Computational Analysis of Heat Transfer through Fins in Exponential profile with Different Types of Notches

Surya Prakash Namdeo[1], Dr. Rajeev Arya[2], Rohit Kumar Gupta[3]

[1]*ME Scholar Thermal Engineering, Truba Institute of Engineering & Information Technology Bhopal*

[2]*Director, Truba Institute of Engineering & Information Technology Bhopal*

[3]*Asst. Prof. Mech. Dept. Truba Institute of Engineering & Information Technology Bhopal*

***Abstract*- To study thermal analysis of extended surfaces or projections of materials on the system called fins. The fins are used to increase the heat transfer rate from the system to the surrounding by increasing the heat transfer area. The heat transfer effect may be varied by changing material of different thermal conductivities, improvising system geometry, increasing cross section area of fins, using perforations on fin and on CFD analysis of fins. Hence the aim of this paper is to study from different literature surveys that how heat transfer through extended surfaces and the heat transfer coefficient affected by changing cross-section this study is useful to know the better geometry and material for the fins for better system cooling. The main objective of the present paper is computational analysis of heat transfer through fins in exponential profile with growing type and decaying type to quantify and compare it in same boundary conditions after that apply the different types of notches in exponential profile. Objective of this analysis to determine the flow of heat at various notches available and compare the heat flux in different types of cases. The analysis is done by using ANSYS-CFD Fluent.**

Index terms- CFD, Flow over fins, Notches, Cooling system and Analysis.

I. INTRODUCTION

Heat transfer is the process of the transfer of energy due to a temperature difference. The calculations we are interested in include determining the final temperatures of materials and how long it takes for these materials to reach these temperatures. This can help inform the level of insulation required to ensure heat is not lost from a system. Typically, heat loss is directly proportional to a temperature gradient.

Heat transfer can be achieved by three processes i.e. conduction, convection or radiation.

To facilitate heat transfer between two bodies there needs to be a temperature difference between them. This means that these bodies must be a two different temperatures one higher than the other to permit heat flow from one body to the other. Cooling system is one of the important system among all of the systems in automobile. Fins are responsible to carry out the produced heat inside the cylinder, for the heat transfer there are various modes like conduction, convection and radiation are taken place. From these modes conduction is carried out in engine cooling fins. There are two different types of cooling system that are used in the automobiles, they are:

1. Air Cooling
2. Water cooling

1. Air-Cooling: The object being cooled will have a flow of air moving over its surface. Most air cooling systems use a combination of fans and heat sinks, which exchanges heat with air. Mostly automobile vehicles is used direct air cooling were built over a long period beginning with the advent of mass produced passenger cars and ending with a small and generally unrecognized technical change.

2. Liquid Cooling: Liquid cooling is also employed in maritime vehicles. The seawater itself is mostly used for cooling. Also chemical coolants are employed (in closed systems) or they are mixed with seawater cooling. By doing the computational Fluid analysis the heat transfer rate of the fins with various types of notches are analyses by using ANSYS workbench.

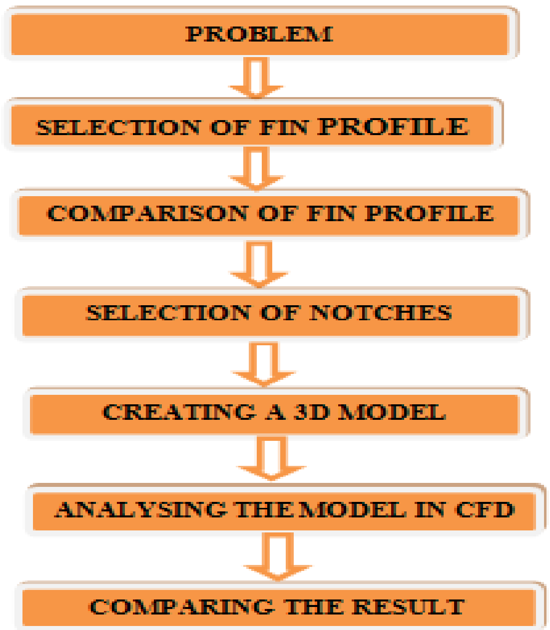
II. LITERATURE REVIEW

Deepak Gupta and Wankhade S.R., (2015), Design and Analysis of Cooling Fins in this paper the author tells about cooling fins are used to increase the heat transfer rate of specified surface. Engine life and its effectiveness can be improved with efficient cooling. The main idea of the this project is to study and comparing with 100 cc Hero Honda Motorcycle fins and analyze the thermal properties in different geometry, material and thickness. The analysis is done using ANSYS workbench [1]. Sanjay Kumar Sharma and Vikas Sharma (2013), Maximizing the Heat Transfer through Fins using ANSYS as a Tool. In this paper describes the results of computational analysis of air flow and heat transfer in a light weight automobile engine, considering three different types of morphology pin fins. The outcome indicate that the drop shaped pin fins show improved results on the basis of heat transfer and pressure drop by comparing with other fins [2]. Deepak Tekhre and Jagdeesh Saini, (2017), they can be concluded that the geometry and cross section area of the fin is the most important criteria that decides the efficiency of the cooling fin. For increasing the cross section area by making holes on the surfaces of fins this will also increases the heat rejection from fins faster than the rectangular fin. Increasing the hole size also improves the heat dissipation up to a limit as the hole size increases the minimum temperature on the fin gets reduced [3]. V. Karthikeyan, et al., (2015), studied that heat transfer rate through rectangular fins arrays is examine by varying geometry with perforated and with extension, and this analysis is carried out using ANSYS Workbench. In case of steady state heat transfer, temperature variations with respect to distance at which heat flow occur through the fin is analyzed. Heat transfer through fin with rectangular extensions higher than that of fin with other type of fins compared to it. Temperature at tip of fin with rectangular extensions is minimum as compare to fin with extensions, without extension and with perforated. Fin with rectangular extensions provide near about 13 % to 21% more enhancement of heat transfer as compare to other type of fins. This result may vary for forced convection heat transfer[4]. Pardeep Singh, (2014), compared the heat transfer performance of fin with same geometry having various extensions and without extensions is in their thermal analysis, temperature variations with respect to distance at which heat flow occur through Design Modification and Thermal Analysis of IC Engine Fin is analyzed Fin with extensions provide near about 5 % to 13% more enhancement of heat transfer as compare to fin without extensions also the heat transfer through fin with rectangular extensions higher than that of fin with other types of extensions[5]. S. Jamala Reddy, et al., (2015), the author studied that Design and Thermal Analysis of Fins by changing its Geometry and Material. In this paper the main idea of using these cooling fins is to cool the engine cylinder by air. The main purpose of the project is to analyze the thermal properties by varying geometry, material and thickness of cylinder fins. Transient thermal analysis determines temperatures and other thermal quantities that vary over time [6]. Vivek Kumar and Dr. V. N. Bartaria, (2013), CFD Analysis of an Elliptical Pin Fin Heat Sink using Ansys Fluent in the present study carries out numerical physical insight into the flow and heat transfer characteristics. The governing equations are solved by adopting a control volume-based finite difference method with a power-law scheme on an orthogonal non-uniform staggered grid [7]. G. Babu and M. Lava kumar, (2013), Heat Transfer Analysis and Optimization of Engine Cylinder Fins of Varying Geometry and Material in this paper the main aim of the project is to analyze the thermal properties by varying geometry, material and thickness of cylinder fins. Parametric models of cylinder with fins have been developed to predict the transient thermal behavior. The models are created by varying the geometry, rectangular, circular and curved shaped fins and also by varying thickness of the fins [8]. Mustafa Turkyilmazoglu, (2018), The heat transfer of exponential fins in movement and under the influence of heat generation (absorption) is considered in the present paper. Straight rectangular fins have lower temperature values than the growing type but higher values than the decaying type exponential fins. The highest fin efficiency occurs for growing type of exponential profiles. The growing shaped fin profiles thermally perform better and thus they are potential alternatives to commonly used rectangular fins in industrial instruments. [9]. Sandhya Mirapalli and Kishore.P.S,(2015), Heat Transfer Analysis on a Triangular Fin in this In an air-cooled engine, rectangular and triangular fins are provided on the periphery of engine cylinder. Heat transfer analysis is carried out by placing rectangular and then triangular fins. Analysis is carried out by varying temperatures on the surface of the cylinder from 200 ºC to 600ºC and varying length from 6 cm to 14 cm [10]. K. Sathish Kumar,(2016), Design and Analysis of I.C.

Engine Piston and Piston- Ring on Composite Material using Creo and Ansys Software the author had analyzed the stress distribution is evaluated on the four stroke engine piston by using FEA. The finite element analysis is performed by using FEA software. The couple field analysis is carried out to calculate stresses and deflection due to thermal loads and gas pressure. These stresses will be calculated for two different materials. The results are compared for all the two materials and the best one is proposed. The materials used in this project are aluminium alloy, and SiC reinforced ZrB2 composite material [11]. Mohsin A. Aliand and Prof. (Dr.) S.M Kherde,(2015), Design Modification and Analysis of Two Wheeler Engine Cooling Fins by CFD in this paper we understand about the main of aim of this work is to study different shapes and geometry of fins to improve heat transfer rate by changing fin geometry under different velocities [12]. G. Lorenzini et al.,(2013), Constructural design of T-shaped assemblies of fins cooling a cylindrical solid body in this work This paper considers the numerical optimization of a T-shaped assembly of fins cooling a cylindrical solid body. The objective is to minimize the maximum excess of temperature between the solid cylindrical body and the ambient. Internal heat generation is distributed uniformly throughout the solid body. The assemblies of fins are bathed by a steady stream with constant ambient temperature and convective heat transfer [13]. J. Al sultan et al.,(2014), Computational Fluid Dynamics (CFD) Analysis of Natural Convection of Convergent-Divergent Fins in Marine Environments the author had tells about the validation of results of modeling and simulation in CFD. The simulation was carried out using the ANSYS as the CFD modeling software. The main objective of the CFD analysis was to calculate the temperature distribution on the surface of the base plate and surface of the convergent-divergent fins for the given inline and staggered arrangement of fins due to the effect of natural convection heat transfer for different heat power inputs, and also to compare the CFD results with the experimental results [14]. Pulkit Agarwal et al.,(2011), Heat Transfer Simulation by CFD from Fins of an Air Cooled Motorcycle Engine under Varying Climatic Conditions in this paper we understand that the heat transfer rate depends upon the velocity of the vehicle, fin geometry and the ambient temperature. Many experimental methods are available in literature to analyze the effect of these factors on the heat transfer rate. However, an attempt is made to simulate the heat transfer using CFD analysis [15]. Fins are the most effective instruments for increasing the rate of heat transfer, as we know; they increase the area of heat transfer and cause an increase in the transferred heat volume. A complete review on this topic is presented by Krause et al., (2002), [16]. Fins are widely used in the many industrial applications such as air conditioning, refrigeration, automobile, chemical processing equipment and electrical chips. Although there are various type of the fins such as circular and spherical fins, but the rectangular fin is widely used between all of them due to simplicity of its design and its easy manufacturing process. For ordinary fins problem the thermal conductivity assumes to be constant, but when temperature difference between the tip and base of the fin is large, the effect of the temperature on thermal conductivity must be considered, also it is very realistic that we consider the heat generation in the fin (due to electric current or etc.) as a function of temperature. Aziz and Bouaziz (2011) [17] used an analytical method for predicting the performance of a longitudinal fin with temperature dependent internal heat generation and thermal conductivity. They compared their results with Homotopy Perturbation Method (HPM), Variable Iteration Method (VIM) and double series regular perturbation method. Razani and Ahmadi (1977) [18] proposed study on circular fins with an arbitrary heat source distribution and a nonlinear and temperature-dependent thermal conductivity and obtained the results for the optimum fin design. Unal (1987) [19] conducted an analytical study of a rectangular and longitudinal fin with temperature dependent internal heat generation and temperature dependent heat transfer coefficient. Another study about this issue (convective fin with both temperature dependent thermal conductivity and internal heat generation) was also performed by Shouman (1968) [20]. Kundu (2007) [21] has solved a problem about thermal analysis and optimization of longitudinal and pin fins of uniform thickness subject to fully wet, partially wet and fully dry surface conditions. Domairry and Fazeli (2009) [22] solved the nonlinear straight fin differential equation by HAM to evaluate the temperature distribution and fin efficiency. Also, temperature distribution for annual fins with temperature-dependent thermal conductivity using HPM was studied by Ganji et al.,(2011) [23]. The effects of temperature dependent thermal conductivity of a moving fin considering the radiation losses have been studied by Aziz and Khani (2011) [24].

III. METHODOLOGY

In this paper we followed the methodology given in the flow chart below, first collect all the related information about the heat transfer and the cooling fins and then collecting some of the literature review.



After collecting all the related data's the cooling fins are designed using CREO 2.0. After the model is created the analysis are done by using ANSYS – 14.5 (CFD – Fluent). Then the results of each analysis are compared and then
The best notch is selected. The result from the ansys is compared with different cases.

IV. GEOMENTRIC MODELING AND MATERIAL PROPERTY

The three different types of notches which are selected for analysis with exponential profile, they are:

1. Fins without Notch
2. Fins with Holes.
3. Fins with Rectangular Notches.
4. Fins with V – Shaped Notches.

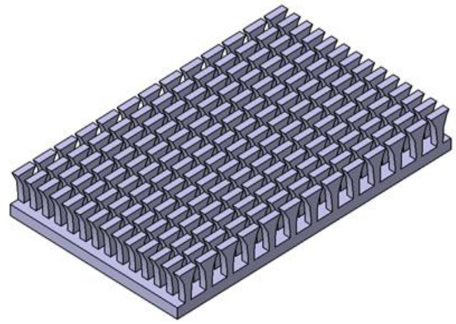


Fig.:1 Fins without any Notch

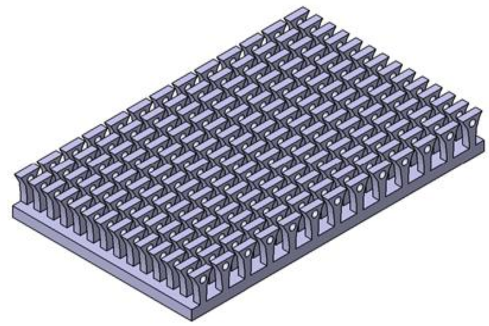


Fig::2 Fins with Holes

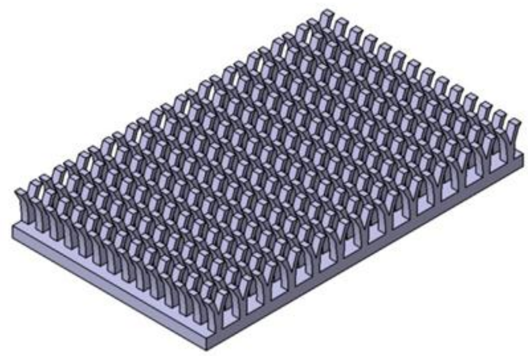


Fig.:3 Fins with V – Shaped Notch

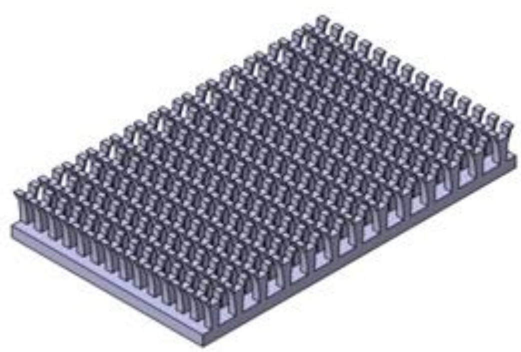


Fig.:4 Fins with Rectangle Notch

V. MATERIAL DATA FOR ALUMINIUM

For the analysis of cooling fins we had choose the material as Aluminium because Aluminium is a good thermal and electrical conductor, having 59% the conductivity of copper, both thermal and electrical, while having only 30% of copper's density. Aluminium is capable of being a superconductor, with a superconducting critical temperature of 1.2 Kelvin. The weight of the aluminium is less and also because of a high thermal conductivity, since aluminium is selected as the material for cooling fins.

Table: 1 Material property of Aluminium

MATERIAL PROPERTY	VALUE
Density	2719 Kg/m3
Thermal Conductivity	202.399 W/m-K
Specific Heat	871 J/Kg-K
Young Modulus	3.4e+11 Pa
Poisson's Ratio	0.22
Bulk Modulus	2.0238e+11 Pa
Shear Modulus	1.3934e+11 Pa

VI. CFD ANALYSIS AND MESH GENERATION

1. Meshing model of a fins

Computational Fluid Dynamics (CFD) is the science of determining numerical solution of governing equation for the fluid flow through space or time to obtain a numerical description of the complete flow field of interest. The equation can represent steady or unsteady, Compressible or Incompressible, and in viscid or viscous flows, including non ideal and reacting fluid behavior. The particular form chosen depends on intended application. The state of the art is characterized by the complexity of the geometry, the flow physics, and the computing time required obtaining a solution. After the model is imported in CFD domain, next step is to mesh the domain. To perform better results using CFD Tool it was mandatory to use better quality of mesh naming of the section is given in the model for computing purpose.

Meshing Detail of the Model in CFD- Fluent

Table: 2 Meshing details of model in ANSYS

Meshing detail of model in ANSYS					
Fin	Number of elements	Nodes	Avg. skewness	Avg. Orthogonal quality	Maximum aspect ratio
Fin without Notch	293834	53864	0.25015	0.748	1.902
Fin with V shaped-Notch	311495	56436	0.2521	0.747	1.927
Fin with Circular-Notch	120962	172018	0.39247	0.605	2.304
Fin with Rectangular-Notch	487690	86400	0.26688	0.73179	2.6238

2. NAMED SECTION AND BOUNDARY CONDITION'S

In this CFD analysis the naming of section is a major thing in fluent. The left surface of the fluid domain is named as Inlet and the right surface the fluid domain is named as outlet then the bottom surface of the fin is attached to source named as a Boundary-1 and the fins named as sink are named as a Boundary-2. In CFD mesh quality denotes the accuracy of the results and the quality of meshing will vary from each geometry.

Boundary Conditions

Material – Air

Density ρ = 1.1768Kg/m3

Specific Heat, Cp= 1005 J / Kg-k

Thermal Conductivity, K = 0.0262 W/m-k

Inlet Velocity of Air is 1 m/s

Material – Solid (Source)

Inlet Air Temperature 373k

VII. RESULTS IN CFD

A three-dimensional model is developed to investigate flow and heat transfer rate in the automobile fins. A series of numerical calculations have been conducted by FLUENT and the results are presented in order to show the effects of temperature distribution, overall heat transfer coefficient, heat transfer rate and velocity of the heat flow. The results are calculated for 120 Iteration Cycles and the figures and graph are given below,

1. TEMPERATURE CONTOUR

After the analysis are done the results are seen in CFD post processing , by choosing the domain the results are seen by means of vectors and contour diagrams the following images shows the temperature contour of various notches and the results are given below.

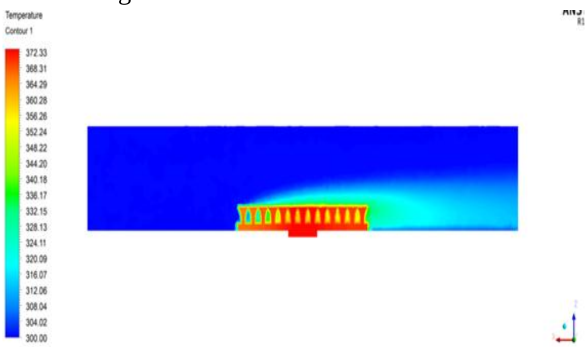


Fig.:5 Heat Flux Change in Normal Fins

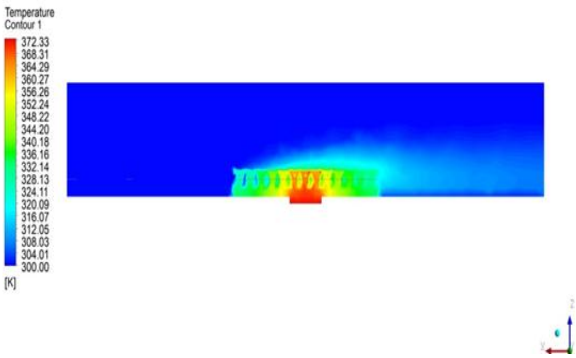


Fig.:6 Temperature Change in Fins with Holes.

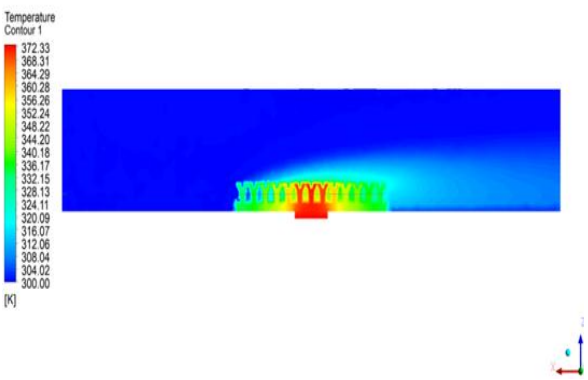


Fig.:7 Temperature Change in Fins with V – Shaped Notch

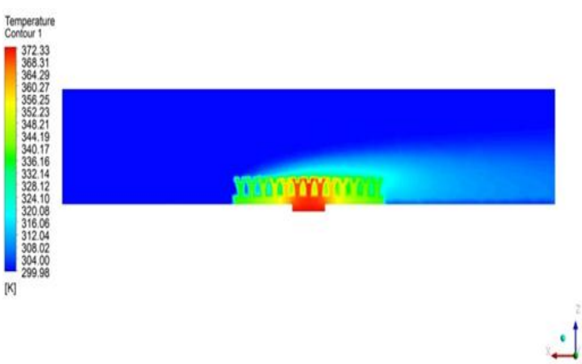


Fig.:8 Temperature Changes in Fins with Rectangular Notch

Due to the change in shapes of the fins the temperature distribution is varied in the above and 5, 6, 7and 8 it can be determined by using CFD fluent.

2. HEAT FLUX CONTOUR

Heat flux is the rate of heat energy transfer through a given surface per unit time. Since the surface area of the fins are increased in different notch so the heat transfer rate is also increased, the following images shows the heat flux contour of various notches and the results are given below.

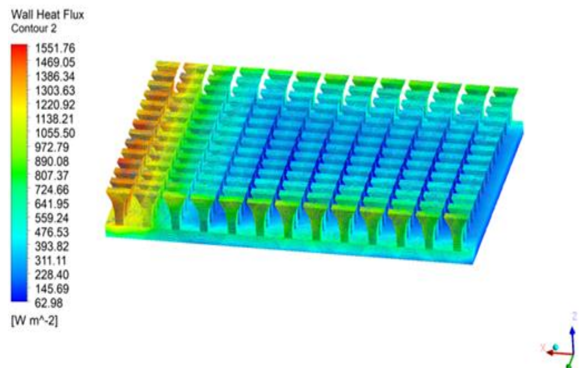


Fig.:9 Heat Flux Changes in Normal Fins

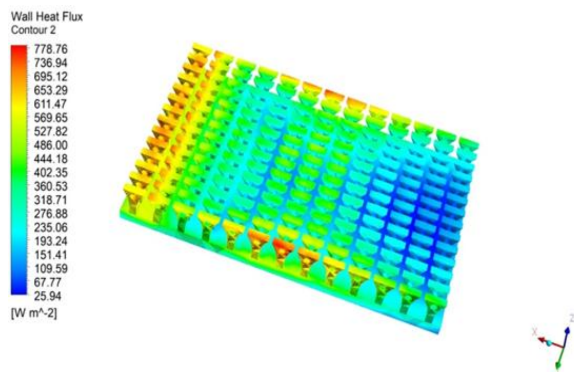


Fig.:10 Heat Flux Changes in Fins with Holes

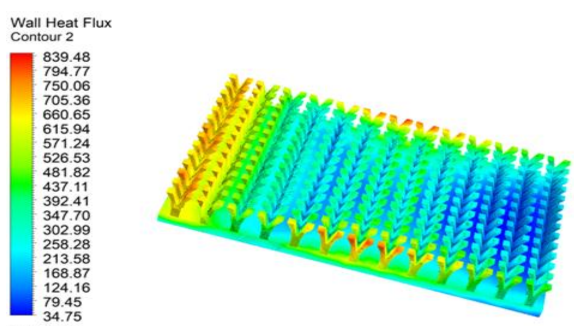


Fig.:11 Heat Flux Changes in Fins with V – Shaped Notch

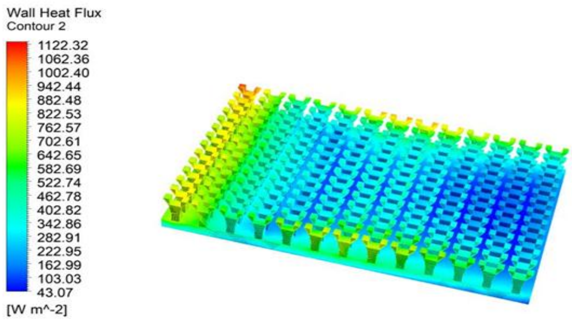
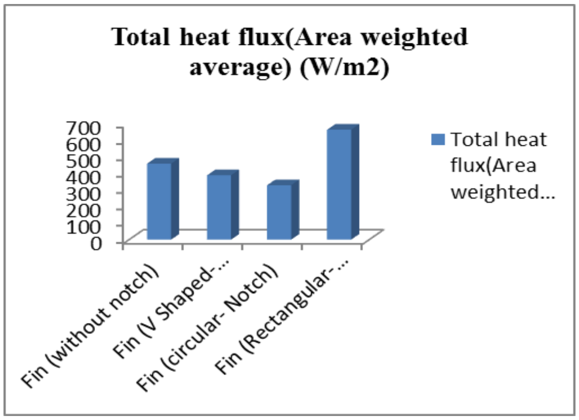


Fig.:12 Heat flux Changes in Fins with Rectangular Notch

The above figures 9, 10, 11 and 12 will shows the Heat flux changes in all types of fins. From the results of the different fins the graph is drawn to find the best and effective fin and the graph-1 is shown below.



Graph: 1- Heat Flux Change of the Fin

From the above analysis which is done in CFD – Fluent, the various analyses such as temperature contour and Heat flux contour are taken and the results are discussed below. Thus the same operating conditions are specified and the changes in output values are seen by using CFD – Post processing.

Table: 3 Results from CFD- Fluent

Results from ANSYS FLUENT				
Parameter	Fin (without notch)	Fin (V Shaped-Notch)	Fin (circular-Notch)	Fin (Rectangular-Notch)
Temperature(k)	369.506	345.546	343.797	348.593
Total heat flux (Area weighted average) (w/m2)	455.852	386.348	326.726	659.614

The above table-2 will clearly shows the result from CFD – Fluent. From the above results we can easily conclude that rectangular notch is more effective when it compared with other notches. Since the rectangular notch has more heat transfer and temperature distribution than other notches.

VIII. CONCLUSION

The fins with various configurations were modeled using ANSYS software and analyses are done by using CFD – Fluent in order to find out the heat transfer rate per unit area i.e. heat flux. It is clear that the results from software as follow

1. Exponential growing type fins have 27.96% higher heat flux than exponential decaying type fins.
2. By considering the Exponential growing fins, fin without notch has 18% and 39.52% higher total heat flux than fin with v-shaped notch and circular notch respectively.

But exponential fin without notch has 30.89% lower total heat flux than exponential fin with rectangular notch.

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