Improvement in Heat Transfer Rate of Rectangular Fin by Geometrical Modification

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Abstract— In this review paper, the performance of fin is studied by design of fin with various geometrical modifications. Heat transfer is necessary to enhance the efficiency and life of any compressor. Heat transfer can be achieved by conduction, convection and radiation. Convection is the frequent used method for engine cooling purpose due to its higher heat transfer rate. Fin is a surface which extends from a surface to increase the rate of heat transfer to the environment by increasing convection. This study examines the natural convective heat transfer from rectangular fins with different geometry under natural convection. In this steady state thermal analysis and temperature variations with respect to distance at which heat flow occur through the fin is analyzed.

Key words: Geometry of the fin, Transient thermal analysis, extended surface, Analysis, Extensions

I. Introduction

Air cooling is a method of transferring the heat. By putting the object to be cooled has a larger surface area or has an increased flow of air over its surface area. For that fins are provided on the objects, by attaching them tightly to the object's surface area.

A fin is a surface that extends from an object to increase the rate of heat transfer to the atmosphere by increasing convection. The amount of conduction, convection and radiation of an object determines the maximum amount of heat it can transfer. Increasing the temperature difference between the object and the atmosphere increasing the convection heat transfer coefficient, or increasing the total surface area of the object increases the heat transfer. Sometimes it is not economical or feasible to change the first two options. Adding a fin to an object increases the surface area and can sometimes be an economical solution to heat transfer cases.

Natural convection heat transfer is often increased by provision of fins on horizontal or vertical surfaces in many electronic applications, motors and transformers.The current trend in the electronic industry is miniaturization, making the overheating problem more acute due to the reduction in surface area available for heat dissipation.

The basic type of commonly used fins are:

- Constant area fins
- Variable area straight fins
- Pin fin
- Annular fin

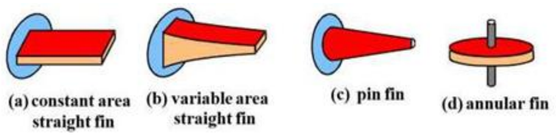

Fig. 1: Types of fins

II. Major Area of Analysis

Pardeep Singh et al.[1] analyzed the heat transfer performance of fin by design of fin with various extensions such as rectangular extension, trapezium extension, triangular extensions and circular segmental extensions. The heat transfer performance of fin with same geometry having various extensions and without extensions is compared. Near about ranging 5% to 13% more heat transfer can be achieved with these various extensions on fin as compare to same geometry of fin without these extensions. Fin with various extensions design with the help of software AutoCAD.

Analysis of fin performance done through the software Autodesk® Simulation Multiphysics. In this thermal analysis, temperature variations w.r.t. distance at which heat flow occur through the fin is analyzed. Extensions on the finned surfaces is used to increases the surface area of the fin in contact with the fluid flowing around it. So, as the surface area increase the more fluid contact to increase the rate of heat transfers from the base surface as compare to fin without the extensions provided to it.

Types of Extension	Heat transfer (in W)	Increase in heat transfer (in W)	Percentage increase in heat transfer (in %)
Fin with rectangular extensions	24.5557	2.7892	12.93
Fin with trapezium extensions	22.9052	1.1387	5.23
Fin with triangular extensions	22.4495	0.683	3.14
Fin with circular segmental extensions	22.7155	0.949	4.36

Table 1. Comparison of Heat Transfer for various extensions on fin

They conclude that the use of fin (extended surface) with extensions provides efficient heat transfer. Fin with extensions provide near about 5 % to 13% more enhancement of heat transfer as compare to fin without extensions. And heat transfer through fin with rectangular extensions higher than that of fin with other types of extensions. Also the effectiveness of fin with rectangular extensions is greater than other extensions.

K.A. Rajput et al.[2] studied the natural convection heat transfer from perforated fins. The temperature distribution was examined for an array of rectangular fins with uniform cross-sectional area embedded with different vertical body perforations that extend through the fin thickness. This study examines the natural convective heat transfer from rectangular fins with different forms of perforations under natural convection. In this analysis six different forms of perforations are used with including non-perforated fin. The different forms are circle, square, triangle, Ellipse and hexagon and having same cross sectional area of 113mm2. These perforations distributed on 3 columns and 6 rows. The parameters considered were geometrical dimension and thermal properties of fin such as material properties, convective heat transfer coefficient. The fins are design with the help of Creo- Parametric software. Analysis is carried out using Autodesk Simulation Mechanical 2014.In this steady state thermal analysis and temperature variations with respect to distance at which heat flow occur through the fin is analyzed.

They Analyzed the Fin Arrays of aluminium for Heat Transfer. Aluminium has selected for the model due light weight and high heat transfer rate and heat dissipation in this material. The material having thermal conductivity, convection coefficient of heat transfer for air, temperature of surface and ambient temperature as: Thermal conductivity k = 109W/m °C, Convection coefficient of heat transfer, h = 6.012 W/m^2 °C, Temperature of wall surface at which fin attached, T_b = 100 °C, Ambient temperature, T_a = 30 °C.

They concluded that heat transfer increased by increasing the surface area of extended surface. In finite element analysis, it is found that as the number of perforations increases heat transfer rate increases.

Sr. No.	Form of Perforation	Temperature at the end
1	Circular	82.92 °C
2	Square	82.62 °C
3	Triangle	82.84 °C
4	Hexagon	83.20 °C
5	Ellipce	76.11 °C
6	Not Perforated	83.85 °C

Table 2. Temperature at the end of the fins

V. Karthikeyan et al.[3] analyzed the heat transfer rate of rectangular fin arrays by design with perforated and with extension. The effectiveness is compare to the fin arrays with extension and with perforated. The fin arrays ware Perforated with various diameter and different types of extensions such as rectangular extension, trapezium extension, triangular extensions and circular segmental extensions ware used. The Perforated and Extensions on the finned surfaces used to increases the surface area of the fin in contact with the fluid flowing around it. It is reasonable because the surface area increase the more fluid contact to increase the rate of heat transfers from the base surface.

The fin arrays with various extensions and perforation in fin arrays designed with the help of design software Solidworks. After designing the next process was analysis the fin arrays for heat transfer by using software Ansys Workbench. In that steady state thermal analysis, temperature variations with respect to distance at which heat flow occur through the fin was analyzed.

The Table 3 shows that comparison of variation in heat transfer rate of various fin geometry. Also compare the increase in heat transfer rate for the given geometry of fin. The fin without extensions having 22.5645 W heat transfer value.

Sr. No.	Types of Rectangular fin arrays	Heat transfer (in W)	Increase in heat transfer (in W)	Iincrease in heat transfer (in %age)
1	Fin arrays with Rectangular extension	27.3208	4.7563	21.0786
2	Fin arrays with Circular extension	25.6313	3.0668	13.5912
3	Fin arrays with Trapezoidal extension	25.6214	3.0569	13.5473
4	Fin arrays with Triangular extension	25.6871	3.1226	13.8365
5	Fin arrays with 18mm perforated	23.8271	1.2626	5.5955
6	Fin arrays with 20mm perforated	23.5274	0.9629	4.2673
7	Fin arrays with 22mm perforated	22.9722	0.4077	1.8068
8	Fin arrays with 24mm perforated	22.6386	0.0741	0.3283

Table 3. Comparison of increase in heat transfer rate

Xiaohui Zhang et al.[4] determined the optimal spacing between isothermal laminar natural convection plates cooled by air for maximum heat transfer. The analysis has been carried out by analytically and numerically. It was found that the optimal plate's allocation spacing is different from the conventional way, where the boundary layers of the plates merge. It is the distinguishing feature of the outlet velocity that causes an enhancement of heat transfer.

They derived the theoretical expression for optimal plate-to-plate spacing by the natural convection boundary layer theory, it was found the optimal spacing is (4/3)δ, where the substantial increase of heat transfer is caused by a coordination of the temperature and the superposition of velocity. The scale analysis was performed to verify the optimal spacing theoretical expression.

In a fixed two-dimensional volume, in order to get heat transfer enhancement, the shorter length of plate is preference, the optimal vertical plate's interval in fixed volume is almost half of that without the constraint.

By inserting multi-scale plates in the boundary layer, the heat transfer enhancement could be conducted effectively and the intervals of the multi-scale plates depend on the height of the plates.

Mr. N. Phani Raja Rao et al.[5] investigated heat dissipated inside the cylinder by thermal analysis of engine cylinder fins. They were analyzed the thermal properties by varying geometry, material and thickness of cylinder fins. They were analyzed the cylinder fins using the material Aluminium alloy A204, Aluminium alloy 6061 and Magnesium alloy. They analyzed the fins having thickness 2.5mm and 3mm with rectangular shape.

In that study they were concluded that by reducing the thickness and also by changing the shape of fin to the circular shaped, the weight of fin body reduces thereby heat transfer rate and efficiency of fin increased. Also the circular shaped fin with material Aluminium alloy 6061 the heat transfer rate, efficiency and the effectiveness of fin is more.

Dialameh, L. et al.[6] study has been carried out to predict natural convection from an array of aluminium horizontal rectangular thick fins of 3 mm< t < 7 mm with short lengths (L 650 mm) attached on a horizontal base plate. The 3-dimensional elliptic governing equations of laminar flow and heat transfer were solved using finite volume scheme. Based on the verified model, fluid flow and thermal structure around various fins were illustrated and two types of flow patterns in the channel of the fin arrays were observed. Effect of various fin geometries and temperature differences on the convection heat transfer from the array was determined for Rayleigh numbers based on fin spacing of 192–6784 and applied correlations were developed to predict Nusselt numbers with corresponding non-dimensional parameters. It was concluded that natural convection heat transfer coefficient increases with increasing temperature differences and increases with fin spacing and decreases with fin length.

F. Illán et al.[7] studies were carried out on transient heat transfer in two stroke SI engine. A zero-dimensional model is presented to simulate the transient processes occurring within a two-stroke SI engine. The boundary conditions for this model are the convective heat transferred to the cooling medium. A gas mixture model has been used to obtain the influence of working fluid properties on combustion development.

After the analysis, the authors found that In order to analyze the transient period, the simulation runs for a period of 300 s, a stable temperature distribution is reached for the entire engine. The cylinder head and the piston 6 min after engine start. As can be seen, for the piston the stable situation is reached in less than 1 min, whereas in the case of the cylinder body and the cylinder head this time increases up to nearly 6 min due to the presence of fins.

III. CONCLUSIONS

In this paper it is concluded that The heat transfer through fin arrays with rectangular extensions is higher than that of fin with perforation and fin without extension. It is also cleared that by reducing the thickness and also by changing the shape of the fin to circular shaped, the heat transfer rate and the efficiency of fin increased. And the contribution of radiation in heat loss, even for small values of surface emissivity, is large and cannot be neglected.

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