International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 10 | Oct 2020 www.irjet.net p-ISSN: 2395-0072

Enhancement of Perforated Pin-Fins Heat Sink under Forced Convection

Mohanad Hatem[1], Hassan Abdellatif [2], Wadhah Hussein[3]

[1]Ph.D student in Dep. of Mechanical Engineering, Sudan University of Since and Technology, Iraq
[2]Associate professor in Dep. of Mechanical Engineering, Sudan University of Since and Technology, Khartoum
[3]Assistance Professor, Dept. of Mechanical Engineering, Tikrit University, Iraq

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Abstract - *As the CPU continues to work at a quick pace, it begins to generate heat. If this heat is not keep in check, the processor could burn and ultimately destroy itself. Luckily, CPUs include a heat sink, which dispels the heat from the processor, stopping it from overheating with the increase in heat dissipation from microelectronic devices and the reduction in overall form factors, thermal administration becomes a more and more important part of electronic product design. Perforations with circular cross section are along the length of direct pin fin and their number varies of perforate from 24 to 56 perforates. Higher performances for perforated fins are observed and effectiveness increased by increasing number of perforations. Higher reduction of weight of fins due to perforation is another major of utilization of the new type of fins structure.*

An experimental study conducted to investigate heat transfer by forced convection in a pin fin with circular perforations as heat sinks. The patterns of the perforations included 24 circular perforations (holes) for the first fin. Experiments carried out in an experimental facility that was specifically designed and constructed for this purpose. It detected that the temperature along the non-perforated fin dropped from 35 to 31°C, but the temperature drop for the perforated fins was from 35 to 29.8°C at low power (10 W). The temperature drop at the highest power (250 W) was from 300 to 55°C for the non-perforated fin and from 300 to 38°C for the perforated fins.

***Key Words*: forced convection, pin fin, circular perforated.**

1. Introduction

Extended surfaces, which are good heat transfer equipment that are widely used for various industrial applications [1]. Due to high request for lightweight, compact, and cost-effective fins, the optimization of fin size is of great importance. Many investigators have studied pin fins extensively. Pressure drag co-efficient and pressure drop due to perforation also considered, as these parameters are responsible for the effective and efficient cooling performance of heat sinks. For this consideration, laminar fluid flow and convective heat transfer around an array of solid and perforated fins analysed practically [2]. Fins having five perforations circular cross sections investigated. These perforations are along the fin and their cross section is perpendicular to the fluid flow direction. In this study, the upgrading in heat transfer coefficient, other thermal and hydraulic attributes of pin fin arrays with circular perforation has been investigate under laminar flow condition. Heat sink performance can be value by several factors: material, surface area, fin configuration, driving power and fan requirements. To obtain higher performance from a heat sink, more surface area, fewer weight, and minor cost are necessary. Thus, efforts to obtain more optimized designs for heat sinks needed to achieve high thermal performance. Most of the previous studies on pin fins or parallel plate fin heat sinks have considered the geometric configurations of the fins such as shape, size or orientations [3]. The study considers the benefits of perforating the pins with circular slot or notch perforations and shows that both of these can provide significantly enhanced rates of heat transfer while simultaneously reducing the fan power required to create the air motion over the heat sink, compared to corresponding solid pins. In addition, stated that perforated fins are higher value of heat transfer coefficient and Nusselt number and lower value of pressure drop. Decreasing the perforation dimension reduces the rate of temperature drop along the perforated fin. Heat transfer coefficient for perforated fin that contained a larger number of perforations higher than the perforated fin that contained a small number of perforations. It believed that comparing of the perforated fins with its solid compartment the best income to evaluate improvement or non-improvement in heat transfer brought about by introducing the perforations [4]. Temperature drop from fin base to fin top surface increases with addition of perforations. For fins with perforation, drag force reduces. In addition, drag ratio becomes smaller by increasing Reynolds number. Fins with the same porosity but larger window sizes have higher Nusselt number than fin with smaller windows. By increasing number of perforations, temperature difference between the fin base and fin tip becomes larger. By making window perforations and especially with increasing number of perforations, lighter fins that are more economical achieved [5].

1.1 Previous Studies

Fins are heat transfer enhancement devices become quite common. As extended surface technology continues to grow, new design ideas come forth; including fins made of anisotropic composites, porous media as well as perforated and interrupted plates (Bayram and Alparslan, 2008). Due to the requirement for lightweight, compact and economical fins, the optimisation of fin size is important. Consequently, fins must designed to achieve maximum heat removal with minimum material expenditure, thereby facilitating manufacture of the fin (Al-Essa and Al-Hussien, 2004). Many studies have investigated optimising fin shapes. Other studies have introduced shape adjustments by cutting some material from the 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 (Elshafei, 2010). One popular heat transfer augmentation technique involves the use of interrupted surfaces in different configurations. The interruption aims at promoting surface turbulence and mainly intended to increase the heat transfer coefficient of the surface area (Kutscher, 1994). It reported that non-flat surfaces have natural convection coefficients that are 50% to 100% greater than of flat surfaces (Chung and Layer, 1993). Many other researchers have reported a similar trend for interrupted, perforated and serrated surfaces, attributing the improvement to restarting the thermal boundary layer after each interruption, indicating that the increase in the convection coefficient is more than enough to offset the area lost, if any (Elshafei, 2010). A straight fin's concave parabolic profile provides maximum heat dissipation for a given profile area (Malekzadeh et al., 2006). For most applications, rectangular fins used to reduce the cost of manufacturing. Based on the widespread application of rectangular fins that normally used for heat exchangers, an understanding of the convection mechanisms and a prediction of the heat transfer performance of rectangular fins is important. These parameters are commonly analysed simultaneously by flow and heat transfer (Suksangpanomrung et al., 2007). Mousa (2000) theoretically analysed the thermal performance for a horizontal rectangular fin with a uniform cross-sectional area embedded with four vertical body perforation patterns that extended through the fin. The investigated patterns included triangular, square, circular and rectangular perforations. Natural convection with the finite element technique used to analyse these patterns. The analysis showed that the heat transfer of the perforated fins was greater than that of the non-perforated fin.

Heat transfer from extended surfaces for a given fin material, base temperature and ambient temperature can be enhanced by increasing the heat transfer coefficient and by increasing the effective heat transfer surface area (Shaeri and Yaghoubi, 2009). The heat transfer coefficient of the fin surface increased by introducing surface roughness and hence promoting turbulence. As for the surface area, the literature has introduced several methods to increase the effective the area of heat transfer of fins (Abdullah and Mohammed, 2009). This paper focuses on investigating the effect of increasing the number of perforations on the distribution of temperature, the heat transfer rate and the coefficient of heat transfer.

1.2 Problem Statement.

For many industrial applications, heat generation can cause overheating problems and occasionally goes to system failure. To overcome this problem, the efficient heat sinks are of the essence. Forced convection from these devices is one of the considered cooling techniques and played an important function in conserving their certain operation.

2. Objectives.

The main objective of this study is to investigate and analyze the uniform pin fins used for cooling of electronic devices in forced convection environment with perforations and augmentation that may provide an increase of the area of heat transfer, heat transfer coefficient, decreasing the thickness of thermal boundary layer.

Perforations are cut out from the fin body with various patterns such as circular, square, rectangular perforations. This study investigates the perforated and augmented models pin fins placed on a board in which heat generated and subjected to forced convection and Investigation of the optimum perforation patterns that would result in the best fin performance. To study the influence of using the perforated fin on the heat transfer heat exchanger (numerically and experimentally). Moreover, the effect of a number of variables such as pressure drop, number of perforations and the effect of perforations shape will be determined numerically using one of the available CFD package and Choosing the best physics preference for solving this problem. In this experiment, ANSYS Mechanical will be selected, and determine the best meshing element.

In other word, the aim of this research is to determine the effect of using perforated and enhancement fins on the heat transfer from a typical heat sink. In order to fulfill the objectives of the current study. Investigated and compared with those for the solid fins.

3. Experimental Setup.

Advances in heat transfer equipment such as heat sinks used in electronic devices and other systems have caused the optimization of fins as a major topic for fin design. The optimization of fins generally based on two approaches. One is to minimize the volume or mass for a given amount of heat dissipation and the other is to maximize heat dissipation for a given volume or mass. Fins frequently used in heat exchanging devices the purpose of increasing the heat transfer between a primary surface and the surrounding fluid.

Various types of heat exchanger fins, ranging from relatively simple shapes, such as rectangular, square, cylindrical, annular, tapered or pin fins, to a combination of different geometries, used. The fins of the plate-fin surfaces frequently cut into segments or otherwise interrupted in various ways. These modifications are for increasing the heat transfer coefficient and sometimes to increase the area of the heat transfer. The modifications by cutting some material from the fin to make cavities, holes, slots, grooves, or perforations through the fin body. Due to the high demand for lightweight, compact, and economical fins, the optimization of fin size is of great importance.

The fin industry is to reduce the fin size, weight and cost. The reduction in fin size and cost achieved by the enhancement of heat transfer carried out by the fins. This enhancement can accomplished by the following means:

- ❖ Increasing the heat transfer coefficient between the fin and its surroundings.
- ❖ Increasing the ratio of the heat transfer surface area of the fin to its volume.
- ❖ Manufacturing fins from materials having high thermal conductivity.

Perforated plates or perforated fins represent an example of surface interruption; this technique is to increase in convection coefficient is more than enough to offset lost area.

The experiments Conduct in an experimental facility that will be specifically designed and construction for this purpose. The experimental setup consisting of the following main parts:

1. Main duct (wind tunnel): manufactured from aluminum sheets to expel certain, while ensuring the flow of air through it on a regular basis to test sample.

2. Test section (heat sink): be chosen for experiments is soled brass sheet of certain dimensions and is the work of the holes inside sheet which heated by heating elements supplied power. Connecting pin fins made of aluminum specific measurements, including solid and perforated them in various forms (various patterns such as circular, square, rectangular perforations) on the outer surface of the sheet to become a test sample.

3. Data acquisition system: is consists from thermocouples, manometers, power supply regulator and computer.

4. Air blower: used to blow air through the tunnel in which the finned surface heat sink is mounted figure 1

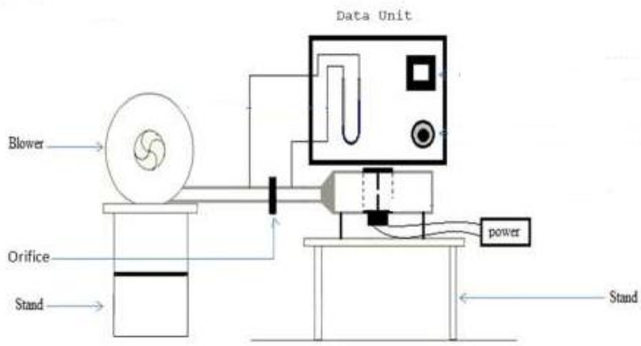

Figure.1 experimental setup used for study

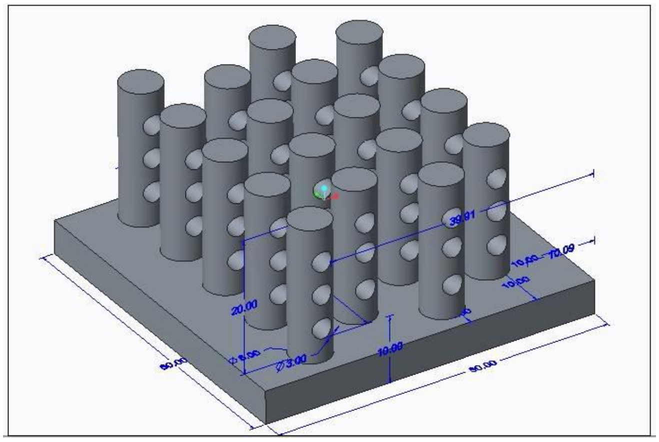

Figure.2 Perforated Drop shaped pin fin array

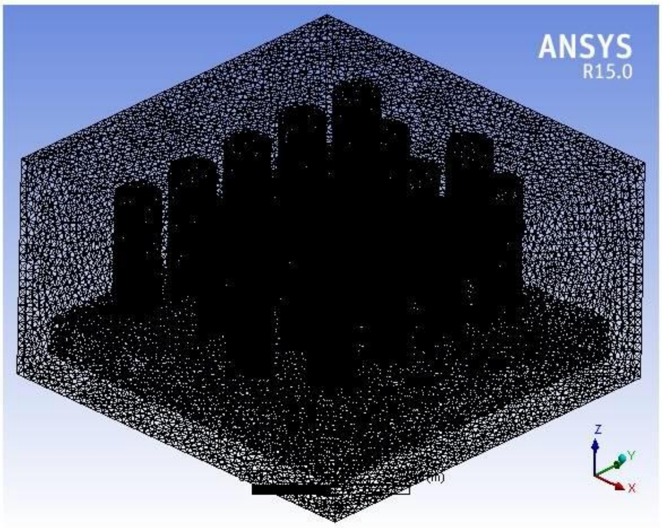

Figure.3 Mesh model for Perforated Circular pin fin array

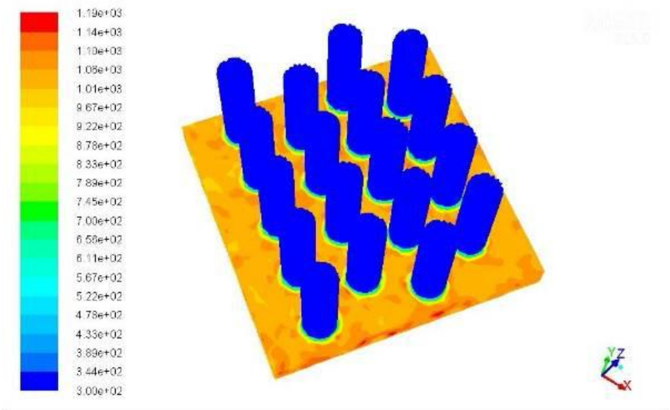

Figure.4 Temperature contour for Perforated Circular pin fin array

The Drop-shaped pin fin with the perforation will increases the contact between the airflow medium and pin fin arrays

This will increase the heat transfer when compared to the Circular and rectangular with perforations.

The following are the pressure results obtained in Histogram plots in ANSYS for circular in XY plot X-axis is for pressure quantity and for Y-axis is for position

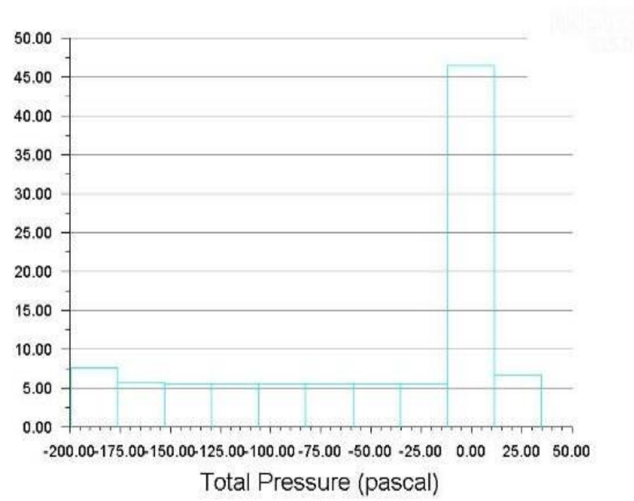

Figure.5 XY Plot for total pressure drop in a Circular pin fin array

The above fig shows the how the pressure varies with the positions of the pin fin array in rectangular duct where the forced air supply given by the blower for heat transfer. The pin fin array heated by using the heater with heat flux of 5000W/m2 and the heat transfer occurred with forced convection. The perforated round pins seem to have a wider separation region in the back, marked by a very small velocity indicating the discontinuity of the flow streamlines and the circulation of the flow downstream of the pins. This problem solved by changing the pin geometry and using the Drop-shaped pin fins. The main advantage in delaying the separation in reattaching the flow after the separation is the decreases in the pressure drop mainly due to the frictional drag in the case of the drop pins. This proves that decreases in pressure drop increases the heat transfer

4. Result and Discussion.

The various observation are made like heat input q i.e., Q_{conv}. In W, mean temperature over the fins Tm1 in °C mean outside temperature Tm2 in °C, temperature difference

ΔT in °C and h heat transfer rate in W/mm2 °C for solid pin fin, one whole pin fin, and two holes pin fin, and three holes pin fins and the result shows that heat transfer increases with number of perforations, when solid fins compared with 3 holes pin fin it is find out that h increases with about 30 to 40%.Also the temperature difference decreases with increase of number of perforation. This shows that low temperature difference leads to high heat transfer.

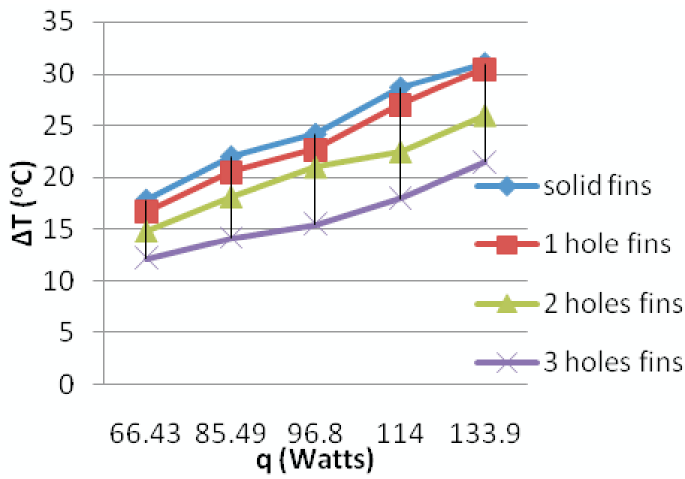

Figure 6: Graph between 'q' on X-axis and Temperature Difference 'ΔT' on Y-axis

Above graph shows that difference between the temperatures for different types of fins used in this experiment. The value of temperature difference is less for three holes fins as compared to other fins. Hence, that will be the reason for more convective heat transfer

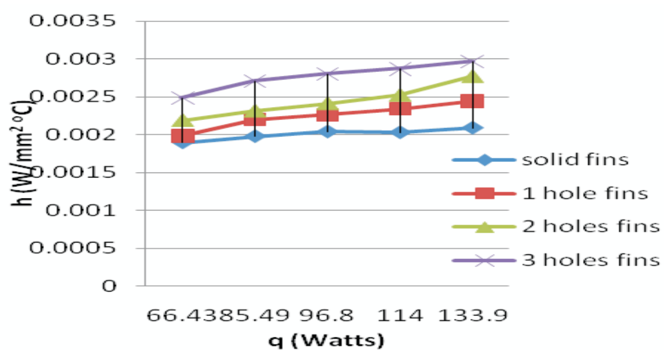

Figure 7: Graph between 'q' on X-axis and 'h' on Y-axis

Figure.7 shows the dissimilarity of the h with respect to q i.e., Q_{conv}. For all types of fins. Here the value of h varies from 0.00189748 W/mm2oC to maximum of 0.00297 W/mm2oC. Which shows that with increase of perforation value of h increases.

5. CONCLUSIONS

The Conclusion of this experiment is that,

a) Convective heat transfer is more in perforated pin fin as compared to solid pin fin. Hence, we can use the perforated fins over various applications where solid fins are used. The value of temperature difference increases with number of perforations and the surface area increases.

b) In this project, we used 4 types of fins, hence 3hole fin is more efficient than other fins used in experiment. The value of convective heat transfer increase by 30 to 40%. The temperature difference vary from 17 to 31oC for solid fins, 16 to 30 °C for 1 hole fins, 14 to 26 °C for 2

Holes fins, 12 to 21 °C for 3hole fins for various values of q.

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AUTHORS

1. MOHANAD HATEM FEZEA

Ph.D. Student in Dep. of Mechanical Engineering, Sudan University of Since and Technology, Iraq

2. Hassan Abdellatif

Associate Professor in Dep. of Mechanical Engineering, Sudan University of Since and Technology, Khartoum

3. Wadhah Hussein

Assistance Professor, Dept. of Mechanical Engineering, Tikrit University, Iraq