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Estimation of Heat Dissipation from Plate with Multiple Tapered and Rectangular Fins

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ABSTRACT

The current work determines the rate of heat flow from a heating element. Extended tapered surfaces are provided on the element in order to enhance better convection. Overall heat transfer during this process is determined by modeling and meshing using finite element software and its validation is done using the governing equations. The heat dissipation from the element is also compared with the rectangular fins provided around it. The study is conducted by considering various materials to obtain optimum material selection to enhance the better flow of heat from the system.

Key words: Thermal Analysis, ANSYS CFX, steady state heat transfer, tapered fins, rectangular fins

INTRODUCTION

Many engineering devices generate heat during their operation. If this generated heat is not dissipated rapidly to its surrounding atmosphere, this may cause rise in temperature of the system components. This cause overheating problems in device and may lead to the failure of component [6]. Fins or extended surfaces are known for enhancing the heat transfer in a system. Liquid-cooling system enhances better heat transfer than air-cooling system, the construction of air cooling system is very simpler. Therefore it is imperative for an air-cooled engine to make use of the fins effectively to obtain uniform temperature in the cylinder periphery [2]. The major heat transfer takes by two modes that is by conduction or by convection. Heat transfer through fin to the surface of the fin takes place through conduction where as from surface of the fin to the surroundings, it takes place by convection. Further heat transfer may be by natural convection or by forced convection [3]. Based upon the cross sectional area type, straight fins are of different types such as rectangular fin, triangular fin, trapezoidal fin parabolic fin or cylindrical fin. Fin performance can be measured by using the effectiveness of fin, thermal resistance and efficiency. Triangular fins have applications on cylinders of air cooled cylinders and compressors, outer space radiators and air conditioned systems in space craft [4]. Fins must be designed to achieve maximum heat removal with minimum material expenditure, taking into account, however, the ease of manufacturing of the fin shape. Large number of studies has been conducted on optimizing fin shapes. Other studies have introduced shape modifications by cutting some material from fins to make cavities, holes, slots, grooves, or channels through the fin body to increase the heat transfer area and/or the heat transfer coefficient [5].

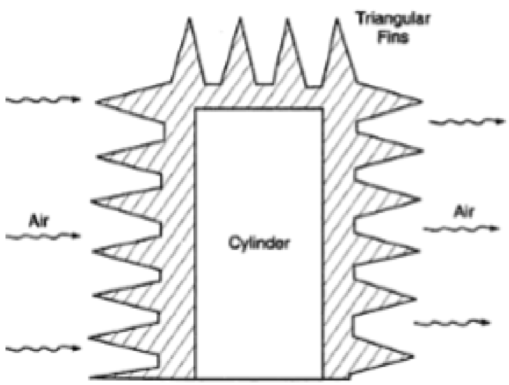

Fig. 1 Air cooled cylinder with rectangular fins [4]

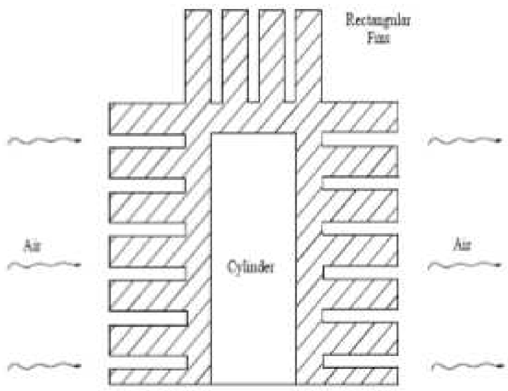

Fig. 2 Air cooled cylinder with triangular fins [4]

Figs 1 and 2 show the triangular and rectangular fins around the cylinder. As the heat developed inside a two stroke engine cylinder is more, the heat has to be dissipated to surroundings by fins. These fins fitted are having an appropriate surface area to take away the heat to surroundings [4].

RELATED WORK

Magarajan et al [2] calculated heat release of an IC engine cylinder cooling fins with six numbers of fins having pitch are determined numerically using commercially available CFD tool Ansys Fluent. The heat release from the cylinder which is calculated numerically is validated with the experimental results. With the help of the available numerically results, the design of the I.C engine cooling fins can be modified for improving the heat release and efficiency. Barhatte et al [3] studied the fin flats which are modified by removing the central fin portion by cutting a triangular notch. This dissertation report presents an experimental analysis of the results obtained over a range of fin heights and heat dissipation rate. Attempts were made to establish a comparison between the experimental results and results obtained by using CFD software. Mirapalli et al [4] provided rectangular and triangular fins 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. Input parameters such as density, heat transfer coefficient, thermal conductivity and thickness o6]f fin are taken and output parameters such as rate of heat flow, heat flow per unit mass, efficiency and effectiveness are determined. Comparisons are presented with rectangular fins. Jassem et al [5] investigated the heat transfer by natural convection in a rectangular perforated fin plates. Five fins used in this work first fin non-perforated and others fins perforated by different shapes these fins perforation by different shapes (circle, square, triangle, and hexagon) but these perforations have the same cross section area. These perforations distributed on 3 columns and 6 rows. Experiments produced through in an experimental facility that was specifically design and constructed for this purpose. Daund et al [6] reviewed convection heat transfer through rectangular fins. Various experimental studies have been made to investigate effect of fin height, fin spacing, fin length and fin thickness over convective heat transfer. He also examined the experimental and numerical studies which are done in natural, mixed and forced convection. He found that sets of correlations to give relation between various parameters of heat sink were derived. Shaikh et al [7] dealt with performance of various available fins profiles. Widely used fins profile viz. Rectangular, Triangular, Trapezoidal, Circular, Rhombic, and Elliptical Fins. In addition to the normal configuration of fins, to new configurations were designed and created. This includes length of each fins its thickness at the base and number of fins on each model this provided a basis for proper comparison of different fin profiles. The result were tabulated and studied for comparison of different fin profiles. The best performing fin was then selected on the basis of maximum heat dissipation from the circular model this study showed the performance of annular fins of different profiles under similar conditions and to quantify the heat losses and finally compare it with fin profiles on the basis of heat dissipation and thermal stress include. The fin profile was then arranged on the basis of performance. Nafar et al [8] presented an analytical simulation model which predicts and optimizes the thermal performance, maximum thermal dissipation and the least material cost in electrical devices. He inputted the Biot number Bi, heat transfer coefficient ratio, H and the shape parameter, the heat transfer equation which is expressed in implicit form which could be solved by iterative method to calculate the optimum fin length and fin thickness. He discussed the optimization of heat- sink designs and typical parametric behaviours based on the sample simulation results. Also the thermal resistance of a heat sink was obtained which illustrates the cooling performance under various design conditions.

METHODOLOGY

Heat source which is maintained at the base temperature will dissipate heat through extended surfaces. Triangular fins and rectangular fins of similar dimensions are used to dissipate the heat. The positioning of the fins depends on the design and the amount of cooling required. Equation (1) shows the fin factor which is a constant related with film coefficient and thermal conductivity.

$$m = \sqrt{\frac{hp}{kA_C}} \tag{1}$$

The heat generated from the source gets transferred by different modes that are conduction and convection, governing equations of heat transfer between the elements are applied. Below equation (2) represents the heat transfer which takes place during conduction derived by the Fourier, and equation (3) represents the heat transfer during conduction which is by Newton’s law of cooling. Temperature distribution and the heat transferred from the short fin is given by the equations (4) and (5).

The Fourier’s Law of conduction

$$Q = -k\, A_c \quad \frac{dt}{dx} \tag{2}$$

Newton’s Law of cooling

$$Q = h\,(t - t_a)A_S \tag{3}$$

Temperature distribution over a short fin (Rectangular cross-section)

$$\frac{(t-t_a)}{(t_o-t_a)} = \frac{Coshm(L-x)+\frac{h}{mk}sinhm(L-x)}{Cosh(mL)+\frac{h}{mk}\sinh(ml)} \tag{4}$$

Heat transfer from a short fin (Rectangular cross-section)

$$Q = \sqrt{hpkA_c}(t_o - t_a)\left[\frac{\tanh(ml)+\frac{h}{km}}{1+\frac{h}{km}\tanh(ml)}\right] \tag{5}$$

Equation 6 represents the amount of heat transfer taking place from the tapered fin.
Heat transfer from a triangular or tapered fin

$$Q = b\sqrt{2hky}\ \frac{I_1\frac{2B}{\sqrt{I}}}{I_O\frac{2B}{\sqrt{I}}}\ \theta_o \tag{6}$$

Q= Heat Transfer rate (W), p= perimeter of the fin (m), A_c= Cross-Sectional Area (m^2), m= Fin factor (m^{-1})
k= Thermal Conductivity of the material (W/m^0C), h= Heat transfer coefficient ($W/m^{20}C$), t= Temperature (^0C)
x= distance from reference (m), A_s= Surface Area (m^2), t_s= Surface Temperature (^0C), t_i= Internal Temperature (^0C)
t_a= Ambient Temperature (^0C), L=Length of the element (m), dt/dx= Temperature gradient ($^0C/m$)
y= thickness of the fin, m

Fig. 3 shows the steps involved in determining the amount of heat transfer from the plate. Thermal equations determine the amount of heat flow. Finite element method software ANSYS is used to model and analyze the element. The results and used to verify with the basic governing equations which is defined.

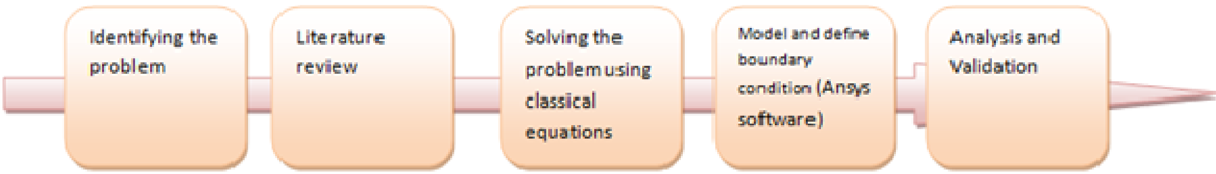

Fig. 3 Methodology involved in determining the rate of heat transfer through the plate using rectangular and tapered fins

MODELLING AND ANALYSIS

In the present analysis rectangular and tapered fins are provided around a heating source. Heating source is maintained at 300°C, the heat transfer from the system is improved by providing multiple fins. Plate has the dimensions of (140 m X 5m X 5m) and the fin is maintained at the thickness of 2 m and the length of the fin is 5 m. Figs. 4, 5, 6 and 7 shows the modelling and meshing of tapered and rectangular fins. Material which is selected has a thermal conductivity 380 W/m°C and is exposed to air which has a heat transfer coefficient 10 W/m^2°C.

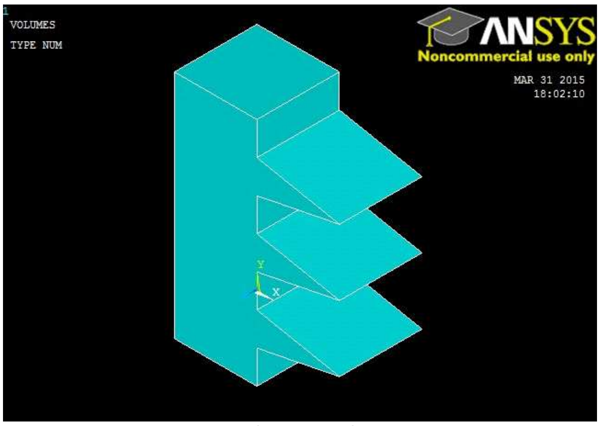

Fig. 4 Modeling of Tapered fins

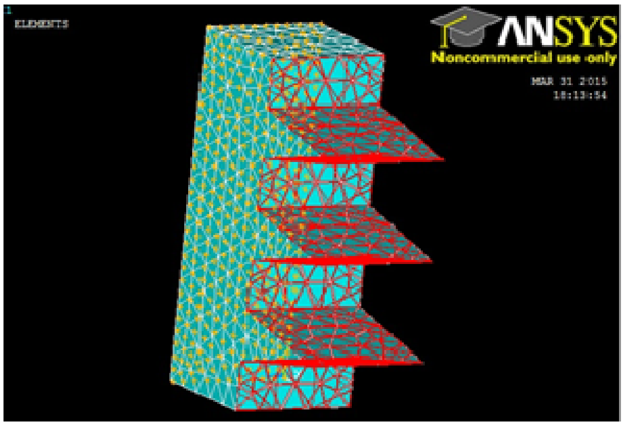

Fig. 5 Meshing and Application of Boundary condition (Tapered fins)

Table -1 Temperature variation with for triangular fin using classical and FEA approaches

Thickness (m)	Temperature distribution for triangular fin using classical method in ^0C	Temperature distribution for triangular fin using FEA in ^0C
0	300	300
2	279	282
4	240	245
6	170	173
8	50	54
10	30	30

Following element is modelled and it is meshed using ANSYS software [1- 2]. Meshing is discretizing of an element into finite number of parts and each element is considered and solved separately. Mesh generation is the practice of generating a polygonal or polyhedral mesh that approximates a geometric domain. The term "grid generation" is often used interchangeably. Typical uses are for rendering to a computer screen or for physical simulation such as finite element analysis or computational fluid dynamics [2]. After this step a thermal steady state simulation is performed. By using ANSYS numerical simulation tool, whole analysis of entire assembly is performed. Present simulations adopt realistic boundary conditions by considering various different materials with different thermal conductivities [1]. As an important boundary condition is the radiation property of the material. But due to the high film coefficient, the part of the heat flow caused by radiation is neglected in this work. Modelling and Meshing is done using FEA and the simulation is performed. By means of the numerical solution, a steady state analysis of the entire heating element is achieved. Validation of the results obtained in the FEA is carried out using dot net frame work software [2-3].

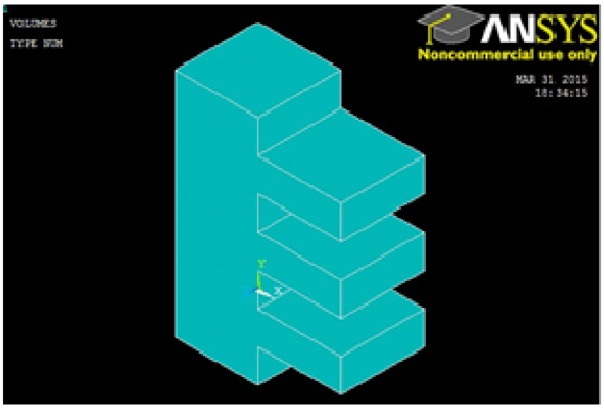

Fig. 6 Modeling of Rectangular fin

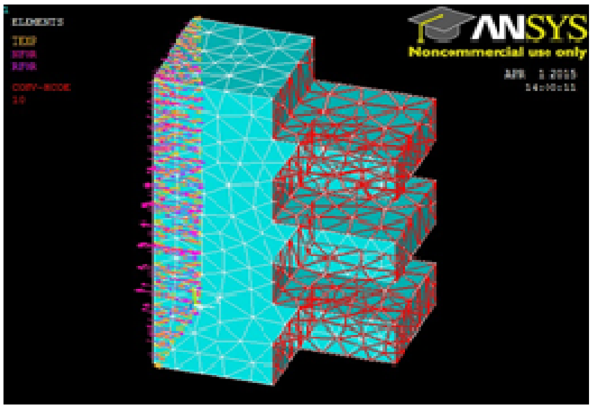

Fig. 7 Meshing and Application of Boundary condition (Rectangular fins)

RESULTS AND DISCUSSIONS

Analysis is carried out with the application of boundary conditions by defining the thermal parameters. Coefficient of convection and the thermal conductivity is defined at appropriate points of the element. Fig. 8 and 9 shows the analysis of tapered and rectangular fin element. It is clear that the temperature drops from the root to the tip which is exposed to the ambient temperature [2].

Table -2 Temperature variation with for rectangular fin using classical and FEA approaches

Thickness (m)	Temperature distribution for rectangular fin using classical method in ^{0}C	Temperature distribution for rectangular fin using FEA in ^{0}C
0	300	300
2	260	263
4	230	235
6	150	160
8	43	50
10	30	30

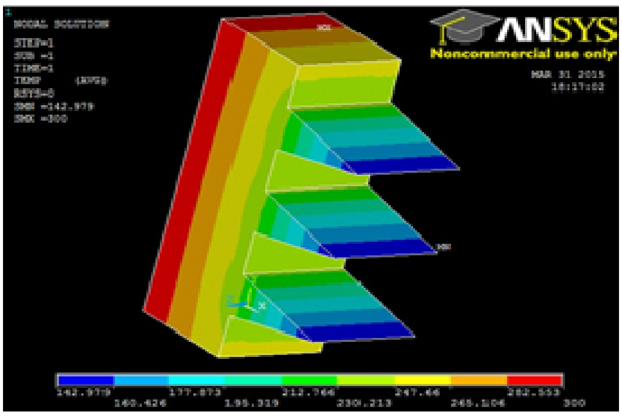

Fig. 8 Temperature distribution in a tapered fin

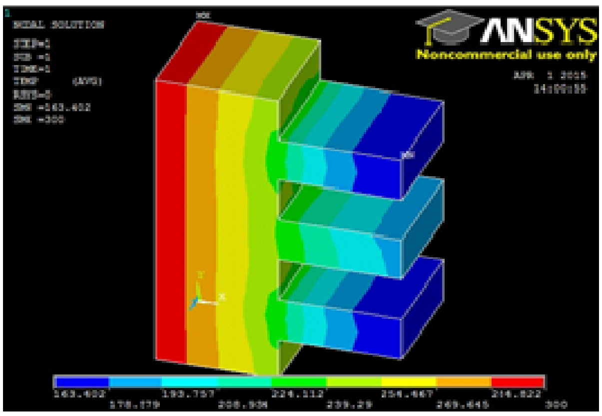

Fig. 9 Results obtained in DOTNET software

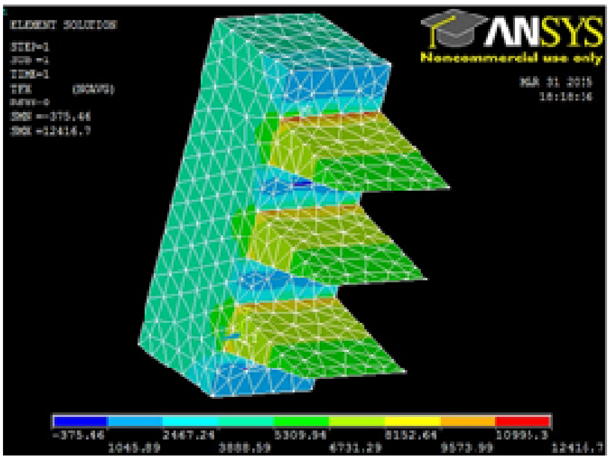

Fig. 10 Thermal Flux in tapered fin

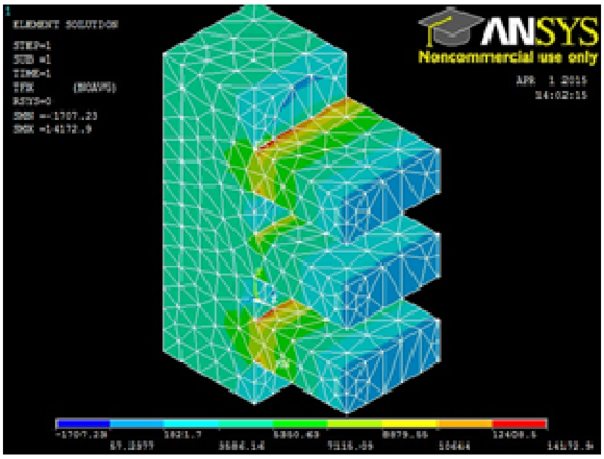

Fig. 11 Thermal Flux in rectangular fin

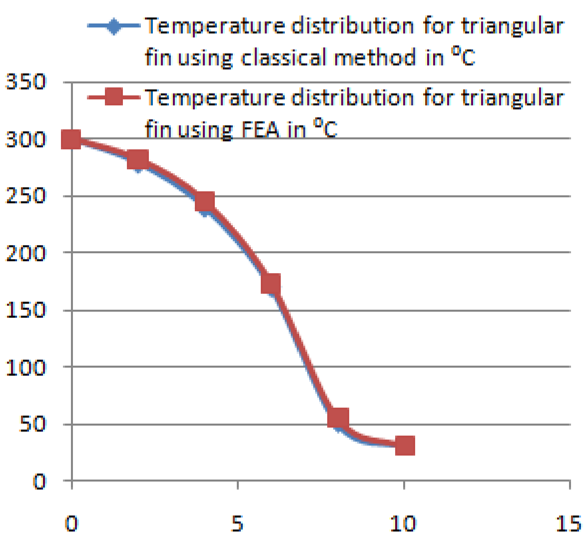

Fig. 12 Variation of temperature with the length of the fin for triangular fin

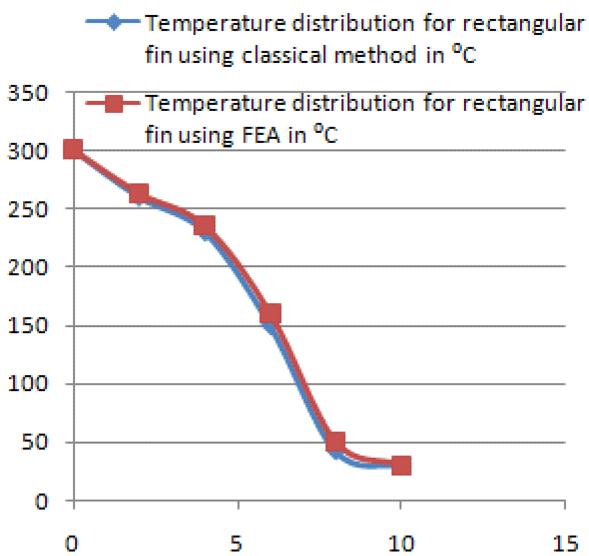

Fig. 13 Variation of temperature with the length of the fin for rectangular fin

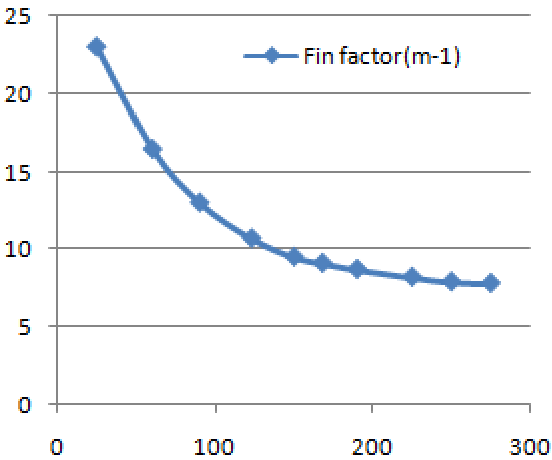

Fig. 14 Change in the fin factor with the change in the thermal conductivity

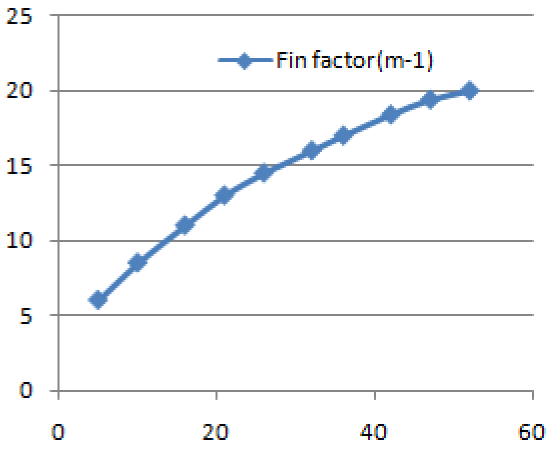

Fig. 15 Change in the fin factor with the change in the film coefficient

Fig. 12 and Fig. 13 infers that the temperature go on decreasing from the root of the fin to the extreme end. It is due to the various thermal parameters which are defined. Heat thus flows from inside to the outside satisfying the law of thermodynamics [2-3]. It is also observed that the temperature variation in both classical and FEA technique is almost similar. Overall heat transfer from the rectangular fins is 12.36 watts and that of triangular fins is equal to 16 W [2]. Fig. 14 and 15 shows the variation of fin factor with the thermal conductivity and heat transfer coefficient. As there is increase in the thermal conductivity there is a drop in the fin factor and when there is a rise in the heat transfer coefficient there is a rise in the fin factor.

CONCLUSION

In the current analysis rectangular and triangular fins are considered and temperature distributions at various points on the fin are calculated. An attempt is made to demonstrate the improvements to enhance the maximum heat dissipation from the system using FEA technique and the validation of this is carried out by using governing equations. Results are thus matching with classical equations. By increasing the value of thermal conductivity and film coefficient, it is possible to increase the heat dissipation rate. Different cross-section fins can be used to enhance the heat transfer rate, also with the consideration of dimensionless numbers heat transfer calculations can be carried out. Transient analysis can also be carried out for the same case. Increase in number of fins can also be considered to enhance maximum heat transfer. Heat transfer coefficient can be increased by increasing the surrounding fluid velocity by forced convection. Higher velocities may sometimes lead to lower heat transfer. So it is necessary to maintain optimum fluid velocities around the fins. Overall calculations show that triangular fins dissipate heat more than rectangular fins based on the magnitude of heat transfer rate. It is because of the exposure of the base to the ambient conditions.

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