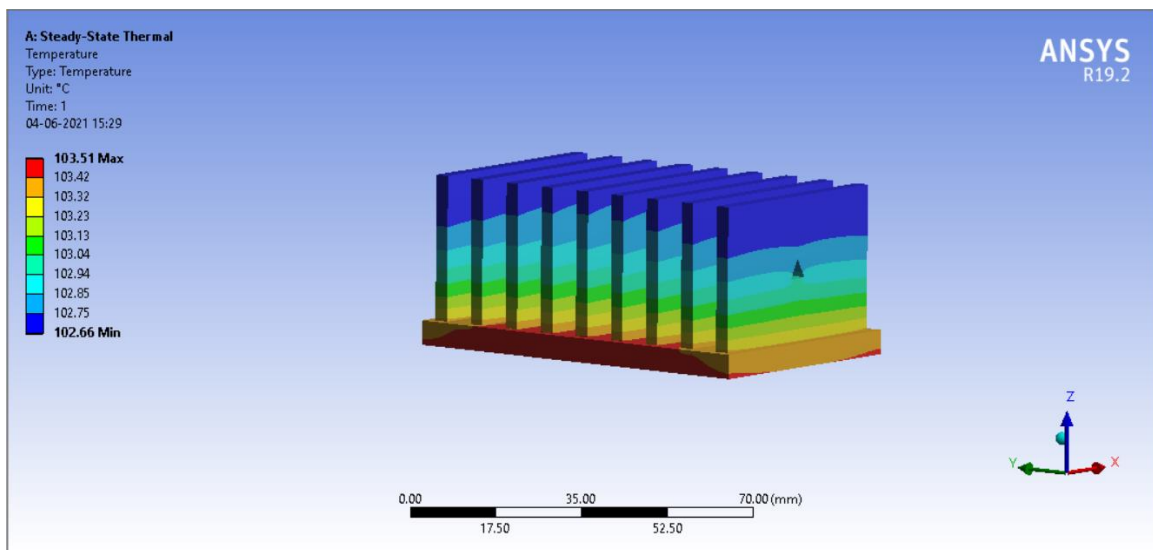


**Fig.5.1.2(d) Rectangular flat-plate fin with four square perforations**

The temperature distribution is obtained with 102.53°C of maximum temperature at the centre of base plate and the minimum temperature of 101.66°C at the tip of fins. The simulated result is shown in fig 5.1.2(d).

**5.1.3 Rectangular flat plate fin with triangular perforations:**

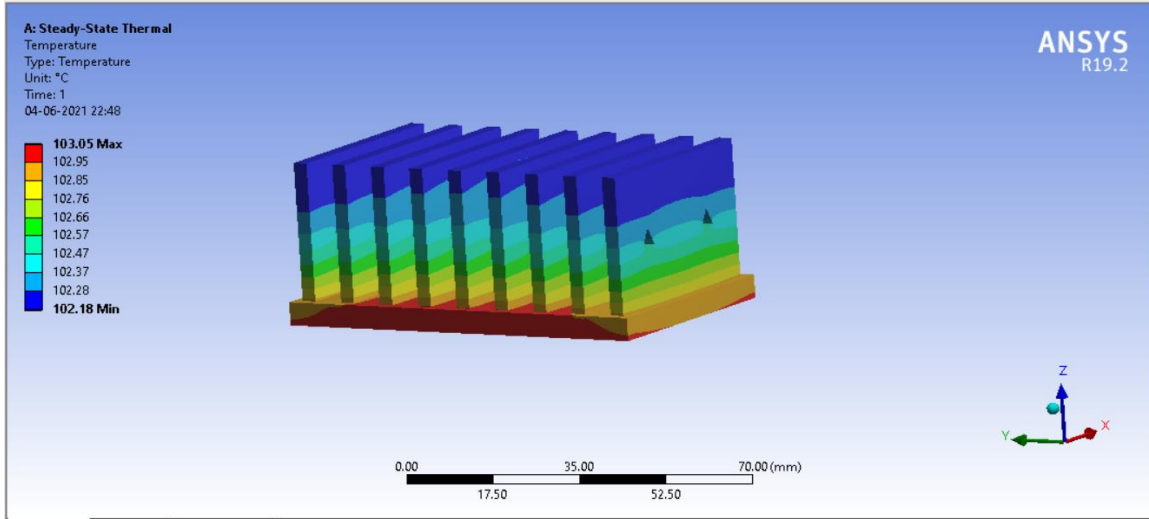
**a). single perforation:**



**Fig.5.1.3(a) Rectangular flat-plate fin with single triangular perforation**

The temperature distribution is obtained with 103.51°C of maximum temperature at the centre of base plate and the minimum temperature of 102.66°C at the tip of fins. The simulated result is shown in fig 5.1.3(a).

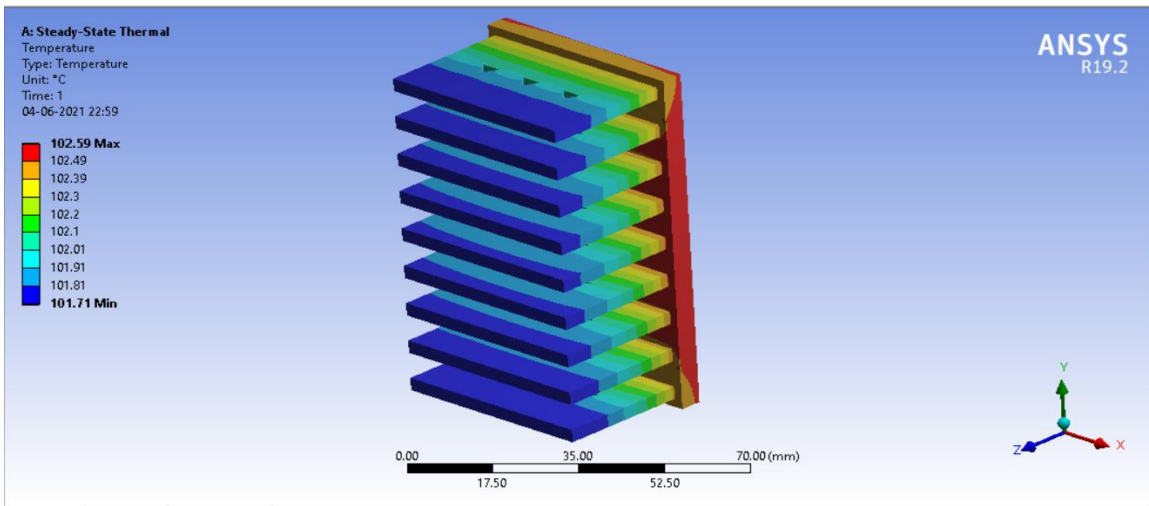
**b). Double perforation:**



**Fig.5.1.3(b) Rectangular flat-plate fin with double triangular perforation**

The temperature distribution is obtained with 103.05°C of maximum temperature at the centre of base plate and the minimum temperature of 102.18°C at the tip of fins. The simulated result is shown in fig 5.1.3(b).

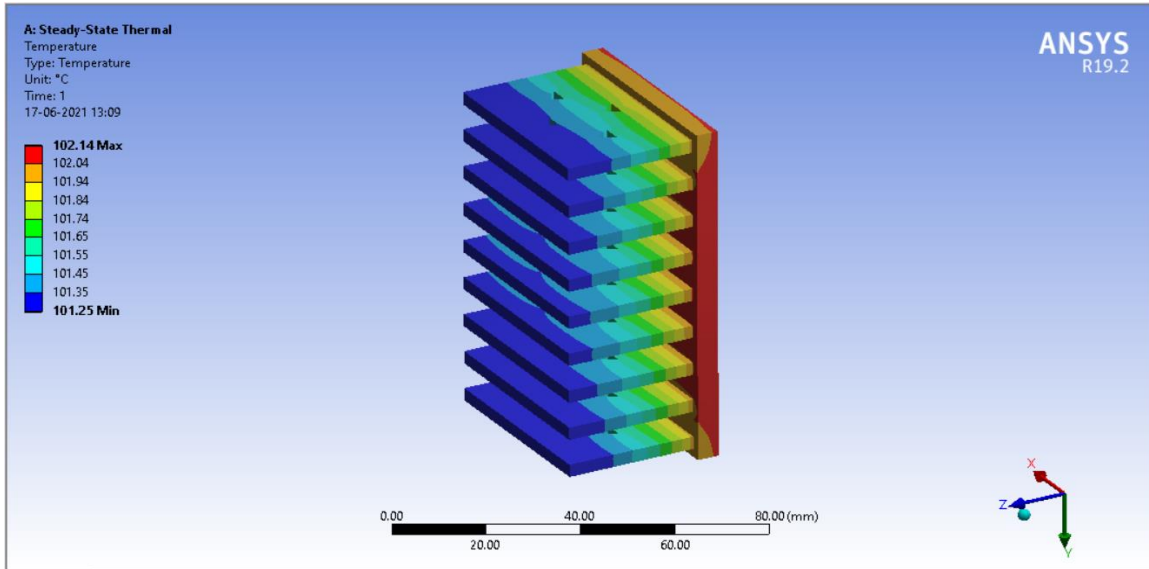
**c). Triple perforation:**



**Fig.5.1.3(c) Rectangular flat-plate fin with triple triangular perforation**

The temperature distribution is obtained with 102.59°C of maximum temperature at the centre of base plate and the minimum temperature of 101.71°C at the tip of fins. The simulated result is shown in fig 5.1.3(c).

### d). Four perforations:



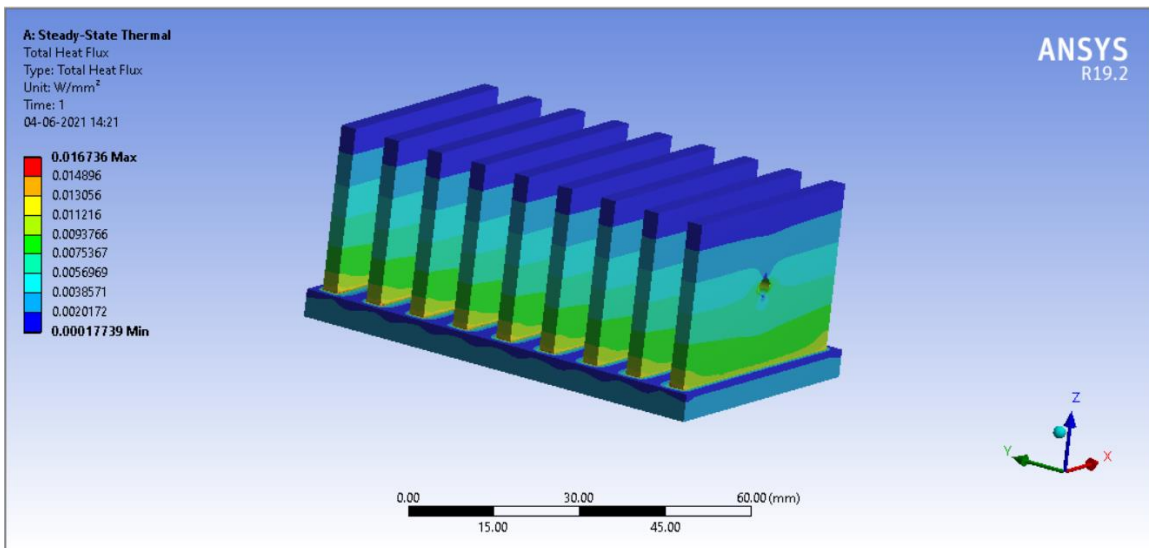
**Fig.5.1.3(d) Rectangular flat-plate fin with four triangular perforations**

The temperature distribution is obtained with 102.14°C of maximum temperature at the centre of base plate and the minimum temperature of 101.25°C at the tip of fins. The simulated result is shown in fig 5.1.3(d).

## 5.2 Heat Flux Distribution:

### 5.2.1 Rectangular flat plate fin with circular perforations:

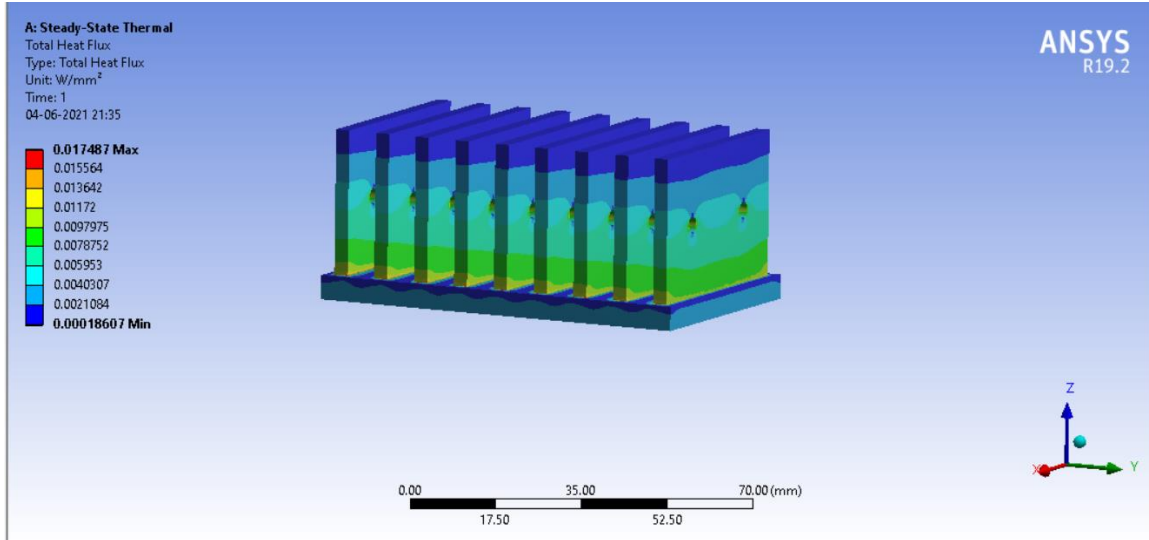
#### a). single perforation:



**Fig.5.2.1(a) Rectangular flat-plate fin with single circular perforation**

The total heat flux distribution of orientation to X- axis is obtained with a maximum of 0.016736 W/mm<sup>2</sup> and minimum of 0.00017739 W/mm<sup>2</sup>. The simulated result is as shown in fig 5.2.1(a).

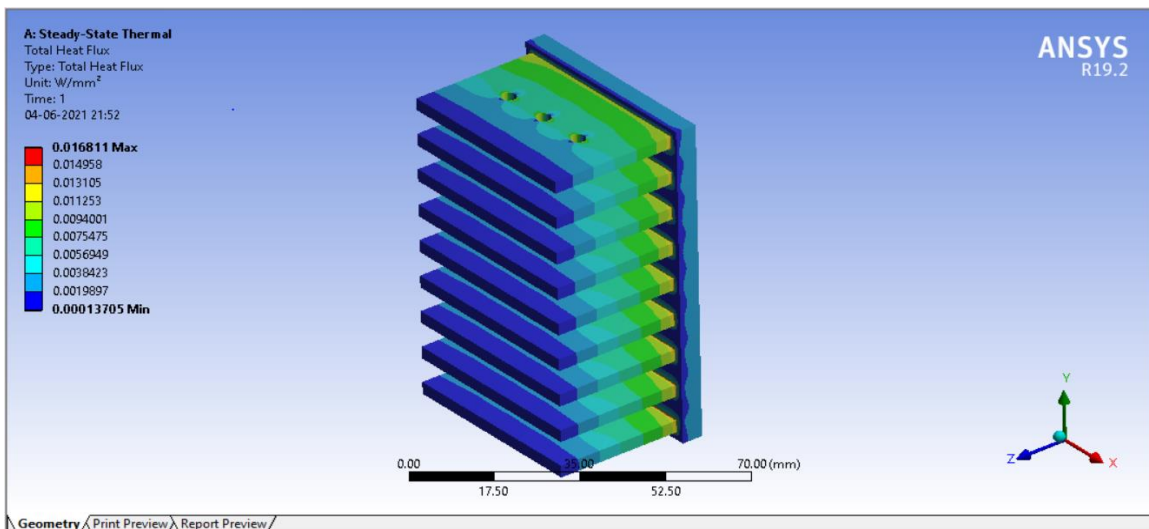
**b). Double perforation:**



**Fig.5.2.1(b) Rectangular flat-plate fin with double circular perforation**

The total heat flux distribution of orientation to X- axis is obtained with a maximum of 0.017487 W/mm<sup>2</sup> and minimum of 0.00018607 W/mm<sup>2</sup>. The simulated result is as shown in fig 5.2.1(b).

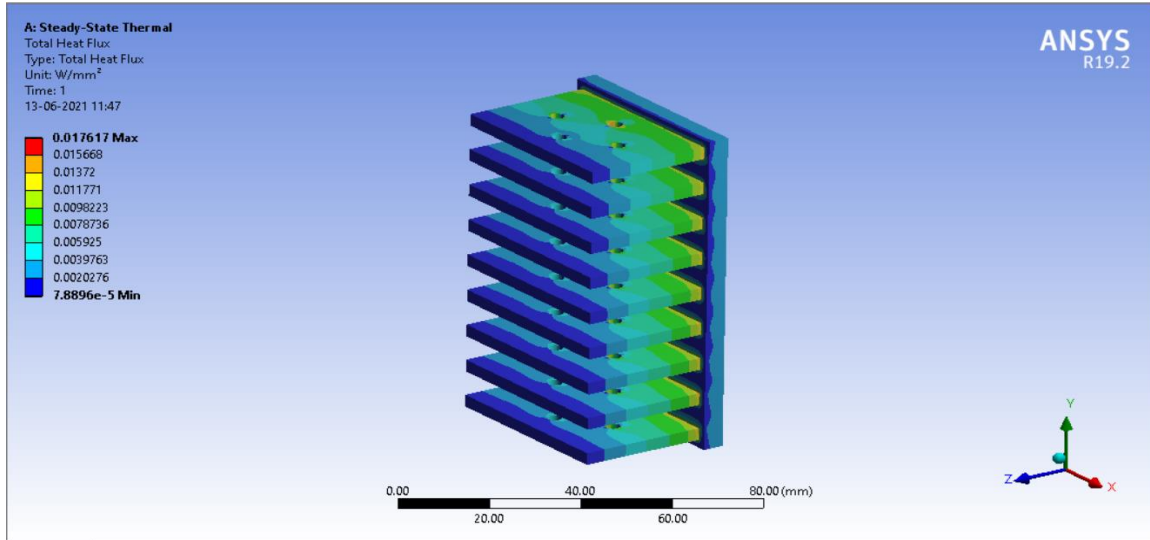
**c). Triple perforation:**



**Fig.5.2.1(c) Rectangular flat-plate fin with triple circular perforation**

The total heat flux distribution of orientation to X- axis is obtained with a maximum of 0.016811 W/mm<sup>2</sup> and minimum of 0.00013705 W/mm<sup>2</sup>. The simulated result is as shown in fig 5.2.1(c).

#### d). Four perforations:

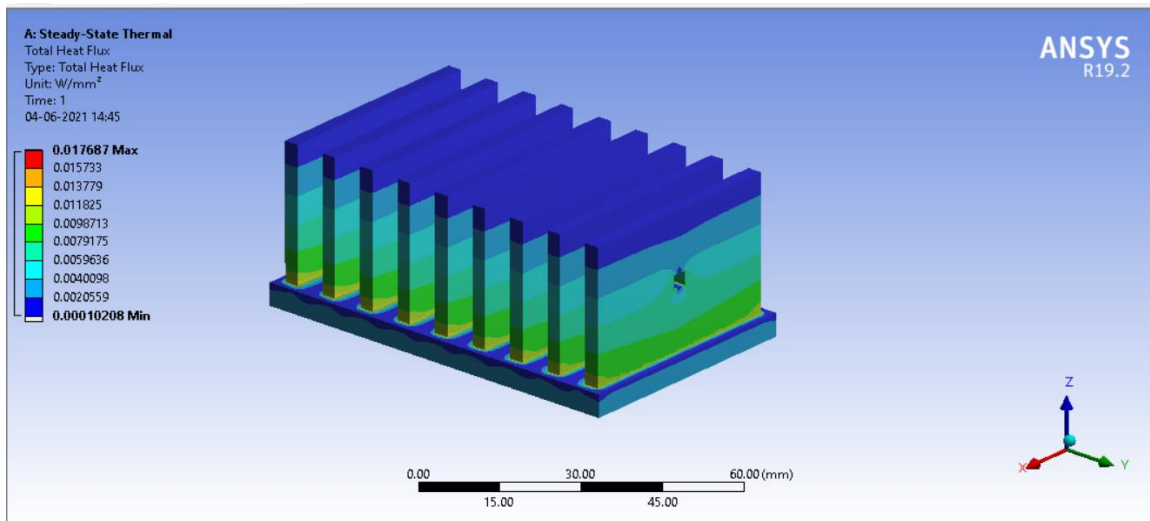


**Fig.5.2.1(d) Rectangular flat-plate fin with four circular perforations**

The total heat flux distribution of orientation to X- axis is obtained with a maximum of 0.017617 W/mm<sup>2</sup> and minimum of 0.000078896 W/mm<sup>2</sup>. The simulated result is as shown in fig 5.2.1(d).

#### 5.2.2 Rectangular flat plate fin with square perforations:

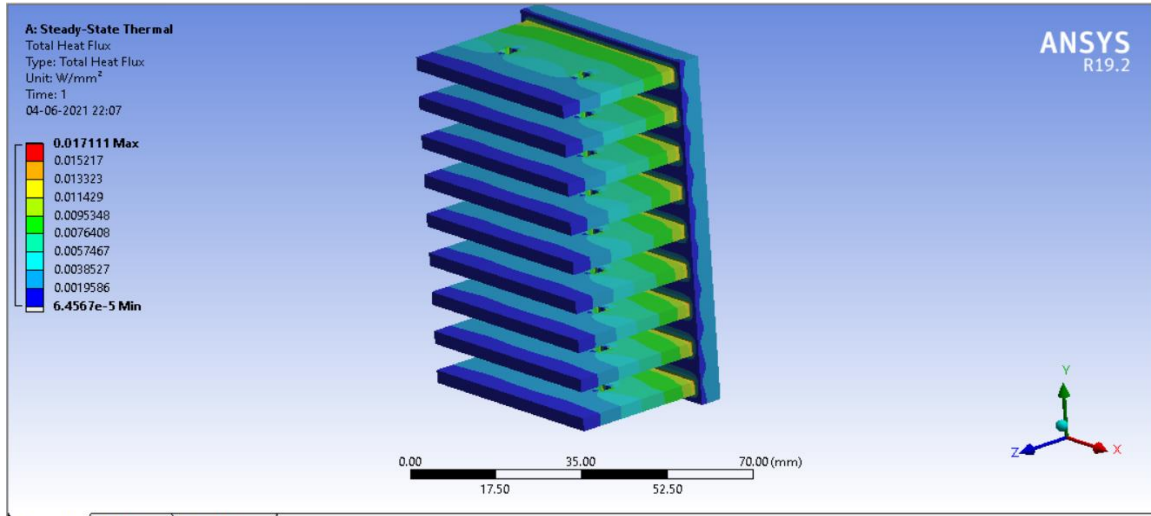
##### a). single perforation:



**Fig.5.2.2(a) Rectangular flat-plate fin with single square perforations**

The total heat flux distribution of orientation to X- axis is obtained with a maximum of 0.017687 W/mm<sup>2</sup> and minimum of 0.00010208 W/mm<sup>2</sup>. The simulated result is as shown in fig 5.2.2(a).

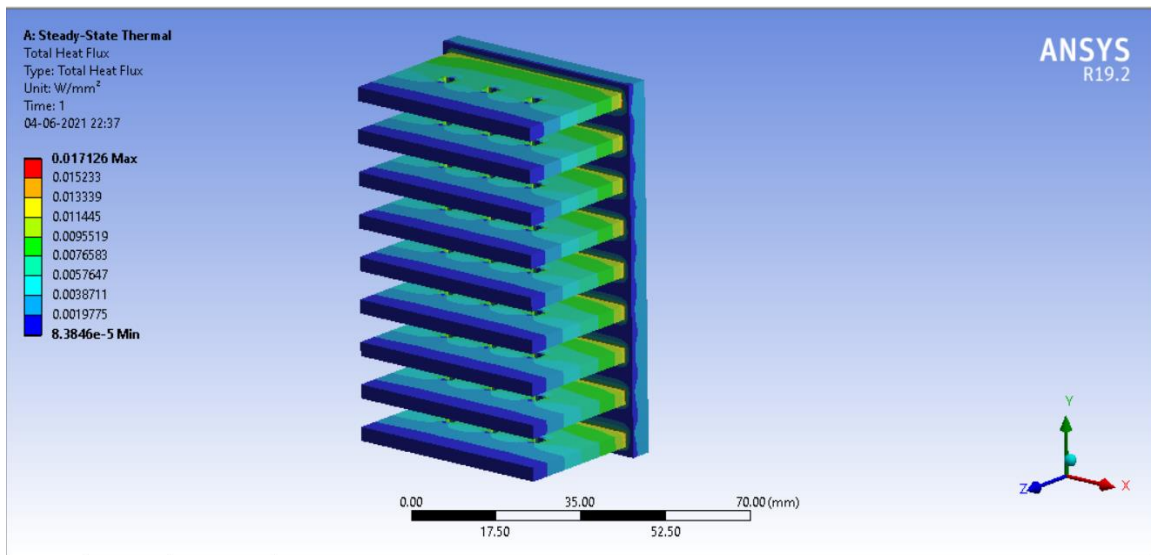
### b). Double perforation:



**Fig.5.2.2(b) Rectangular flat-plate fin with double square perforations**

The total heat flux distribution of orientation to X- axis is obtained with a maximum of  $0.017111 \text{ W/mm}^2$  and minimum of  $0.000064567 \text{ W/mm}^2$ . The simulated result is as shown in fig 5.2.2(b).

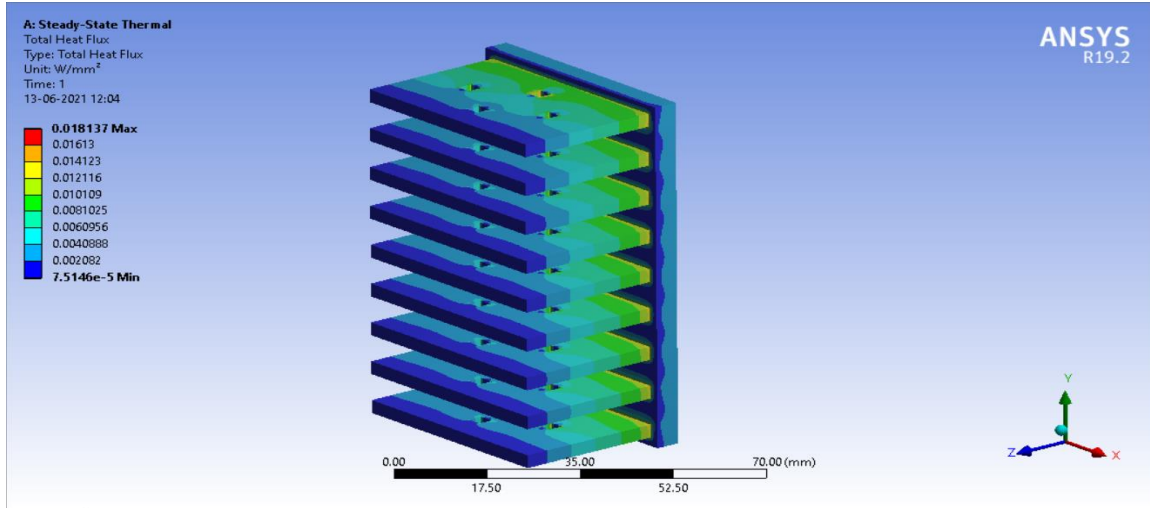
### c). Triple perforation:



**Fig.5.2.2(c) Rectangular flat-plate fin with triple square perforations**

The total heat flux distribution of orientation to X- axis is obtained with a maximum of  $0.017126 \text{ W/mm}^2$  and minimum of  $0.000083846 \text{ W/mm}^2$ . The simulated result is as shown in fig 5.2.2(c).

#### d). Four perforations:

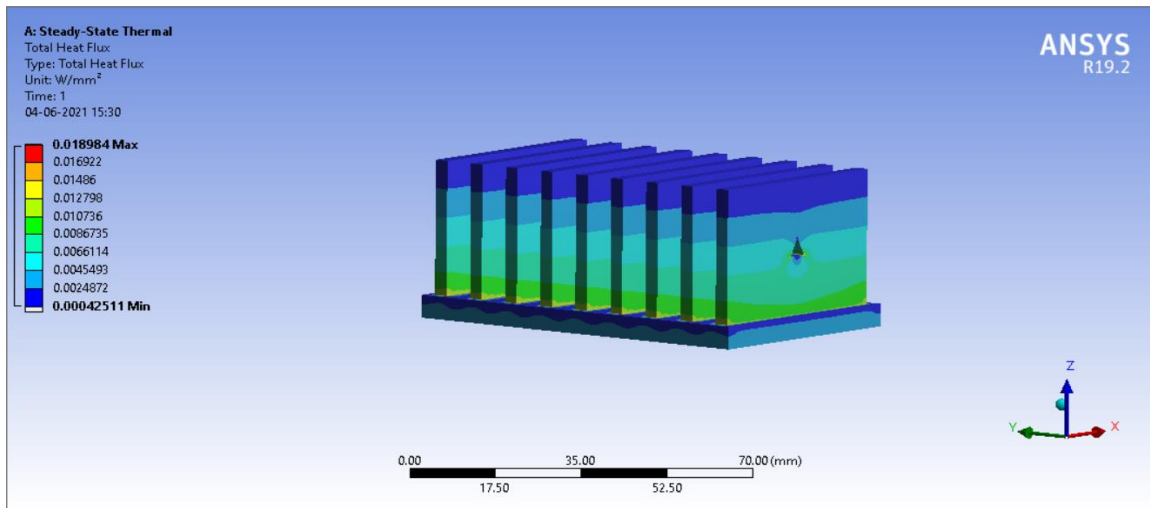


**Fig.5.2.2(d) Rectangular flat-plate fin with four square perforations**

The total heat flux distribution of orientation to X- axis is obtained with a maximum of 0.018137 W/mm<sup>2</sup> and minimum of 0.000075146 W/mm<sup>2</sup>. The simulated result is as shown in fig 5.2.2(d).

### 5.2.3 Rectangular flat plate fin with triangular perforations:

#### a). single perforation:

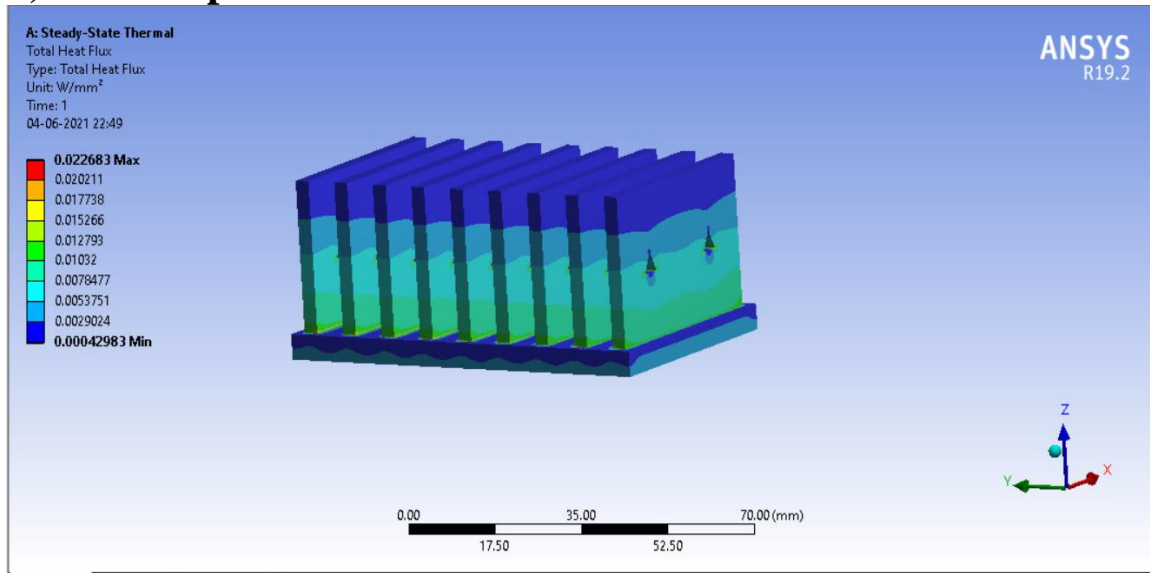


**Fig.5.2.3(a) Rectangular flat-plate fin with single triangular perforations**

The total heat flux distribution of orientation to X- axis is obtained with a maximum of 0.018984 W/mm<sup>2</sup> and minimum of 0.00042511 W/mm<sup>2</sup>. The simulated result is as shown in fig 5.2.3(a).



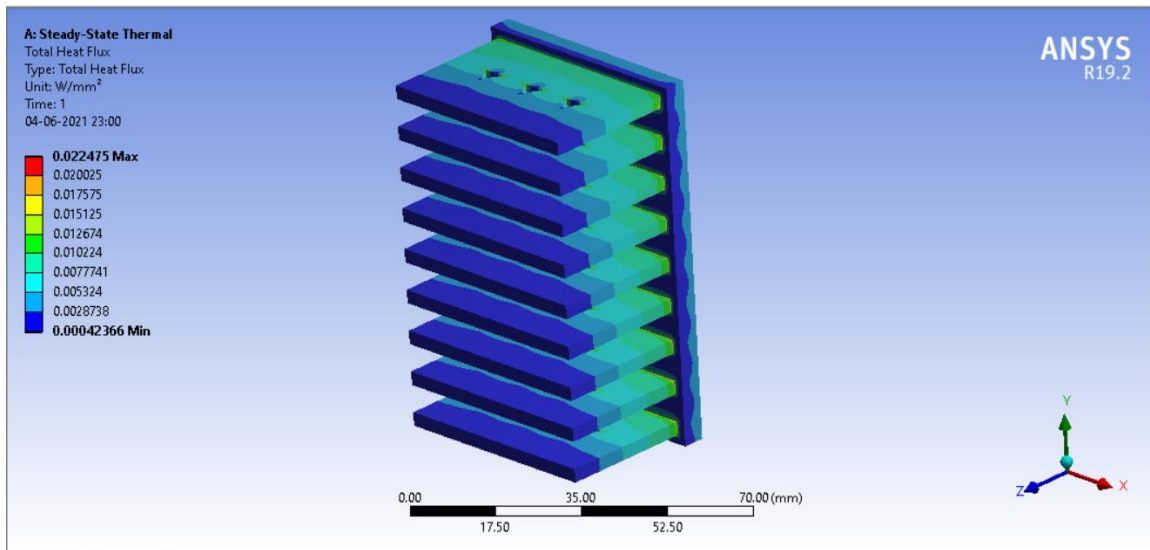
### b). Double perforation:



**Fig.5.2.3(b) Rectangular flat-plate fin with double triangular perforations**

The total heat flux distribution of orientation to X- axis is obtained with a maximum of 0.022683 W/mm<sup>2</sup> and minimum of 0.00042983 W/mm<sup>2</sup>. The simulated result is as shown in fig 5.2.3(b).

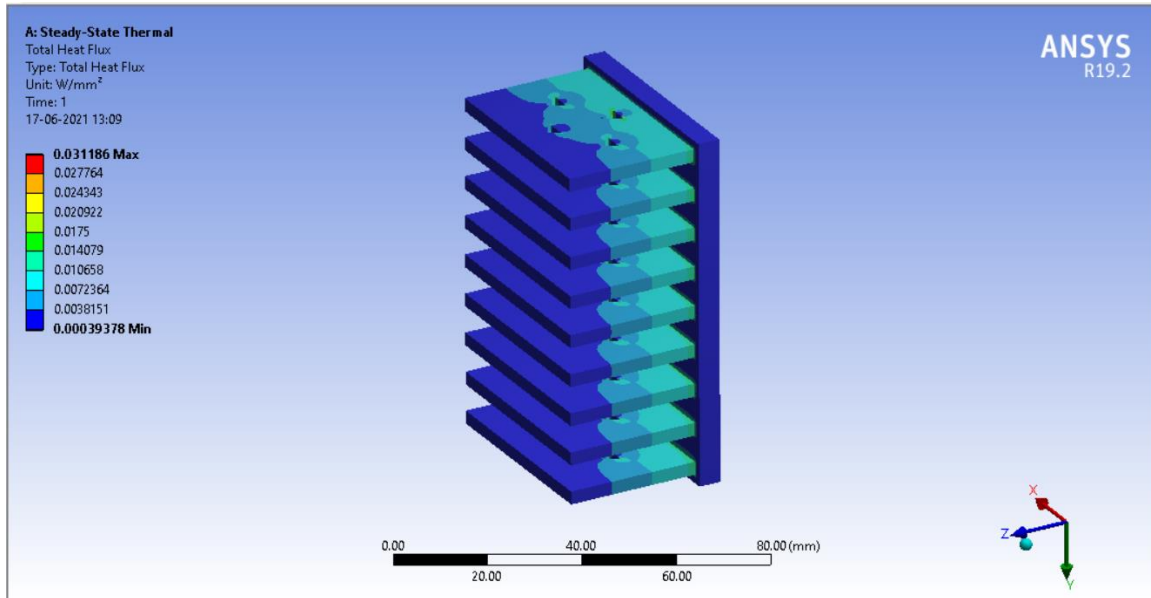
### c). Triple perforation:



**Fig.5.2.3(c) Rectangular flat-plate fin with triple triangular perforations**

The total heat flux distribution of orientation to X- axis is obtained with a maximum of 0.022475 W/mm<sup>2</sup> and minimum of 0.00042366 W/mm<sup>2</sup>. The simulated result is as shown in fig 5.2.3(c).

### d). Four perforations:



**Fig.5.2.3(d) Rectangular flat-plate fin with four triangular perforations**

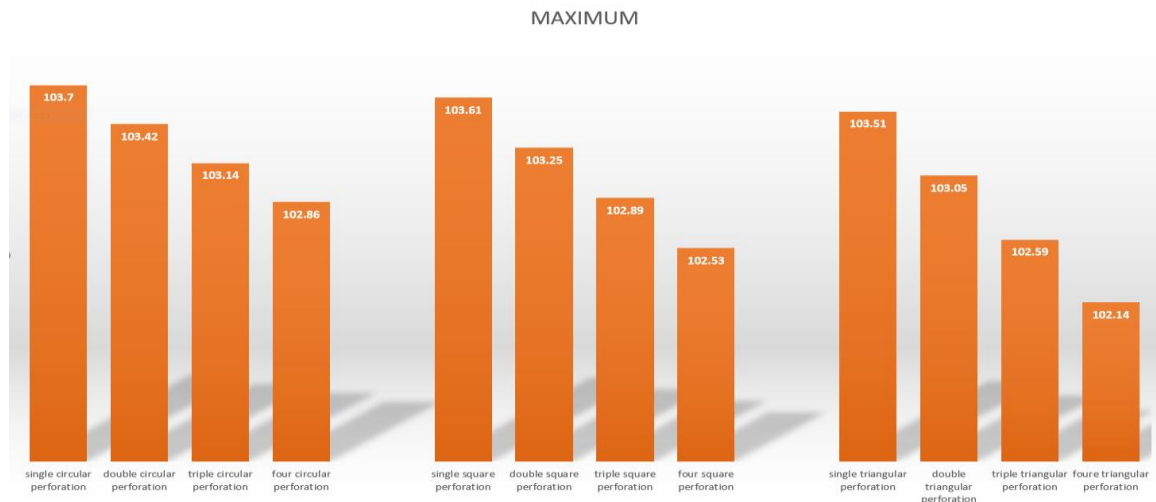
The total heat flux distribution of orientation to X- axis is obtained with a maximum of 0.031186 W/mm<sup>2</sup> and minimum of 0.00039378 W/mm<sup>2</sup>. The simulated result is as shown in fig 5.2.3(d).

### 5.3 Graphs :

	Temperature(C)		Heat Flux(W/mm <sup>2</sup> )	
	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM
single circular perforation	102.85	103.7	0.00010208	0.017687
double circular perforation	102.55	103.42	0.00018607	0.017487
triple circular perforation	102.27	103.14	0.00013705	0.016811
four circular perforation	101.99	102.86	0.000078896	0.017617
single square perforation	102.76	103.61	0.00010208	0.017687
double square perforation	102.39	103.25	0.000064567	0.017111
triple square perforation	102.02	102.89	0.000083846	0.017126
four square perforation	101.66	102.53	0.000075146	0.018137
single triangular perforation	102.66	103.51	0.00042511	0.018984
double triangular perforation	102.18	103.05	0.00042983	0.022683
triple triangular perforation	101.71	102.59	0.00042366	0.022475
four triangular perforation	101.25	102.14	0.00039378	0.031186

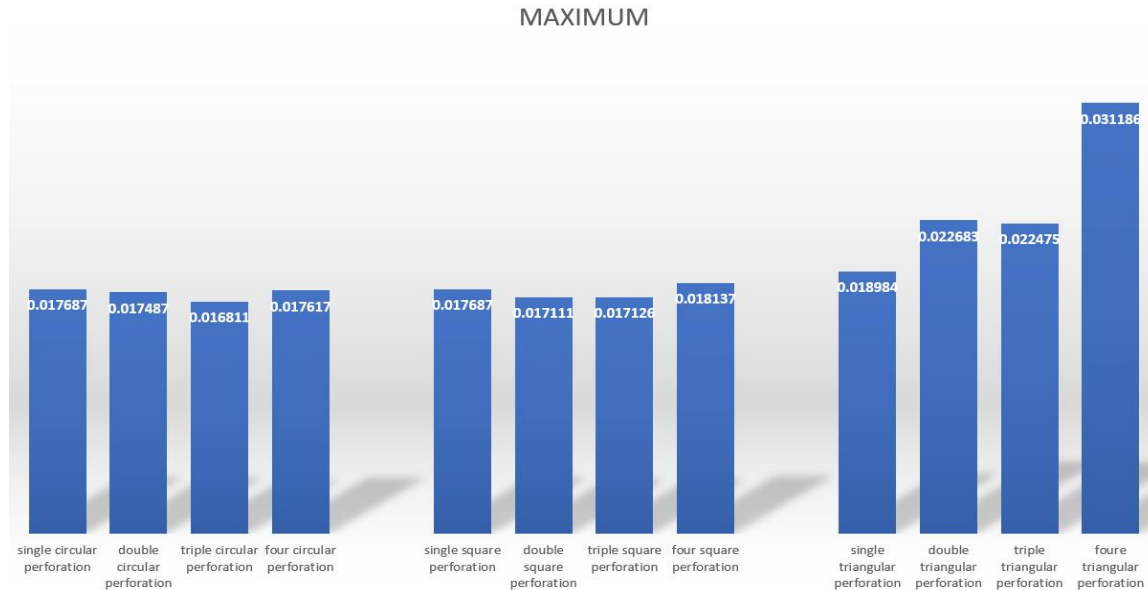
**Table 4: Results of steady. State thermal analysis**

A graph is plotted between the maximum temperature obtained on the surface of each heat sink (on x-axis) and the geometric configuration of fins(on y-axis)



**Fig 5.3.1 Variation of Temperature distribution for different Heat sink configurations**

Another graph is plotted between the maximum heat flux obtained in the surface of each heat sink (on X-axis) and the geometric configuration of fins (on Y-axis).



**Fig 5.3.2 Variation of Total Heat Flux for different Heat sink configurations**

The graphs obtained above show the superiority of rectangular plate fin with four triangular perforations in the process of natural convection. From the above graphs, it is clear that the amount of heat dissipated by the rectangular plate fin with four triangular perforations is the highest when compared to other fin geometrical configurations. This can be evidenced by the minimum possible heat flux and temperature compared to the fins of the other geometric configurations. The rectangular pin fin with four triangular perforations recorded the highest amount of heat flux indicating the highest heat transfer per unit area unit time and also the highest amount of heat dissipation among the considered geometric configurations.

From the results obtained by analysis, it has been found that for a particular chosen material of aluminum and a constant convective heat transfer coefficient, rectangular fin with triangular perforation gives highest heat transfer and as the number of perforations increase, the surface area exposed to air is more so the heat transfer is more. So, the rectangular pin fin with four triangular perforations give much heat transfer and the order is as shown below,

### **Rectangular Plate Fin with**

**Four triangular perforations > four square perforations > triple triangular perforation > four circular perforations > triple square perforation > double triangular perforations > triple circular perforations > double square perforations > double circular perforations > single triangular perforation > single square perforations > single circular perforation**

## CHAPTER 6

### CONCLUSIONS& FUTURE SCOPE

#### **6.1 Conclusions**

In this study, a steady state thermal analysis has been carried out on perforated heat sinks by varying the geometrical configuration of perforations to a rectangular flat-plate fins. The results are evaluated on the basis of temperature distribution and heat flux distribution which indicate the total heat dissipation from the entire surface under a fixed volume condition. The thermal performance of rectangular plate fin with circular, square and triangular perforations and increasing number of perforations as single, double, triple and four perforations were compared for the fixed base plate dimensions and fin height under fixed volume conditions.

According to the results obtained, we can conclude that the rectangular plate fin heat sinks with four triangular perforations show better thermal performance in the most practical regions, especially in the process of natural convection. Plate fin array with four triangular perforations usually has larger surface area compared to other considered fins (of different geometries of perforation). So therefore, the rectangular plate fin with four triangular perforations dissipates the most heat from the equipment in the case of total heat dissipation as in the present study (especially in the case of natural convection).

Therefore, it is recommended to use rectangular plate fin heat sinks with triangular perforations when the total heat dissipation for a given volume of heat sink is to be maximized under a fixed volume condition if the

perforation number is increased then the heat dissipation will be increased as the surface area in contact with surroundings keeps on increasing as the number of perforations increase.

## **6.2 Future scope**

In the present study, for the considered optimized dimensions of the heat sink, chosen material of aluminum and a derived constant convective heat transfer coefficient of  $6e-6 \text{ W/mm}^2 \text{ } ^\circ\text{C}$ , the rectangular plate fin with triangular perforation served the purpose of total heat dissipation, way better compared to fins of other considered geometric configurations. The future work of this study may include modifications of design parameters of fins, orientation of heat sink, change of material, etc. The considered modifications with respect to design and orientation can be optimized using various optimization techniques and finally a heat sink with desirable fin dimensions, material and properties can be obtained to yield better results (high heat dissipation) to enhance the life of expensive electronic components.

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