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## Natural Convective Heat Transfer for Inclined Narrow Plate

VANKAR DURGESH<sup>1</sup>, C. SUDHAKAR<sup>2</sup>

<sup>1</sup>PG Scholar, Dept of Mechanical Engineering, Siddhartha Institute of Engineering and Technology, Hyderabad, TS, India,  
E-mail: durgesh7563@gmail.com.

<sup>2</sup>Professor, Dept of Mechanical Engineering, Siddhartha Institute of Engineering and Technology, Hyderabad, TS, India,  
E-mail: saisudha343@gmail.com.

**Abstract:** This project mainly deals with the design, analysis and manufacture of inclined plate. The inclined plate is designed and analyzed, the manufacturing process has been studied with the help of solid works software, the component is meshed, analysis is done in ansys software, the thermal behavior is studied, and the results are tabulated. The various stresses acting on the cylinder head under various loading conditions have been studied. In the preset thesis, work has been taken up on the following aspects to cover the research gaps and to present the results based on the systematic studies:

- Temperature distribution and heat flow through the cylinder head of an engine.
- Fea analysis of the cylinder head to measure temperature at the points where it is not possible to find out practically and to observe the heat flow inside the cylinder head.

**Keywords:** Inclined Narrow Plate ; Solidworks; Ansys; Thermal Analysis.

### I. INTRODUCTION

Natural convection is a mechanism, or type of heat transport, in which the fluid motion is not generated by any external source (like a pump, fan, suction device, etc.) but only by density differences in the fluid occurring due to temperature gradients. In natural convection, fluid surrounding a heat source receives heat, becomes less dense and rises. The surrounding, cooler fluid then moves to replace it. This cooler fluid is then heated and the process continues, forming convection current; this process transfers heat energy from the bottom of the convection cell to top. The driving force for natural convection is buoyancy, a result of differences in fluid density. Because of this, the presence of a proper acceleration such as arises from resistance to gravity, or an equivalent force (arising from acceleration, centrifugal force or Coriolis Effect), is essential for natural convection. For example, natural convection essentially does not operate in free-fall (inertial) environments, such as that of the orbiting International Space Station, where other heat transfer mechanisms are required to prevent electronic components from overheating.

### A. Convection

Convection is the concerted, collective movement of groups or aggregates of molecules within fluids (e.g., liquids, gases) and rheids, through advection or through diffusion or as a combination of both of them. Convection of mass cannot take place in solids, since neither bulk current flows nor significant diffusion can take place in solids. Diffusion of heat can take place in solids, but that is called heat conduction. Convection can be demonstrated by placing a heat source (e.g. a Bunsen burner) at the side of a glass full of a liquid, and observing the changes in temperature in the glass caused by the warmer fluid moving into cooler areas. Convective heat transfer is one of the major types of heat transfer, and convection is also a major mode of mass transfer in fluids. Convective heat and mass transfer take place both by diffusion – the random Brownian motion of individual particles in the fluid – and by advection, in which matter or heat is transported by the larger-scale motion of currents in the fluid. In the context of heat and mass transfer, the term “convection” is used to refer to the sum of advective and diffusive transfer. In common use the term “convection” may refer loosely to heat transfer by convection, as opposed to mass transfer by convection, or the convection process in general.

Sometimes “convection” is even used to refer specifically to “free heat convection” (natural heat convection) as opposed to forced heat convection. However, in mechanics the correct use of the word is the general sense, and different types of convection should be qualified for clarity. Convection can be qualified in terms of being natural, forced, gravitational, granular, or thermo magnetic. It may also be said to be due to combustion, capillary action, or Marangoni and Weissenberg effects. Heat transfer by natural convection plays a role in the structure of Earth’s atmosphere, its oceans, and its mantle. Discrete convective cells in the atmosphere can be seen as clouds, with stronger convection resulting in thunderstorms. Natural convection also plays a role in stellar physics.

**Natural Convection:** In natural convection, the fluid motion occurs by natural means such as buoyancy. Since the fluid velocity associated with natural convection is relatively low,

the heat transfer coefficient encountered in natural convection is also low.

**Mechanisms of Natural Convection:** Consider a hot object exposed to cold air. The temperature of the outside of the object will drop (as a result of heat transfer with cold air), and the temperature of adjacent air to the object will rise. Consequently, the object is surrounded with a thin layer of warmer air and heat will be transferred from this layer to the outer layers of air. Natural convection heat transfer from a hot body is the temperature of the air adjacent to the hot object is higher, thus its density is lower. As a result, the heated air rises. This movement is called the natural.

- **Convection Current:** That in the absence of this movement, heat transfer would be by conduction only and its rate would be much lower. In a gravitational field, there is a net force that pushes a light fluid placed in a heavier fluid upwards. This force is called the buoyancy force. Buoyancy force keeps the ship float in water. The magnitude of the buoyancy force is the way to fluid displaced by the body.
- **Effect of Fin Length:** A vertical enclosure the dependence of the Nusselt number (Nu) on fin length (L/H) for different values of Rayleigh number (Ra) ranging from 104 to  $3 \times 10^5$  is shown in fig. 2. Nu is plotted against Ra for different values of L/H as a parameter. It can be clearly seen that at any Rayleigh number the effect of increasing L/H increases Nu. This increase in Nu with increasing L/H can be attributed to the increase of heat transfer surface area with increasing L/H. Possibility of formation of separate convection cell between two adjacent fins increases due to increase in L/H for a vertical enclosure and this leads in an enhancement of heat transfer rate.
- **Natural Convection over Surfaces:** Natural convection on a surface depends on the geometry of the surface as well as its orientation. It also depends on the variation of temperature on the surface and the thermo physical properties of the fluid. Note that the velocity at the edge of the boundary layer becomes zero. It is expected since the fluid beyond the boundary layer is stationary.

**Natural Convection Correlations:** The complexities of the fluid flow make it very difficult to obtain simple analytical relations for natural convection. Thus, most of the relationships in natural convection are based on experimental correlation. The Rayleigh number is defined as the product of the Grashof number and Prandtl number.

$$Ra = Gr Pr = \frac{g\beta(T_s - T_\infty)\delta^3}{\nu^2} Pr \quad (1)$$

Convection is as following

$$Nu = \frac{h\delta}{k} = CRa^n \quad (2)$$

**Natural Convective Heat Transfer from Two Adjacent Narrow Plates:** Numerical studies of the interaction of the natural convective flows over two adjacent vertical and inclined narrow isothermal flat plates in the laminar flow

region are discussed. Two cases are considered. In one case, the plates are horizontally adjacent to each other, the plates being horizontally separated while in the other case, one plate is symmetrically placed above the other plate the plates being vertically separated. Attention has been given to the effects of the inclination angle of the plates to the vertical, to the effects of the vertical or horizontal dimensionless gap between the heated plates, and to the effects of the dimensionless plate width on the mean heat transfer rates from the two heated plates for a wide range of Rayleigh numbers. It is shown that when there are two adjacent narrow flat plates with a relatively small gap between the plates the flow near the adjacent plates is altered compared to that over a single narrow plate and this can lead to a significant change in the mean heat transfer rate compared to that from a single isolated plate under the same conditions. Empirical equations for both the case of horizontally separated and vertically separated plates are given

## B. An Interaction of Natural Convective Heat Transfer from Two Adjacent Isothermal Narrow Vertical And Inclined Flat Plates

Natural convective heat transfer from a two narrow adjacent rectangular isothermal flat plates of the same size embedded in a plane adiabatic surface, the adiabatic surface being in the same plane as the surfaces of the heated plates, has been numerically investigated. The two plates have the same surface temperature and they are aligned with each other but are separated from each other by a relatively small gap. Results for the case where the plates are vertical and where they are inclined at positive or negative angles to the vertical have been obtained. It has been assumed that the fluid properties are constant except for the density change with temperature which gives rise to the buoyancy forces, this having been treated using the Boussinesq approach. It has also been assumed that the flow is symmetrical about the vertical center plane between the two plates. The solution has been obtained by numerically solving the full three-dimensional form of governing equations, these equations being written in dimensionless form. The solution was obtained using the commercial finite volume method based CFD code, FLUENT. The solution has the Rayleigh number, the dimensionless plate width, the angle of inclination, the dimensionless gap between two flat plates, and the Prandtl number as parameters. Results have only been obtained for a Prandtl number of 0.7. Results have been obtained for Rayleigh numbers between 103 and 107 for plate width-to-height ratios of between 0.15 and 0.6, for gap between the adjacent edges to plate height ratios of between 0 and 0.2, for angles of inclination between  $+45^\circ$  and  $-45^\circ$ .

## II. INTRODUCTION TO CAD AND SOLIDWORKS

### A. Introduction of Computer-Aided Design And Drafting

It also known as computer-aided design and drafting (CADD), is the use of computer technology for the process of design and design-documentation. Computer Aided Drafting describes the process of drafting with a computer. CADD software, or environments, provides the user with input-tools for the purpose of streamlining design processes;

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drafting, documentation, and manufacturing processes. CADD output is often in the form of electronic files for print or machining operations. The development of CADD-based software is in direct correlation with the processes it seeks to economize; industry-based software (construction, manufacturing, etc.) typically uses vector-based (linear) environments whereas graphic-based software utilizes raster-based environments. CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) objects.

### B. Introduction To Solidworks

Solid Works is a 3D solid modeling package which allows users to develop full solid models in a simulated environment for both design and analysis. In Solid Works; you sketch ideas and experiment with different designs to create 3D models. Solid Works is used by students, designers, engineers, and other professionals to produce simple and complex parts, assemblies, and drawings. Designing in a modeling package such as Solid Works is beneficial because it saves time, effort, and money that would otherwise be spent prototyping the design.

**Solid Works Components Parts:** Before we begin looking at the software, it is important to understand the different components that make up a Solid Works model.

#### Part:

- The first and most basic element of a Solid Works model is a Part.
- Parts consist of primitive geometry and feature such as extrudes, revolutions, lofts, sweeps, etc.
- Parts will be the building blocks for all of the models that you will create.

#### Assembly:

- The second component is the assembly. Assemblies are collections of parts which are assembled in a particular fashion using mates (constraints).
- Any complex model will usually consist of one, or many assemblies.

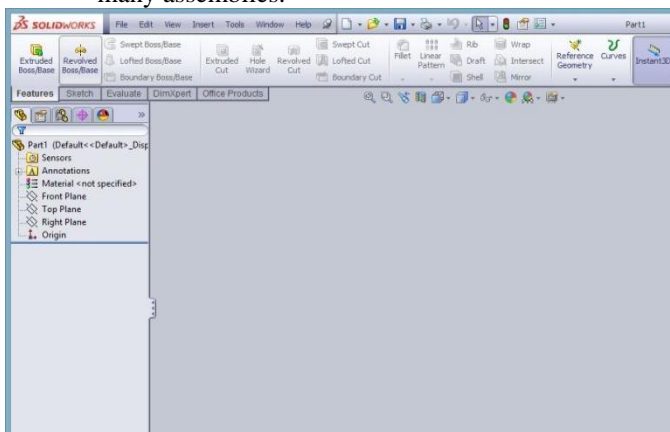


Fig.1.

**Drawing:** The third and final component in Solid Works is the Drawing.

- A drawing is the typical way to represent a 3D model such that any engineer (or manufacturer) can recreate your part.
- Drawings are important because they provide a standard way of sharing your design.

Let's begin by creating a new part. To do this, click on Part, then OK. Once you do this, you will be brought into the modeling view which should open several toolbars and panes.

### C. Terminology

These terms appear throughout the Solid Works software and documentation.

**Origin:** Appears as two blue arrows and represents the (0, 0, 0) coordinate of the model. When a sketch is active, a sketch origin appears in red and represents the (0, 0, 0) coordinate of the sketch. You can add dimensions and relations to a model origin, but not to a sketch origin.

**Plane:** Flat construction geometry. You can use planes for adding a 2D sketch, section view of a model, or a neutral plane in a draft feature, for example.

**Axis:** Straight line used to create model geometry, features, or patterns. You can create an axis in different ways, including intersecting two planes. The Solid Works application creates temporary axes implicitly for every conical or cylindrical face in a model.

**Face:** Boundaries that help define the shape of a model or a surface. A face is a selectable area (planar or non planar) of a model or surface. For example, a rectangular solid has six faces.

**Edge:** Location where two or more faces intersect and are joined together. You can select edges for sketching and dimensioning.

**Vertex:** Point at which two or more lines or edges intersect. You can select vertices for sketching and dimensioning.

**User Interface:** The Solid Works application includes user interface tools and capabilities to help you create and edit models efficiently, including:

**Windows Functions:** The Solid Works application includes familiar Windows functions, such as dragging and resizing windows. Many of the same icons, such as print, open, save, cut, and paste are also part of the Solid Works application.

**Solid Works Document Windows:** Solid Works document windows have two panels. The left panel, or Manager Pane, contains:

**Feature Manager /design tree:** Displays the structure of the part, assembly, or drawing. Select an item from the Feature Manager Design tree to edit the underlying sketch, edit the feature, and suppress and un suppress the feature or component, for example.

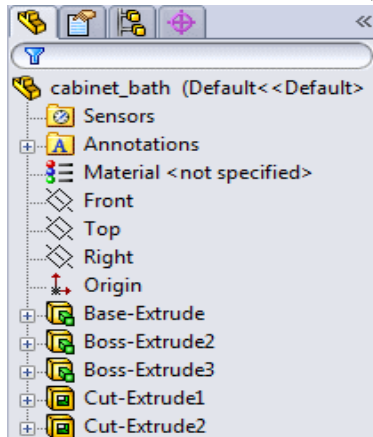


Fig.2.

**Property Manager:** Provides settings for many functions such as sketches, fillet features, and assembly mates.

**Configuration Manager:** Lets you create, select, and view multiple configurations of parts and assemblies in a document. Configurations are variations of a part or assembly within a single document. For example, you can use configurations of a bolt to specify different lengths and diameters.

**Mouse Buttons:** Mouse buttons operate in the following ways:

**Left:** Selects menu items, entities in the graphics area, and objects in the Feature Manager Design tree.

**Right:** Displays the context-sensitive shortcut menus.

**Middle:** Rotates, pans, and zooms a part or an assembly, and pans in a drawing.

**Mouse gestures:** You can use a mouse gesture as a shortcut to execute a command, similar to a keyboard shortcut. Once you learn command mappings, you can use mouse gestures to invoke mapped commands quickly. To activate a mouse gesture, from the graphics area, right-drag in the gesture direction that corresponds to the command. When you right-drag, a guide appears, showing the command mappings for the gesture directions.

**Extrude:** The application of this feature is to add or remove the material of a cross section in the normal direction.

**Revolve:** The application of this feature is to add or remove the material of a cross section in the counter clock direction with reference to an axis.

**Mirror:** This to create the object with same dimension and to maintain same distance from the reference. The reference which we will take in this operation is Axis, plane and surface.

**Datum:** This operation is used to create an offset plane with specified dimension.

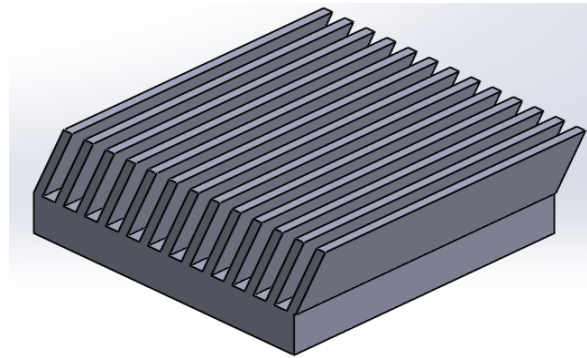


Fig.3.

### III. INCLINED FINS

#### A. Introduction To Fem And Ansys

**Introduction To Fem:** The finite element method represents an extension of the matrix methods for the analysis of framed structures to the analysis of the continuum structures. The basic philosophy of the method is to replace the structure of the continuum having an unlimited or infinite number of unknowns at certain chosen discrete points. The method is extremely powerful as it helps to accurately analyze structures with complex geometrical properties and loading conditions. In the infinite method, a structure or continuum is discretized and idealized by using a mathematical model which is an assembly of subdivisions or discrete elements, known as finite element, are assumed to be interconnected only at the joints called nodes. The equations, which are obtained using the above conditions, are in the form of force-displacement relationship. Finally, the force-displacement equations are solved to obtain displacements at the nodes, which are the basic unknowns in the finite element method. The basic idea in the finite element method is to find solution of a complicated problem by replacing it by simpler one. Since a simpler one in finding the solution replaced the actual problem, we will be able to find only an approximate solution rather than exact solution. In finite element method, it will often be possible to improve or refine the approximate solution by sending more computational effort. The original body or continuum is then considered as assemblage of these elements connected at a finite number of joints called nodes.

- Equilibrium or steady state or time independent problem,
- Eagan value problem,
- Transient or propagation programs.

**General Description of Fem:** The step-by-step procedure for static problem can be stated as follows:

- Discretization of continuum
- Selection of proper Interpolation model
- Derivative of element stiffness matrices and load vectors
- Assemblage of element equation to obtain the overall equilibrium equations:
- Solution of systems equations to find nodal values of the displacement:
  - Types of Elements
  - Number of Elements
  - Size of Elements

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- Convergence Requirements
- Nodal Degrees of Freedom

### Advantages of Fem:

- Its ability to use various size and shape and to model a structure of arbitrary geometry.
- Its ability to accommodate arbitrary boundary conditions, loading, including thermal loading.
- Its ability to model composite structures involving different structural components such as stiffening member on a shell and combination of plates, bars and solids, etc.,
- The finite element structure closely resembles the actual structure instead of being quite different obstruction that is hard to visualize.
- The FEM is proven successfully in representing various types of complicated material properties and material behavior (nonlinear, anisotropic, time dependent or temperature dependent material behavior).
- It readily account for non-homogeneity of the material by assigning different properties to different elements or even it is possible to vary the properties within an element according to a pre-determined polynomial pattern.

### IV. INTRODUCTION TO ANSYS SOFTWARE

The purpose of a finite element analysis is to model the behavior of a structure under a system of loads. In order to do so, all influencing factors must be considered and determined whether their effects are considerable or negligible on the final result. The ANSYS program is self-contained general purpose finite element program developed and maintained by Swanson Analysis Systems Inc. The program contains many routines, all interrelated and all for main purpose of achieving a solution to an engineering problem by finite element method. ANSYS provides a complete solution to design problems. It consists of powerful design capabilities like full parametric solid modeling, design optimization and auto meshing, which gives engineers full control over their analysis. The following are the special features of ANSYS software:

- It includes bilinear elements.
- Heat flow analysis, fluid flow and element flow analysis can be done.
- Graphic package and extensive preprocessing and post processing.

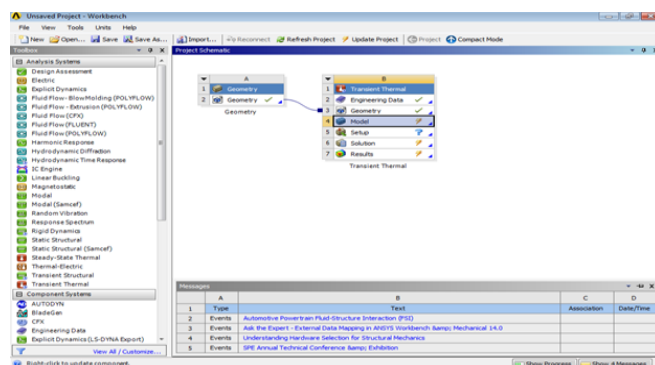


Fig.4.

**Meshing:** The default meshing controls that the program uses may produce a mesh that is adequate for the model we are analyzing. In this case, we need not specify any meshing controls. However if we do use meshing controls we must set them before meshing the solid model. Meshing controls allow us to establish the element shape, midsize node placement and element size to be used in meshing the solid model, this step is one of the most important of the entire analysis for the decisions we make at this stage in the model development will profoundly affect the accuracy and economy of the analysis. Smart element sizing (Smart sizing) is a meshing feature that creates initial element sizes for free meshing operations. Smart sizing gives the mesher a better chance of creating reasonably shaped elements during automatic mesh generation.

**Pre-Processor:** The pre-processor stage in ANSYS package involves the following:

- Specify the title, which is the name of the problem.
- Set the type of the analysis to be used, i.e., structural, thermal, fluid, or electro-magnetic, etc.,
- The model may be created in pre-processor or it can be imported from another CAD drafting package through a neutral file format like IGES, STEP
- Apply mesh – Mesh generation is the process of dividing the analysis continuum in to number of discrete parts or finite elements. The finer the mesh, the better the result, but the longer the analysis time. Therefore, the compromise between accuracy and solution speed is usually made.
- Assign the properties – Material properties (Young's Modulus, Poisson's ratio, density, and if applicable coefficient of expansion, friction, thermal conductivity, damping effect, specific heat, etc.,) have to be defined.

### Solution:

- Apply the loads. Some type of load is actually applied to the analysis model. The loading may be in the form of a point load, pressure or a displacement in a stress analysis, a temperature or heat flux in a thermal analysis and a fluid pressure or velocity in a fluid analysis.
- Applying the boundary conditions. After applying load to the model in order to stop it accelerating infinitely through the computer virtually either at least one boundary condition must be applied
- FE solver can be logically divided in to three main parts, the pre-solver, the mathematical-engine and the post-solver. The pre-solver reads the model created by the pre-processor and formulates the mathematical representation of the model and calls the mathematical-engine, which calculates the results. The result returned to the solver and the post-solver is used to calculate the strains, stresses, etc., for each node within the component or continuum.

**V. PROCESS OF ANALYSIS**

Importing of the cylindrical head will be done after opening the workbench. For the supporting purpose of the geometry, the file format of solid works will be changed to step format. This is to match up the graphical properties of the solid works v5 to ansys workbench. The full form of the step is standard for the exchange of product model data which itself states that will exchange the graphical properties of models. The material properties are the important factor which will be considered as the second preference after importing or creating the geometry. The procedure of material application, double click on the engineering data which will appear on the top of the analysis system. The analysis system which we are using in this project is transient thermal analysis. After opening the window of engineering data the material application will be done by selecting the add symbol in the general materials. These materials are available in thermal materials from engineering data source and select the above mentioned material, and reset layout from view menu and update project.

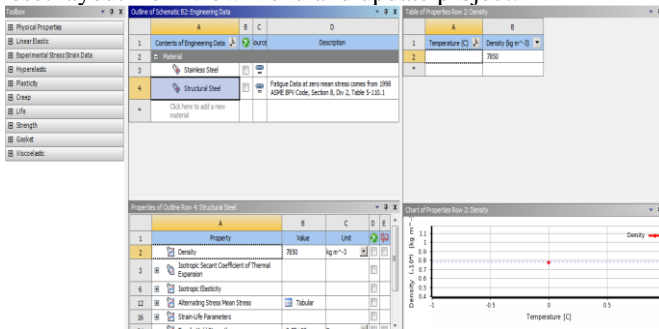


Fig.5.

**A. Steady State Thermal Analysis**

**Work Bench:** After importing the model into project schematic window drag and drop the steady state thermal tab on to the screen from the toolbox window and link the geometry to geometry both will be linked together. Double click on the model it opens the mechanical window with object.



Fig.6.

**Modal Tree:**

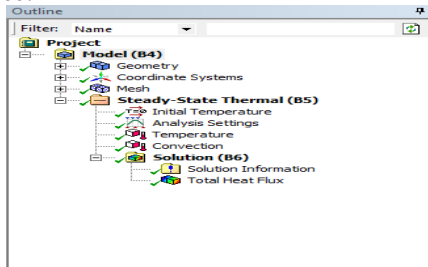


Fig.7.

**Geometry And Meshing:**

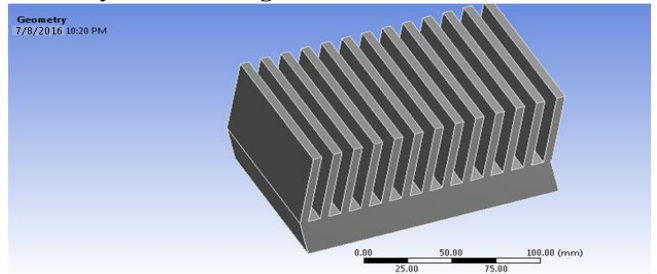


Fig.8.

From the outline tab – select the geometry – Part – from the bottom detailed window- material –Assignment – Select required material.

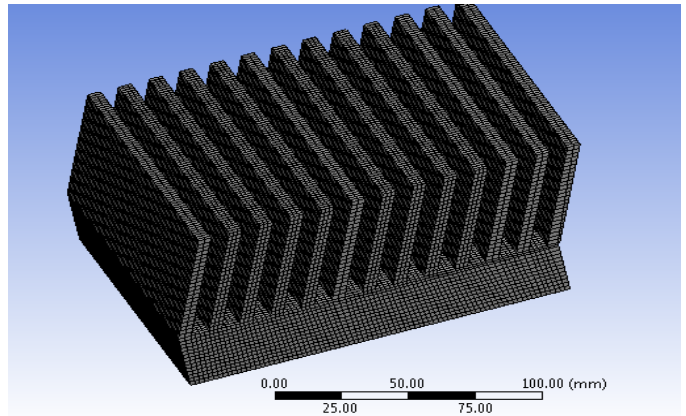


Fig.9.

**Mesh:** To generate the meshing, there are two methods one is automatic mesh generation and the other is with required size meshing. In this we used auto meshing with medium meshing.

**Temperature And Convection:**

Set the initial temperature as 30 °C , Right click on Analysis settings – Insert – convection – Enter the film coefficient as 22 °C & 30 W/mm<sup>2</sup> °C.

Right click on Analysis settings – Insert – Temperature – enter 300 °C and select the bottom

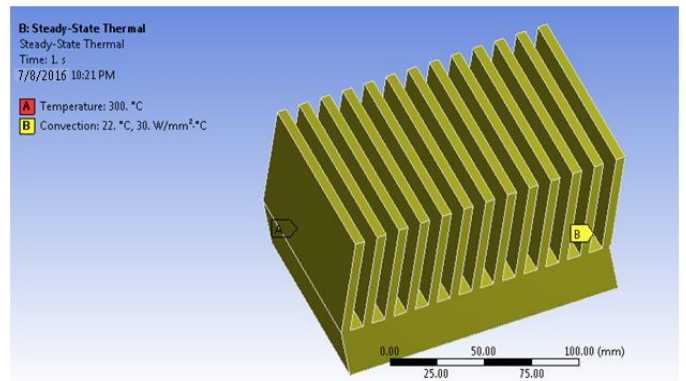
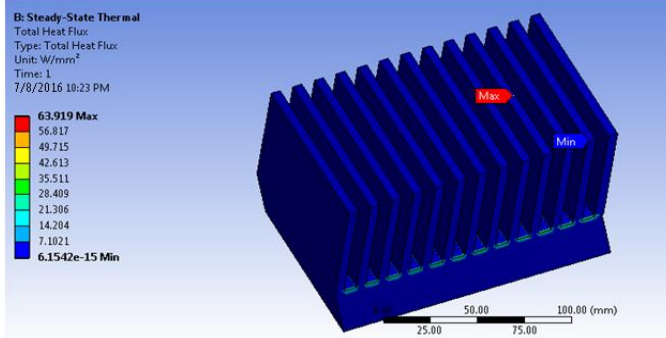


Fig.10.

## Natural Convective Heat Transfoerm for Inclined Narrow Plate

**Solution:**

**Right Click on solution – Insert Total Heat Flux:**



**Fig.11.**

### VI. RESULTS

**TABLE I: Aluminum Alloy> Isotropic Resistivity**

Resistivity ohm mm	Temperature C
2.43e-005	0
2.67e-005	20
3.63e-005	100

**TABLE II: Aluminum Alloy> Isotropic Elasticity**

Temperature C	Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
	71000	0.33	69608	26692

**TABLE III: Aluminum Alloy> Isotropic Permeability**

Relative Permeability
1

#### A. Steady – State Thermal Analysis

The loads are like;

- Convection is maintained at 22°C
- Temperature is varied for different conditions as 300°C, 600°C, 900°C, &1200°C
- And the corresponding

**TABLE IV: Thermal Heat Flux Is Tabulated In Below Table**

S.NO	TEMP In °C	THF In W/mm2
1	300	63.919
2	600	132.9
3	900	201.81
4	1200	270.85

### VII. CONCLUSION

By using solid works the modeling of the parts of the inclined plate's engine were completed successfully. And the component converted into IGES (integrations graphical element system). And analysis was done on master rod of modal analysis and static structural analysis was completed and behavior of the master was examined from these analysis and the natural frequencies, equivalent stress and total deformation were calculated as shown in results page. Thermal analysis was completed and total heat flux and directional heat flux were calculated by using ansys 14.0 work bench.

### VIII. ACKNOWLEDGMENT (HEADING 5)

The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g.” Avoid the stilted expression “one of us (R. B. G.) Thanks ...”. Instead, try “R. B. G. thanks...”. Put sponsor acknowledgments in the unnumbered footnote on the first page.

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