

COMPUTATIONAL ANALYSIS FOR HEAT TRANSFER THROUGH FINS WITH DIFFERENT TYPES OF NOTCHES (CFD)

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Abstract:- The fins are generally used to increase the heat transfer rate from the system to the surroundings by increasing the heat transfer area. The fins are generally extended surfaces or projections of materials on the system. The fins are commonly used on small power developing machine as engines used for motorcycles as well as small capacity compressors. They are also used in many refrigeration systems (evaporators and condensers) for increasing the heat transfer rates. In the present analysis, the fins that are of different cross sections and of same material (aluminium) are considered. The knowledge of efficiency and effectiveness of the fin are necessary for proper design of fins. The main objective of our analysis is to determine the most effective cross section among the various cross sections available. The efficiency and effectiveness of various cross sections are determined experimentally by cross sectional area and volume as constant for each cross section and the analysis using with ANSYS software.

Samples tested:- Rectangular, v-shape, rectangular with holes

1. INTRODUCTION TO HEAT EXCHANGERS

Heat exchangers are widely used in various, transportation, industrial, or domestic applications such as thermal power plants, means of heating, transporting and air conditioning systems, electronic equipment and space vehicles. In all these applications improvement in the efficiency of the heat exchangers can lead to substantial cost, space and material savings. Hence considerable research work has been done in the past to seek effective ways to improve the efficiency of heat exchangers. The referred investigation includes the selection of fluid with high effective heat transfer surfaces made out of high conductivity materials, high thermal conductivity and selection of their flow arrangements

2. PRELIMINARY CONSIDERATIONS ON HEAT TRANSFER AND ENHANCEMENT TECHNIQUES.

2.1 BASIC HEAT TRANSFER

2.1.1 HEAT TRANSFER AND THERMODYNAMICS

The study of transfer phenomenon which includes transfer of momentum, energy, mass etc has been recognized as a unified discipline of fundamental importance on the basis of thermodynamic fluxes and forces. The transfer of such phenomena occurs due to a conjugate force of temperature gradient, velocity gradient, concentration gradient chemical

affinity etc. The transfer of heat energy due to temperature difference or gradient is called heat transfer.

2.1.2 MODES OF HEAT TRANSFER

The modes of heat transfer can be divided into three segments.

- CONDUCTION
- RADIATION
- CONVECTION

2.1.2.1 CONDUCTION

Conduction refers to the transfer of heat between two bodies or two parts of the same body through molecules which are, more or less, stationary, as in the case of solids. The governing equation for conductive heat transfer is:

In Cartesian coordinates

$$\Delta f = \frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} + \frac{\partial^2 f}{\partial z^2} = 0.$$

In cylindrical coordinates,

$$\Delta f = \frac{1}{r} \frac{\partial}{\partial r} \left(r \frac{\partial f}{\partial r} \right) + \frac{1}{r^2} \frac{\partial^2 f}{\partial \phi^2} + \frac{\partial^2 f}{\partial z^2} = 0$$

In spherical coordinates,

$$\Delta f = \frac{1}{\rho^2} \frac{\partial}{\partial \rho} \left(\rho^2 \frac{\partial f}{\partial \rho} \right) + \frac{1}{\rho^2 \sin \theta} \frac{\partial}{\partial \theta} \left(\sin \theta \frac{\partial f}{\partial \theta} \right) + \frac{1}{\rho^2 \sin^2 \theta} \frac{\partial^2 f}{\partial \phi^2} = 0.$$

2.1.2.2 RADIATION

Thermal radiation refers to the radiant energy emitted by bodies by virtue of their own temperatures, resulting from the thermal excitation of the molecules. Radiation is assumed to propagate in the form of electromagnetic waves.

The governing equation for Radiation heat transfer is:

PLANK'S LAW

$$B_{\nu}(T) = \frac{2h\nu^3}{c^2} \frac{1}{e^{\frac{h\nu}{k_B T}} - 1}, \quad B_{\lambda}(T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda k_B T}} - 1}$$

2.1.2.3: CONVECTION

When energy transfer takes place between a solid and fluid system in motion, the process is known as convection. If the fluid motion is impressed by compressor or pump, it is called FORCED CONVECTION. If fluid motion is caused due to density difference, it is called NATURAL CONVECTION.

2.3.4 GRASHOF'S NUMBER (Gr):

The Grashof number is a dimensionless number in fluid dynamics and heat transfer which approximates the ratio of the buoyancy to viscous force acting on a fluid. It frequently arises in the study of situations involving natural convection.

$$\begin{aligned} Gr_L &= \frac{g\beta(T_s - T_{\infty})L^3}{\nu^2} \text{ for vertical flat plates} \\ Gr_D &= \frac{g\beta(T_s - T_{\infty})D^3}{\nu^2} \text{ for pipes} \\ Gr_D &= \frac{g\beta(T_s - T_{\infty})D^3}{\nu^2} \text{ for bluff bodies} \end{aligned}$$

2.3.5 RAYLEIGH'S NUMBER (Ra)

Is defined as the product of the Grashof number, which describes the relationship between buoyancy and viscosity within a fluid, and the Prandtl number, which describes the relationship between momentum diffusivity and thermal diffusivity. Hence the Rayleigh number itself may also be viewed as the ratio of buoyancy and viscosity forces times the ratio of momentum and thermal diffusivities.

$$Ra_x = Gr_x Pr = \frac{g\beta}{\nu\alpha}(T_s - T_{\infty})x^3$$

2.4 HEAT TRANSFER BY EXTENDED SURFACE

Convection heat transfer is governed by the relation: $Q = hA(T_w - T_{\infty})$

To increase the heat transfer rate the following ways can be adopted.

1. Increasing heat transfer coefficient (h). However increasing the value of h does not significantly influence the value of Q.
2. Surrounding fluid temperature (T_{∞}) can be decreased. But it is often impractical as in most cases the surrounding is atmosphere.
3. Hence the only way is by increasing the surface area across which convection occurs.

2.2 Thermoplastics

3. STUDY ON FINS

The purpose of fins is to improve heat dissipation from a surface to surroundings. Fins are widely used in engineering heat transfer equipments. Electrical apparatus like transformers and motors in which the generated heat should be efficiently transferred, are provided with fins on the outside surface. Similarly fins are provided on the cylinders of air cooled LC. Engines (like that of a motor cycle) and on a large variety of heat exchanger

The increase in cross sectional convection area can be achieved by using fins that extend from the wall of the convection shell. The thermal conductivity of the fin material has a very strong effect on the temperature distribution across the wall of the convection shell and thus the degree to which the heat transfer rate is enhanced.

Various types of fins are usually used:

- Straight fins of uniform cross section
- Straight fins of non-uniform cross section
- Annular fins
- Cylindrical fins
- Pin fins

3.1 TYPES OF FINS

The fins are designed and manufactured in many shapes and forms. These are mainly of following types.

(i) Straight fin: It is an extended surface attached to a plane wall. It may be of uniform cross sectional area, or its cross sectional area may vary along its length to form a triangular, parabolic or trapezoidal shape.

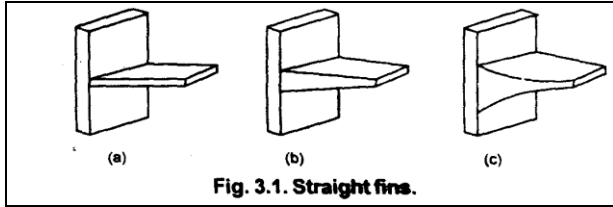


Fig. 3.1. Straight fins.

(ii) Annular fin: This is a fin circumferentially attached to a cylinder and its cross section varies with radius from centre line of cylinder.

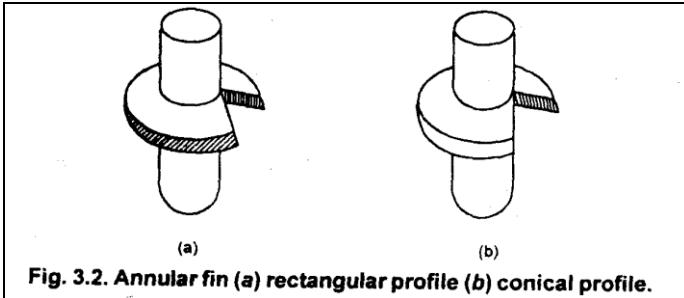


Fig. 3.2. Annular fin (a) rectangular profile (b) conical profile.

(iii) Pin Fin or spine: These fins are of circular cross section whose diameter is much smaller than its length. The pin fins may also be of uniform or non-uniform cross section.

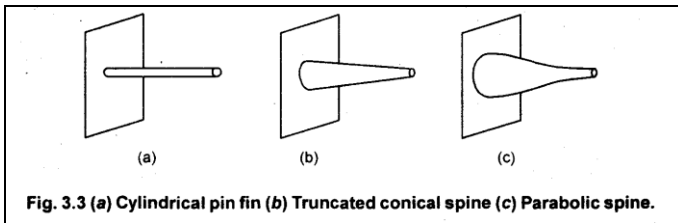


Fig. 3.3 (a) Cylindrical pin fin (b) Truncated conical spine (c) Parabolic spine.

3.2 FIN PERFORMANCE

Fin performance can be described in three different ways. The first is fin effectiveness. It is the ratio of the fin heat transfer rate to the heat transfer rate of the object if it had no fin. The formula for this is

$$\epsilon_f = \frac{q_f}{hA_{c,b}\theta_b}$$

where $A_{c,b}$ is the fin cross-sectional area at the base. Fin performance can also be characterized by fin efficiency. This is the ratio of the fin heat transfer rate to the heat transfer rate of the fin if the entire fin were at the base temperature.

$$\eta_f = \frac{q_f}{hA_f\theta_b}$$

The fin efficiency is defined as

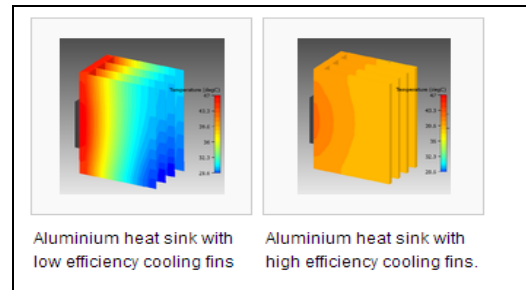
A_f in this equation is equal to the surface area of the fin. Fin efficiency will always be less than one. This is because

assuming the temperature throughout the fin is at the base temperature would increase the heat transfer rate.

The third way fin performance can be described is with overall surface efficiency.

$$\eta_o = \frac{q_t}{hA_t\theta_b}$$

Where A_t is the total area and q_t is the sum of the heat transfer rates of all the fins. This is the efficiency for an array of fins.



Aluminium heat sink with low efficiency cooling fins

Aluminium heat sink with high efficiency cooling fins.

3.3 FIN EFFICIENCY

This is the ratio of the fin heat transfer rate to the heat transfer rate of the fin if the entire fin were at the base temperature.

$$\eta_f = \frac{q_f}{hA_f\theta_b}$$

3.4 FIN USES

Fins are most commonly used in heat exchanging devices such as radiators in cars and heat exchangers in power plants. They are also used in newer technology such as hydrogen fuel cells. Nature has also taken advantage of the phenomena of fins. The ears of jackrabbits and Fennec Foxes act as fins to release heat from the blood that flows through them.

4. MATERIAL USED-ALUMINIUM

Aluminium > Constants

Density	3900 kg m ⁻³
Thermal Conductivity	25 W m ⁻¹ C ⁻¹
Specific Heat	3684.4 J kg ⁻¹ C ⁻¹

Aluminium > Isotropic Elasticity

Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
3.4e+011	0.22	2.0238e+011	1.3934e+011

5. FINITE ELEMENT METHOD

The Finite Element Method (FEM) is a reliable numerical technique for analyzing engineering designs. FEM replaces a complex problem with many simple problems. It divides the model into many small pieces of simple shapes called elements.

Elements share common points called nodes. The behavior of these elements is well-known under all possible support and load scenarios. The motion of each node is fully described by translations in the X, Y, and Z directions. These are called degrees of freedom (DOFs). Analysis using FEM is called Finite Element Analysis (FEA).

5.1 STEPS IN FEA

- ❖ *Definitions of the problem and its domain.*
- ❖ *Discretisation of the domain the continuum.*
- ❖ *Identification of state variable.*
- ❖ *Formulation of the problem.*
- ❖ *Establishing coordinate system.*

5.2 USES OF FEA

- **Structural analysis**
- **Heat transfer analysis**
- **Fluid flow analysis**
- **Mass transport**

6. ANALYSIS USING ANSYS

The following figure shows the imported model of the Fins model.

6.1CFD

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions.

With high-speed supercomputers, better solutions can be achieved. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Initial experimental validation of such software is performed using a wind tunnel with the final validation coming in full-scale testing, e.g. flight tests.

6.2 METHODOLOGY

In all of these approaches the same basic procedure is followed during preprocessing. The geometry (physical bounds) of the problem is defined. The volume occupied by the fluid is divided into discrete cells (the mesh). The mesh may be uniform or non-uniform. The physical modeling is defined – for example, the equations of motion enthalpy + radiation + species conservation. Boundary conditions are defined. This involves specifying the fluid behavior and properties at the boundaries of the problem. For transient problems, the initial conditions are also defined.

The simulation is started and the equations are solved iteratively as a steady-state or transient.

finally a postprocessor is used for the analysis and visualization of the resulting solution

6.3 THE BENEFITS OF CFD:

There are three reasons to use CFD software: insight, foresight, and efficiency.

6.3.1 INSIGHT

Think of an object which is difficult to produce practically and do some experiment on it. CFD provides the break through. Using the CFD software, one can easily design the object and use the boundary conditions to get output. The simulation thus helps in getting results much easily than constructing the real object.

6.3.2 FORESIGHT

In CFD first we make the model then use certain boundary conditions to get the output. Thus using CFD we can give some real world condition say as pressure or temperature and simulate things to get the output. Many variations can be adopted till an optimal result is reached. All of this can be done before physical prototyping and testing.

6.3.3 EFFICIENCY

The analysis gives better idea of, how the object works. So necessary changes could be brought about to facilitate better production of the product. Thus CFD helps to design better and faster bringing about improvement in each step.

6.3.4. CFD SIMULATION

In this work FLUENT software is used for simulation. Main focus of this work is on heat transfer

Analysis of a duct for different types of Pin Fins. In CFD simulation selection of turbulence model is an important issue. Although in most of the research papers STD k For building simulation but k_ SST show better results.

6.3.5 Boundary Conditions for Domain

After mesh generation boundary conditions are defined for CFD domain.

Materials

air

Density- bousinqness= 1.1768

Cp - 1005

K - .0262

V -1.8249e-05

1/k - .0033

Fin is Aluminum alloy used

Material: aluminum (solid)

Property	Units	Method	Value(s)
Density	kg/m ³	constant	2719
Cp (Specific Heat)	j/kg-k	constant	871
Thermal Conductivity	w/m-k	constant	202.39999

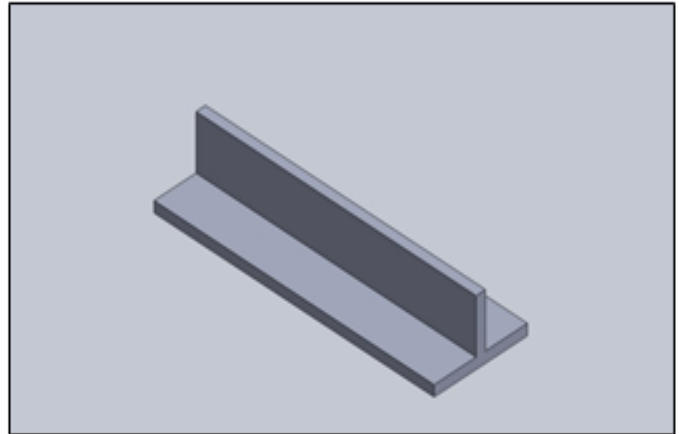
Inlet Velocity of Air is 0.1 m/s

Inlet Air Temperature 300k

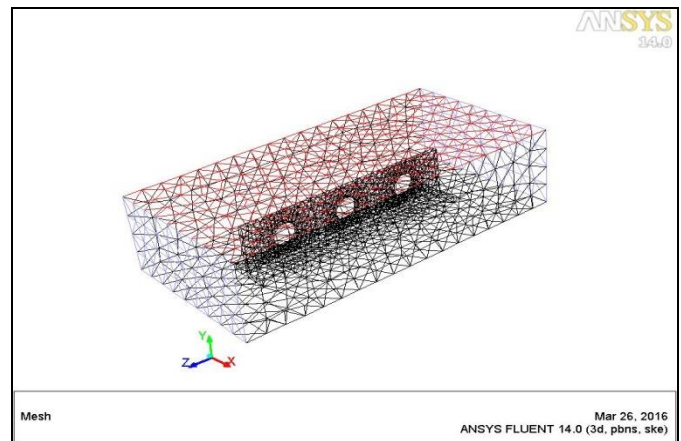
Operating condition 1atm

6.4 FINS WITHOUT HOLES

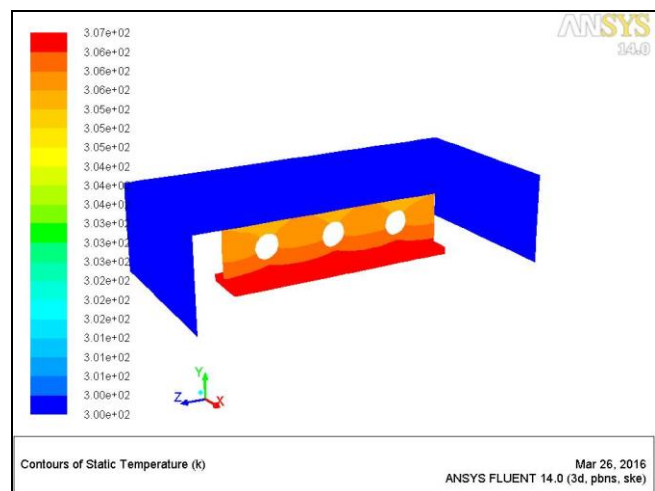
MODEL



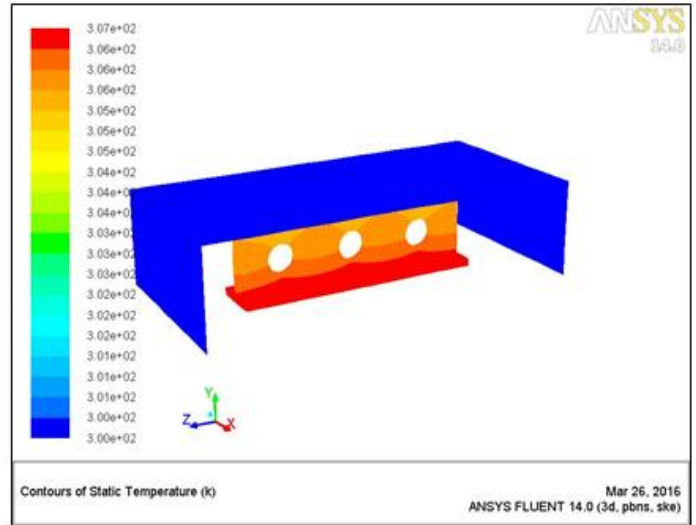
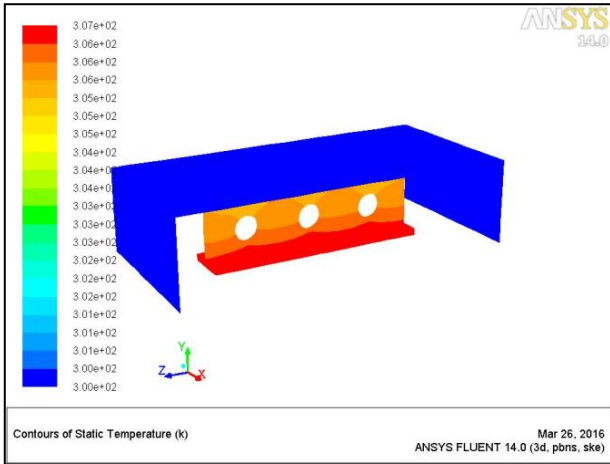
MESH



VELOCITY PLOT

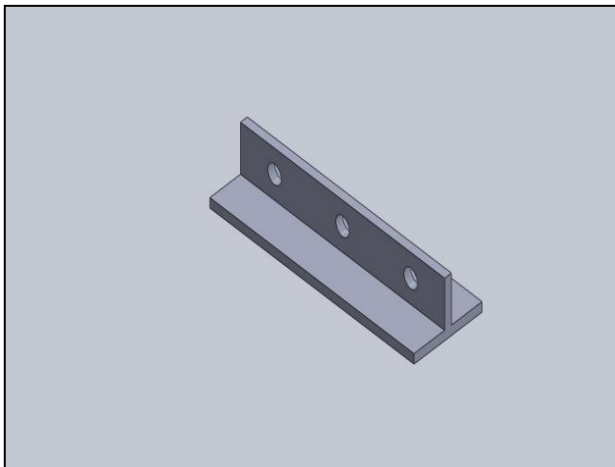


TEMPERATURE CONTOUR RESULTS

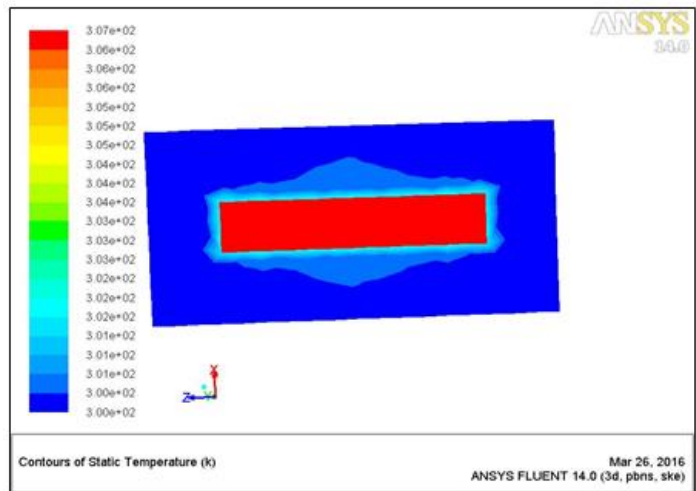


6.5 FINS WITH HOLES

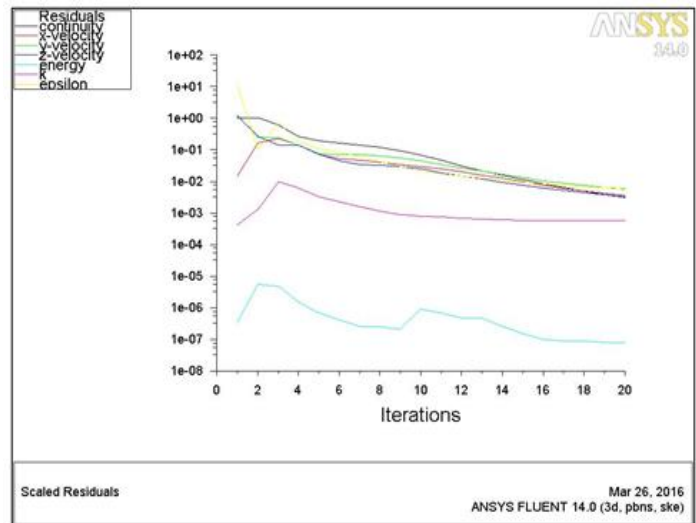
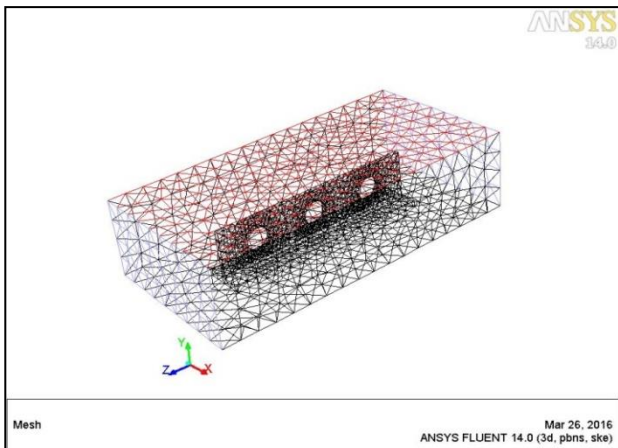
Model:-



TEMPERATURE CONTOUR RESULTS



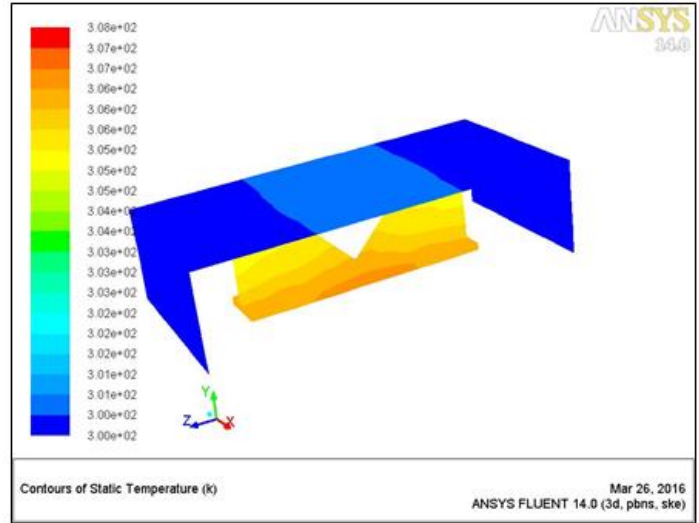
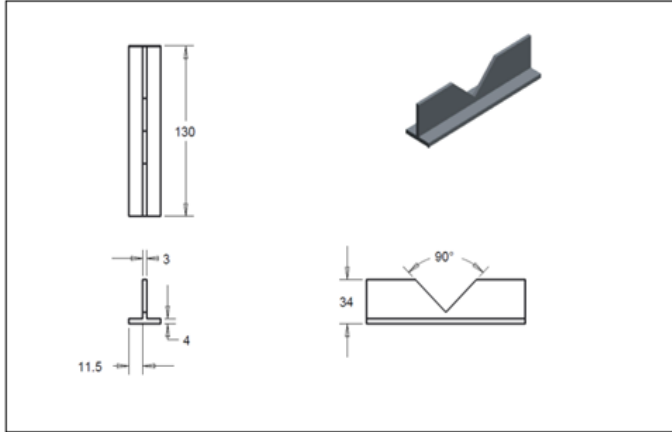
Mesh:



6.6 V SHAPE FIN

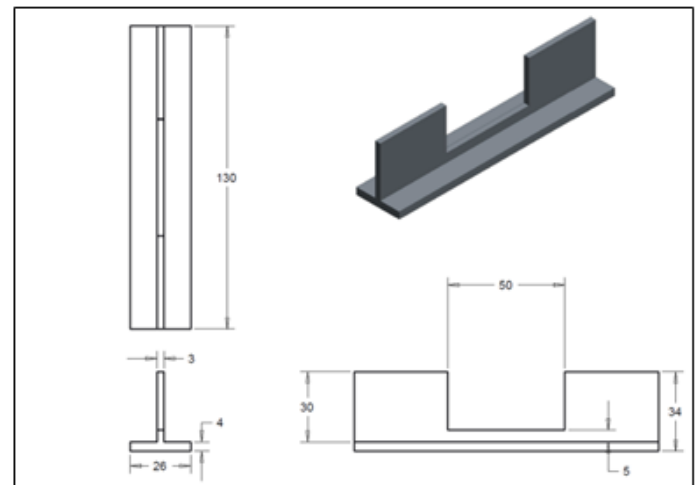
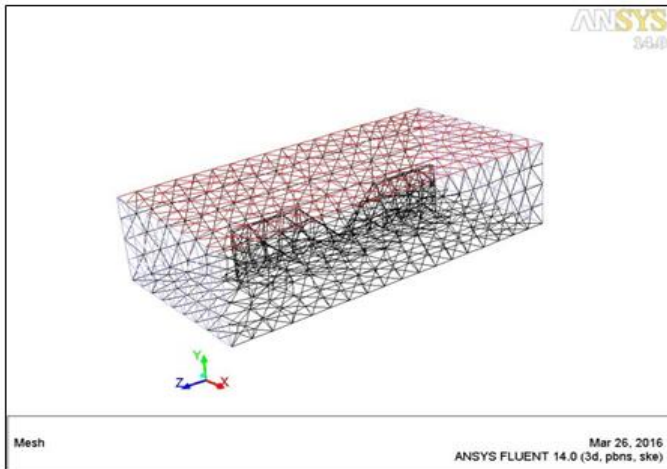
6.7 FINS WITH RECTANGULAR NOTCH

Model:-



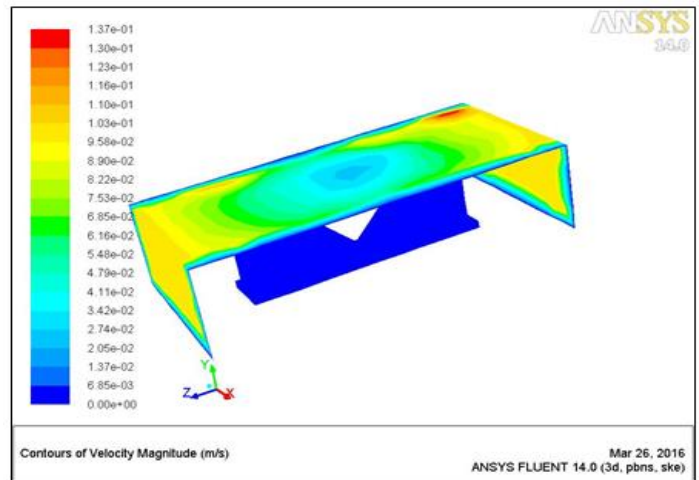
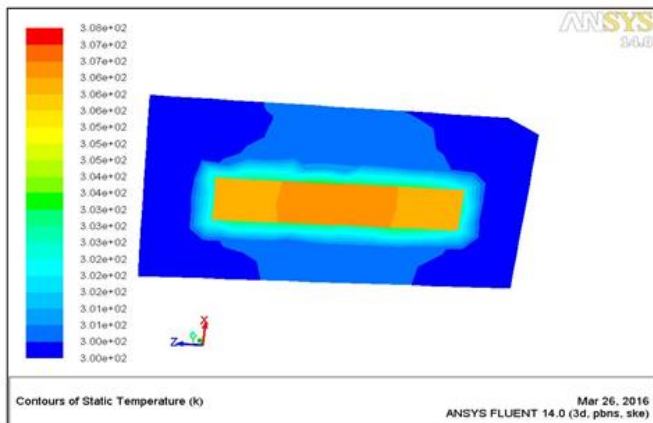
6.8 Rectangular fin:-

Mesh:-



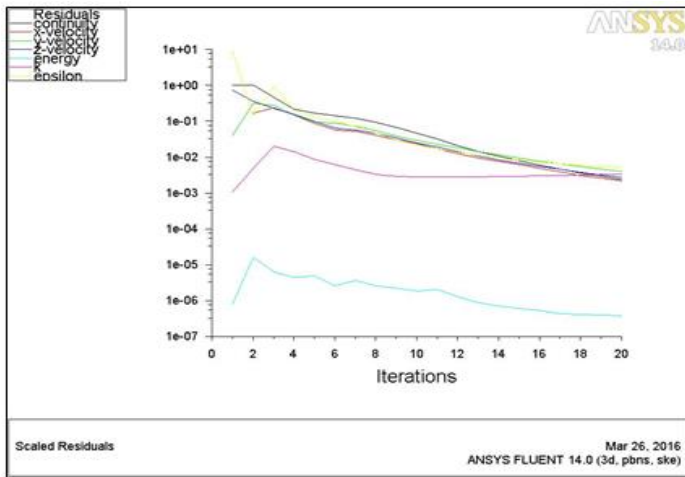
Velocity plot:-

TEMPERATURE CONTOUR RESULTS

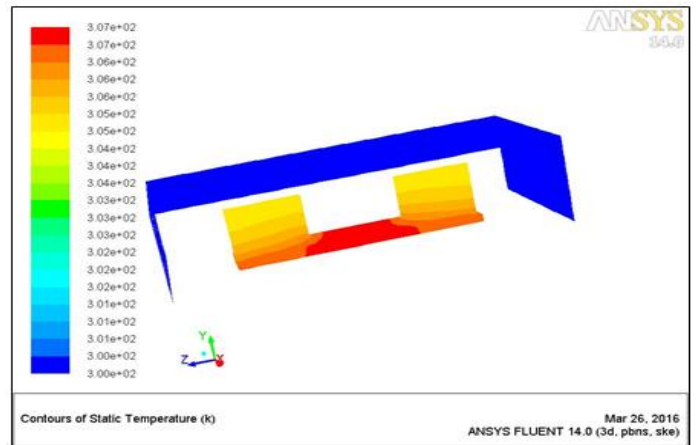


TEMPERATURE VS FIN LENGTH

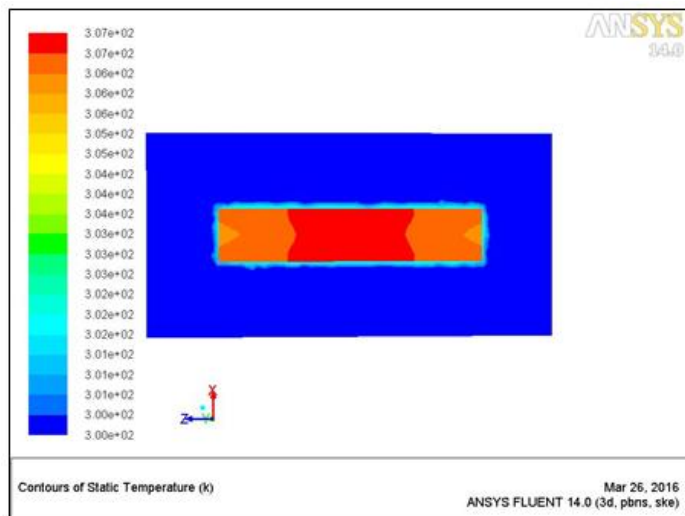
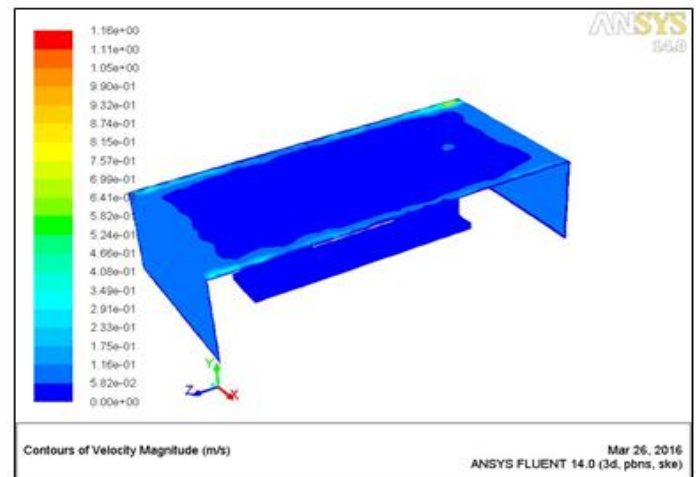
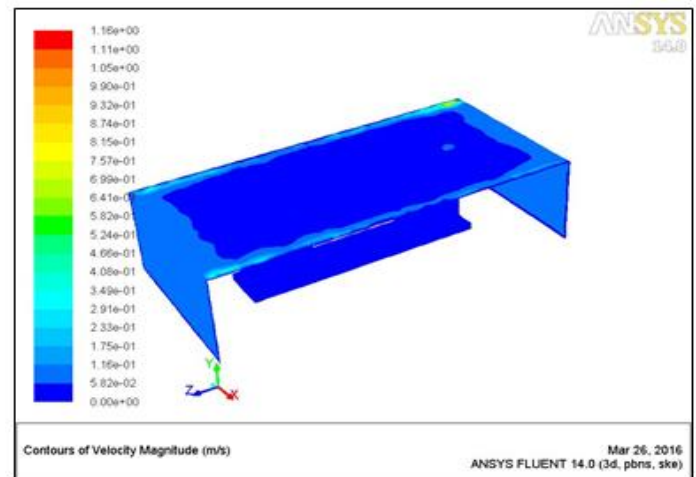
TEMPERATURE CONTOUR RESULTS



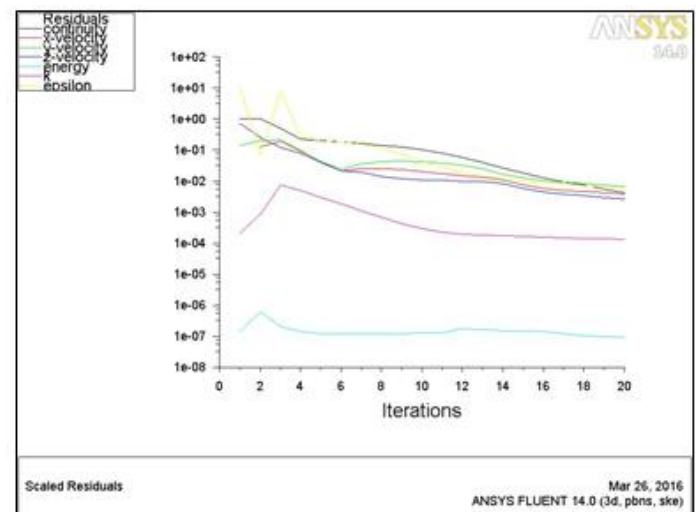
Velocity plot:-



MESH



TEMPERATURE VS FIN LENGTH



7. RESULT

Medium	FIN WITH OUT HOLE	FIN WITH HOLE	RECTANGULAR FIN	V FIN
INLET AIR TEMPERATURE(K)	300	300	300	300
MAX FIN TEMPERATURE(K)	3.14e+02	3.07e+02	3.07e+02	3.08e+02
INLET VELOCITY OF AIR(m/s)	3.34e-01	1.59e-01	1.16e+00	1.37e-01

S.no	Material	Deformation mm	Stress N/mm ²	Stiffness GPa	Tensile strength N/mm ²
1.	GRE	1.72	335	10	1140
2.	STEEL	0.017	51	204	351

8. DISCUSSION OF ANALYSIS RESULT

This project work has provided us an excellent opportunity and experience, to use our limited knowledge. We gained a lot of practical knowledge regarding, planning, purchasing, assembling and machining while doing this project work. We feel that the project work is a good solution to bridge the gates between the institution and the industries.

We are proud that we have completed the work with the limited time successfully. **The COMPUTATIONAL ANALYSIS FOR HEAT TRANSFER THROUGH FINS WITH DIFFERENT TYPES OF NOTCHES** is working with satisfactory conditions. We can able to understand the difficulties in maintaining the tolerances and also the quality. We have done to our ability and skill making maximum use of available facilities.

The fins with various configurations were modeled and analysed in order to find out the heat transfer rate. It is clear from the results that the fins with holes have greater heat transfer rate compared to that of the fins without holes, rectangular and V shaped fins.

9. REFERENCE

- ❖ *S C Arora, S Domkundwar ' A Course in Heat & Mass Transfer'*
- ❖ *R K Rajput 'Heat & Mass Transfer'*
- ❖ *C P Kodandaraman 'Fundamentals of Heat & Mass Transfer'*