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HEAT TRANSFER RATE ENHANCEMENT BY PERFORATED FINS: A REVIEW

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Abstract— *Heat dissipation is one of the main problems which we come across while dealing with high load and high speed machines. Because of the work they perform, some amount of heat is generated inside the machine. This heat has to be transferred outside the system to obtained efficient output. If it is not done, then this heat may cause damage to machine parts. To do this, fins are used. Main purpose of fins is to increase surface area of machine so that heat can be transmitted in atmosphere. In this project, we are trying to increase surface area of fins by providing perforations to it. these perforations may be of any shape and size. Our aim is to find those shapes and size which will increase the efficiency of fin.*

Index Terms—*Natural convection,perforated fin*

I. INTRODUCTION

Heat transfer enhancement in heat systems has always been an important step when designing them. One of the most effective methods in heat transfer enhancement is the use of extended surfaces, i.e. fins. The term “extended surface” is used when the conduction inside the body and the convection from boundaries occur simultaneously. The thermal conductivity of fins greatly affects the temperature distribution along the fin and, consequently, the heat transfer rate. The choice of fins for various applications depends on factors such as size, weight, increased pressure drop, and increased convection coefficient. Many studies have been conducted on the use of fins with various shapes to increase the heat transfer rate.

Reducing the size and cost of fins are the prime goals of fin industry. This requirement is often justified by the high cost of the high-thermal conductivity metals that are employed in the manufacturing of finned surfaces and by the cost associated with the weight of the fin especially in airplanes and motorcycles applications. The reduction in the size and cost of fins is achieved by the enhancement of the heat transfer carried out by the fins. The enhancement of heat transfer from fins has become an important factor that has captured the interest ofmany researchers. This enhancement can be accomplished through the following techniques:
(1) Increasing the surface area to volume ratio
(2) Increasing the thermal conductivity of the fin and
(3) Increasing the convective heat transfer coefficient between the surface of the solid fin and the surrounding fluid.

In this project we are trying to increase the efficiency of fins by increasing its surface area. This is done by providing perforations to fins that may be of any size and shape. To do this we have gone through various papers which are discussed further.

II. THEROTCAL BACKGROUND

a. Fins:
Fins are nothing but the extended area to increase the convective heat transfer rate. By Newton’s law of cooling the convective heat transfer rate is directly proportional to normal area to flow of fluid. Hence by increasing area heat transfer rate increases.

- **Types of fins:**

1. Rectangular or Plate Fin
2. Tapered Fin
3. Radial Plate Fin
4. Disk Fin
5. Pin Fin

b.Fin Effectiveness:

It is defined as the ratio of actual heat transfer rate from fin surface to heat transfer rate from the area blocked by the fin. Where,area at the root equivalent to cross-sectional area of fin (Ac).

When

(i) ε = 1 : Fin does not affect the heat transfer at all.

(ii) ε 1 : Fin act as insulation (if thermal conductivity (k) of fin material is low) .

(iii) ε 1 : Heat transfer will be increased.

c. Fin Efficiency

It is defined as the ration of actual heat transfer rate taking place through the fin and the maximum possible heat transfer rate that could occur through the fin i.e. when the entire fin is at its root temperature or base temperature. The entire fin will be at its root temperature only when the material of the fin has infinite thermal conductivity.

d.Reynolds Number:

The transition from laminar to turbulent flow depends on the surface geometry, surface roughness, flow velocity, surface temperature and type of fluid, among other things. the ratio of the inertia forces to viscous forces in the fluid. This ratio is called the Reynolds number, which is dimensionless quantity.

E.Nusselt Number:

In convection studies, it is common practice to nondimensionalize the governing equations and combines the variables, which group together into dimensionless numbers in order to reduce the number of total variables.

f.Prandtl Number:

The relative thickness of velocity and the thermal boundary layers is best described by dimensionless parameter Prandtl number.

III. LITRATURE REVIEW

"The effect of orientation of square perforations on the heat transfer enhancement from a fin subjected to natural convection" by Abdullah H. Al-Essa and Fayez M.S. Al-Hussie studied the heat transfer dissipation from a horizontal rectangular fin embedded with square perforations of two orientations under natural convection is numerically investigated &Introducing square perforations to fin body increases surface area and heat dissipation for a given range of the perforation dimension. "Thermal Analysis of Natural Convection Porous Fins" by Suhil Kiwan, introduced a simple method of analysis to study the performance of porous fins in a natural convection environment. The method is based on using energy balance and Darcy's model to formulate the heat transfer equation. The thermal performance of porous fins is then studied for three types of fins: long fin, finite-length fin with insulated tip and a finite-length fin with tip exposed to a known convection coefficient.

"Natural Convection Heat TransferEnhancements From a Cylinder Using Porous Carbon Foam: Experimental Study"by Yorwearth L. Jamin and A. A. Mohamad, carried out the study to quantify and compare the heat transfer enhancement of carbon foam and aluminium fins in natural convection. The study measures steady state heat transfer from a heated vertical pipe, with and without porous medium.

"Natural Convection Heat TransferEnhancements From a Cylinder Using Porous Carbon Foam: Experimental Study" by Rencai Chu,et al, studied , on the heat transfer characteristic of the dispersed fin, the heat transfer coefficient decreases in the case of small fin pitch, but increases in the case of large fin pitch, when compared with the continuous fin. The heat transfer coefficient rises by around 10%, for the dispersed fin with a narrower lateral groove. They have found that the rectangular fin shows a higher heat transfer coefficient of 20% when compared with a triangular fin with the same fin pitch. "The Use of Porous Fins for Heat Transfer Augmentation in Parallel-Plate Channels" by Mohammad Hamdan and Moh'd A. Al-Nimr, presented the numerical solution in this study for steady, developing forced convection between two isothermal parallel-plate channels with porous fins. The results show that heat transfer can be enhanced with the use of high thermal conductivity fins, by decreasing the Darcy number, and by increasing microscopic inertial coefficient.

"Effects of Different Fin Spacings on the Nusselt Number and Reynolds Number in Perforated Finned Heat Exchangers" by Gülay Yakar and Rasim Karabacak, studied, the effect of holes placed on perforated finned heat exchangers on convective heat transfer was experimentally investigated. Six-millimeter-diameter holes were opened on each circular fin on a heating tube in order to increase convective heat transfer. These holes were placed on the circular fins in such a way as to follow each other at the same chosen angle. The holes created turbulence in a region near the heating tube surface on the bottom of the fin.“Enhancement of Natural Convection Heat Transfer from Rectangular Fins by Circular Perforations” by Wadhah Hussein and Abdul Razzaq Al- Doori, conducted an experimental study to investigate heat transfer by natural convection in a rectangular fin plate with circular perforations as heat sinks. The patterns of the perforations included 24 circular perforations (holes) for the first fin;the number of perforations increased by eight for each fin to 56 in the fifth fin.

“Modeling natural convection heat transfer from perforated plates” by Zan WU,et al,evaluated theoretically based on existing correlations by considering effects of ratios of open area, inclined angles, and other geometric parameters. It is found that staggered pattern perforations can increase the total heat transfer rate for isolated isothermal plates and vertical parallel plates, with low ratios of plate height to wall-to-wall spacing. The study aims to examine the extent of heat transfer enhancement from isolated isothermal perforated plates, vertical parallel isothermal perforated plates, and vertical rectangular isothermal perforated fins compared with their non-perforated counterparts with the same weight, under natural convection conditions.

“Numerical Analysis Of Convection Heat Transfer From An Array Of Circular Perforated Fins Due To Variable Perforation Size” by Yaghoubi, investigated a numerical analysis of three dimensional, turbulent convection heat transfer from an array of rectangular perforated fins with increasing the perforation size from bottom to top. The perforations considered are like circular channels along the length of fins and the number of perforations is 3. For investigation, incompressible air as working fluid is modeled using Navier Stokes equations.“Forced convective heat transfer enhancement with perforated pin fins” by Swee-Boon Chin and Ji-Jinn Fooinvestigated experimentally and numerically the use of staggered perforated pin fins to enhance the rate of heat transfer in these devices.DP across the heat sink is smaller with increasing number of perforation and perforation diameter. Nu increases with increasing number of perforation and perforation diameter. Maximum system performance may be obtained with perforated pin fins when the number of perforations and perforation diameter are optimized. “Thermal analysis of porous pin fin used for electronic cooling” by Dipankar Bhanjaa,b et al, they investigated the temperature distribution, performance parameters and heat transfer rate through a porous pin fin in natural convection condition for finite-length fin with insulated tip. From the study it can be concluded that variation of temperature increases with the increase in Darcy parameter , an increase in Rayleighimproves the effective convective heat transfer coefficient between the fin and the working fluid, a high porosity decreases the effective thermal conductivity of the porous fin due to the removal of solid material and thus maintains lower temperature at the fin tip, dimensionless temperature increases with the increase of thermal conductivity ratio, increasing Rayleigh number increases the heat transfer rate.

“An Experimental Investigation on the Effect of a Perforated Fin on Free Convection Heat Transfer from a Confined Horizontal Cylinder” by Amir Abbas Rezaei and Masoud Ziabasharhagh, focused on the effect of a perforated fin attached to the bottom of a cylinder while the vertical position of the cylinder (*Y*) changes between two walls with a constant distance of *W* measuring 1.5 times the cylinder diameter. “Numerical study on heat transfer enhancement in a receiver tube of parabolic trough solar collector with dimples, protrusions and helical fins” by Z. Huanga, et al,they focused on the heat transfer of the HTF side. A numerical simulation on the fully developed turbulent flow and heat transfer in the inner tube with and without helical fins, protrusions and dimples has been investigated.“Optimization of triangular fins with/without longitudinal perforate for thermal performance enhancement” by A. Shadlaghani,et al, aimed at the heat transfer enhancement is depending on pin fin dimensions, the perforation geometry, and number of perforation and thermal conductivity of material, as well as the fluid heat transfer coefficient, and is independent of the Rayleigh number, fluid viscosity, and fin length. The most important parameter affecting the heat transfer is Reynolds number.

“Natural convection heat transfer from a heat sink with hollow/perforated circular pin fins” by E.A.M.Elshafei, studied the geometric dependence of heat dissipation from heat sink so widely spaced solid and hollow/perforated circular pin fins with staggered combination, fitted into a heated base of fixed area is discussed. “A Review On Heat Transfer Enhancement By Using Perforated Fins” by C.F. Kalaskar, et al, focused on the analysis of the heat transfer enhancement and the considerable pressure drop below a flat surface equipped with circular or square perforated fins in a rectangular channel.“Heat transfer enhancement by filling metal porous medium in central area of tubes” by T Z Ming et al, the authors filled metal porous medium with high thermal conductivity, high porosity and high filling radius in the central area of fully developed laminar flow within the tube, and established corresponding numerical models for fluid flow and heat transfer.

“Experimental Study on Heat Transfer Enhancement Method Using Porous Material with High Porosity” by Yuta Asari et al, they studied the pressure drop and heat transfer enhancement in a horizontal circular pipe after insertion of high porosity material. This material was cut off in three blocks and inserted with interval in a horizontal pipe to suppress the pressure drop.“Thermal Enhancement of Triangular Ducts using Compound of Vortex Generators and Nanofluids” by Hamdi E. Ahmed and Mohd Z. Yusoff, experimented Laminar flow and heat transfer of three different types of nanofluids; Al_2O_3, CuO, and SiO2 suspended in ethylene glycol, in a triangular duct using delta-winglet pair of vortex generator are numerically simulated in three dimensions.

“Analysis of two-dimensional porous fins with variable thermal conductivity” by Hossein Shokouhmand,et al, carried out a two-dimensional thermal analysis of a porous fin having variable thermal conductivity coefficient is performed using finite difference method, they introduced a novel method that enhances the heat transfer from a given surface by using an array of porous fins under laminar force convection.“Thermal Enhancement from Pin Fins by Using Elliptical Perforations with Different Inclination Angles” by Hisham H. Jasim and Mehmet S. Söylemez, used innovative form of the perforated fin (with inclination angles), signum function was used for modeling the opposite and the mutable approach of the heat transfer area. “Heat Transfer Enhancement Through Perforated Fin” by Noaman Salam,et al, conducted an experiment of convective heat transfer which is performed on three fins and carried out for different Reynolds number under laminar flow conditions with same input heat supplied condition.

“Thermal Analysis of Square and Circular Perforated Fin Arrays by Forced Convection” by Kavita H. Dhanawade, Vivek K. Sunnapwar reports an experimental study to investigate the heat transfer enhancement over horizontal flat surface with rectangular fin arrays with lateral square and circular perforation by forced convection. They conclude that Reynolds number and size perforation have a larger impact on Nusselt number. “One-dimensional finite element heat transfer solution of a fin with triangular perforations of bases parallel and towered its base” by Abdullah H. M. AlEssa computed Heat transfer dissipation from a horizontal rectangular fin embedded with equilateral triangular perforations. Also perforated fin is compared with solid fin. This shows hest dissipation is improved by perforations.

“CFD Analysis of Steady Laminar Natural Convection Heat Transfer from a Pin Finned Isothermal Vertical Plate” by L. K. Sahoo,M. K. Roul,and R. K. Swain quantify and compare the natural convection heat transfer enhancement of fin array with different fin aspect ratio and at different angles of inclination. They developed a general correlation to predict the average Nusselt number and heat transfer augmentation factor for conductive and nonconductive fin arrays as a function of different fin configurations.“A numerical investigation of the thermal-hydraulic characteristics of perforated plate fin heat sinks” by Waleed Al-Sallami, Amer Al-Damook , H.M. Thompson investigated the notch, slot and multiple circular perforations in plate fin heat sinks numerically. They compare design and it is found that each type of perforation can provide significantly reduced pressure drops. Most effective design in terms of heat transfer is with slot perforations. If manufacturing complexity is considered, then notch perforations may well offer an attractive, effective and practical solution to the important problem of improving the performance.

“Computational Heat Transfer Analysis and Genetic Algorithm–Artificial Neural Network–Genetic Algorithm-Based Multiobjective Optimization of Rectangular Perforated Plate Fins” by Balachandar Chidambaram, Madhumitha Ravichandran did the study of various dimensions of fin and perforations to obtain a physical insight into the enhanced heat transfer characteristics of a perforated fin. They determine optimized geometry with a limited set of numerical solutions by using computerized efficient algorithm. Their main two objectives were minimum base plate temperature and minimum weight of fins. “Computational Investigation of Heat Transfer Analysis through Perforated Pin Fins of Different Materials” by Ambarish Maji, Dipankar Bhanja, et al, used straggled perforated pin fins of different materials to investigate the enhancement in heat transfer. They find out different parameters like fin number, perforation size etc by using three dimensional CFD analysis.

“Effect Of Perforation Size To Perforation Spacing On Heat Transfer In Laterally Perforated-Finned Heat Sinks” by Mohammad Reza Shaeri and Richard Bonner investigate Thermo-fluid characteristics of laterally perforated-finned heat sinks (LA-PFHSs) experimentally in laminar forced convection. According to them, the flow interactions over the perforations with each other are dominant mechanisms that affect transport phenomena in LAPFHSs. “Enhancement of Confined Air Jet Impingement Heat Transfer Using Perforated Pin-Fin Heat Sinks” by Md. Farhad Ismail and Suvash C. Saha they employed FEA analysis to investigate the thermal performance of perforated heat sinks at various impinging Reynolds number. It is to evaluate the possibility of improving the thermal performance by introducing perforated fins.

“Experimental study on the effect of perforations shapes on vertical heated fins performance under forced convection heat transfer” by Thamir K. Ibrahim, Marwah N. Mohammed investigates the effect of perforation shape or geometry on the heat transfer of perforated fins. They found out the heat coefficient of heat sink by 35-52% regarding to perforation shape and size. Heat transfer analysis of lateral perforated fin heat sinks by M.R. Shaeri, M. Yaghoubi, did numerical study on conduction-convective heat transfer from rectangular fins having square perforations. They made numerical solution to find fluid flow and temperature distribution for various arrangements. Result shows that perforated fins are better than solid fins.

Heat Transfer and Pressure Drop Correlations for the Rectangular Offset Strip Fin Compact Heat Exchangerby Raj M. Manglik and Arthur E. Bergles studied the rectangular offset strip fin compact heat exchangers. Rational design equations for f and j are presented in the form of single continuous expressions covering the laminar, transition, and turbulent flow regimes. Investigation of Flow and Heat transfer Characteristics In Micro Pin Fin Heat SinkvWith Nanofluid by Mushtaq Ismael Hasan studied micro pin fin with three fin geometries numerically in addition to the unfinned micro channel heat sink. They showed that nanofluids can be better coolant than normal fluids. They increase the heat dissipation and also increases pressure drop.

IV. PROBLEM STATEMENT

A. Most of the work is done by considering natural convection.
B. Size of perforation is proportional to the size of fins.
C. Rectangular fins are mostly use in above researches.
D. As copper has high conductivity of heat, we decided to use it as fin material.
E. Size of heating coil is kept slightly higher.

V. SCOPE AND OUTCOMES

A. Various shapes can be used, eg. Circular, triangular etc.
B. Mostly, size of perforations is depends upon application. So, accordingly we can change it.
C. Fins with threads can be another option to increase heat transfer.
D. Porous material can be used as fin material.
E. We can change mountings of fins according to flow of air.

- **Expected Outcomes**

A. To increase heat transfer rate.
B. To minimise the material used for fins.
C. Increase the efficiency of fins.

VI. CONCLUSION

We come to know that-
a. heat transfer can increase with the help of perforations.
b. Natural convection is good in that case.

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