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Forced Convection Heat Transfer Enhancement from Heat Sinks using Perforated Fins: A Review

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Abstract— **The present review paper focus on the analysis of the heat transfer enhancement and the considerable pressure drop below a flat surface equipped with Various forms of perforated fins in a rectangular channel. Heat sinks are widely employed in electronics industries for lowering the temperature to avoid any damage of integrated circuits and improve its overall performance. Fins play key role in heat sinks. The various geometrical aspects of the fin as well as material properties plays vital role in heat transfer rate. These properties should be optimized to obtain maximum possible thermal efficiency. Lot of researches are done by researchers to obtain the relation between various thermodynamic properties such as heat, temperature gradient due to ambient conditions. The heat transfer is enhanced by optimizing the geometrical aspects of the heat sink. As the geometrical aspects have higher impact on overall results. this review paper investigate how the fin arrangement (staggered or in-line), orientation, perforation and geometry affect heat transfer and friction characteristics of convective heat transfer in a force convection.**

Index Terms— **Forced Convection, Perforated Fins, Heat Sink.**

I. INTRODUCTION

Heat sinks are devices that enhance heat dissipation from a hot surface, usually the case of a heat-generating component, to cooler ambient, usually air. In most situations, heat transfer across the interface between the solid surface and the coolant air is the least efficient within the system, and the solid-air interface represents the greatest barrier for heat dissipation. A heat sink lowers this barrier mainly by increasing the surface area that is in direct contact with the coolant. This allows more heat to be dissipated and/or lowers the device operating temperature. The primary purpose of a heat sink is to maintain the device temperature below the maximum allowable temperature specified by the device manufacturers.

In selecting an appropriate heat sink that meets the required thermal criteria, one needs to examine various parameters that affect not only the heat sink performance itself, but also the overall performance of the system. The choice of particular type of heat sink depends largely on the thermal budget allowed for the heat sink and external conditions surrounding the heat sink. It is to be emphasized that there can never be a single value of thermal resistance assigned to a given heat sink, since the thermal resistance varies with external cooling conditions. When selecting a heat sink, it is necessary to classify the airflow as natural, low flow mixed, or high flow forced convection. Natural convection occurs when there is no externally induced flow and heat transfer relies solely on the free buoyant flow of air surrounding the heat sink. Forced convection occurs when the flow of air is induced by mechanical means, usually a fan or blower. There is no clear distinction on the flow velocity that separates the mixed and forced flow regimes.

In order words, natural convection is very simple and cost effective yet is generally only suitable for lower power density application. Forced convection is cost and capable of removing a greater amount of heat than by natural convection but required a large volumetric air supply. Liquid cooled heat sinks provide the highest thermal performance per unit volume and higher cost

II. LITERATURE REVIEW

Rasim Karabacak , Gülay Yakar [1] experimentally studied the effect of holes placed on perforated finned heat exchangers on convective heat transfer. Six millimeter diameter holes on each circular fin on a heating tube in order to increase convective heat transfer. The holes created turbulence in a region near the heating tube surface on the bottom of the fin. They performed to analyze the effect of this turbulence on heat transfer with pressure drop. In this experiment there are six different angular locations to find the best angular location. They observe the differences between, perforated finned heaters along with imperforate finned heater with both additions. Re above the critical value, then Nusselt numbers for the perforated finned positions are 12% larger than the imperforate state. The correlation has been obtained between the Re and Nu in the Re number above and below the critical value.

K.Dhanawade and V.Sunnapwar et.al. [2], they have done the thermal analysis of square and circular perforated fin array by forced convection. They have varied the size of perforation for the analysis i.e. 10mm square, 8mm square, and 6mm square and for circular perforation 10mm, 8mm, 6mm diameter. The result obtained showed that the Nusselt numbers increased with increase in Reynolds number, thermal friction increased with increase in perforation and use of perforated fin increase the heat transfer and also there is reduction in weight, saving of material that ultimately decreases the expenditure on fin material.

Md. Farhad Ismail et al. [3], it reviews that fins having the square and circular perforation along the fin length to raise the cooling performance of heat sink. The 3-D fluid flow and convective heat transfer from an array of solid and perforated fins that are mounted on flat plate has been investigated. It

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shows that fins of circular perforations have remarkable heat transfer growth and less pressure drop. This study result in designing micro heat sinks for heat dissipation from electronic devices.

M. Ali, Tabassum et.al. [4], they have performed thermal and hydraulic analysis of rectangular fin arrays with different perforation size and number. They have done experiment study by taking base area 1088 mm . They varied perforation from 0 to 2, and varied perforation diameter form 0mm to 3mm. The results showed that heat transfer and pressure drop increased with increase in Reynolds number for all fins. With experiments it was found that with more or larger perforations the efficiency and effectiveness increased, whereas the thermal resistance and pressure drop decreased.

A.B.Ganorkar, V.M.Kriplani [5], studied whole performance of suitable designed lateral perforated fins in a rectangular channel. Different type of perforated fins are used in the rectangular channel. Effect of perforated fins in a rectangular channel is observed for other Reynolds numbers. In respect of the Nusselt numbers as well as heat transfer coefficient were analyzed. Reynolds number range taken 2500-10000, diameter range of perforated holes 6-10 mm. As Re number raises the ratio of ($Nu_{Perforated}$ /Nu_{Solid}) fin increases. Increase in no. of holes, the ratio ($Nu_{Perforated}$ /Nu_{Solid}) increases. Increase in diameter of holes the ratio ($Nu_{perforated}$ /Nu_{Solid}) increases. The enhancement of ($Nu_{Perforated}$ /Nu_{Solid}) is not significant with increase in no. of holes.

O.N. Sara [6], the paper shows that the convective heat transfer through a rectangular channel with square cross-section fins mounted below a flat surface. The experimental outcomes showed that use of square fins may cause to benefit on the basis of heat transfer augmentation. For higher heat transfer performance, less inter-fin distance ratio clearance ratio so that comparatively less Reynolds numbers should be important for the zigzagged arrangement. They found that the average Nusselt number enhancing with reducing -fin distance clearance ratio and inter ratio, the friction factor enhancing with reducing clearance as well as inter-fin distance ratio.

Kai-Shing Yang , Wei-Hsin Chu [7], performs an experimental study of pin fin heat sinks having circular, elliptic, and square cross -section. A total of twelve pin fin heat sinks with inline and staggered arrangements were made and tested. The effect of fin density on the heat transfer performance is examined. For an inline arrangement, the circular pin fin shows an appreciable influence of fin density whereas no effect of fin density is seen for square fin geometry. This is associated with the unique deflection flow pattern accompanied with the inline circular fin configuration. For the staggered arrangement, the heat transfer coefficient increases with the rise of fin density for all the three configurations. The elliptic pin fin shows the lowest pressure drops. For the same surface area at a fixed pumping power, the elliptic pin fin possesses the smallest thermal resistance for the staggered arrangement. One of the reasons for superior performance of circular pin fin under inline arrangement is associated with the unique deflection flow. For a staggered arrangement where deflection flow pattern vanishes, the elliptic pin fin yields slightly better performance than circular pin fin surface.

Kavita H. Dhanawade et at.[8], experimental to investigate the heat transfer Enhancement over horizontal flat plate surface with rectangular fin arrays will lateral square and circular perforation by force convection They varied sizes of perforation as well as Re from $2.1x10^4$ to $8.7x10^4$.They found that average of percentage improvement of square perforated fin is more than that of the fin array of circular perforated fin of same size. Friction factor slightly increases with increase in the size of perforation. This type of arrays can becomes for air cooling of IC engines and other industrial application.

Bayram Sahin , Alparslan Demir [9],carried out the performance of heat transfer Augmentation with related pressure drop through a rectangular channel with circular fins attached to a flat surface. Reynolds number ranges are selected for this experiment 13500–42,000.They defined the clearance ratio of space above fins to the height of fin in rectangular channel. They found that average Nusselt number and friction factor enhanced with reducing clearance ratio and interfin spacing ratio. Rise of the efficiencies varied at middle 1.1 and 1.9 reliant for both the ratio.

Ahmad Khoshnevis et al. [10], carried out the effect of extended surface perforation on heat transfer augmentation of a 3-D channel with a ground attached heater. Two types of perforation are studied, Hole and slot. Ranges of work: Re number 6000-40000 and open area perforation ratio 0.05 to 0.15 perforation inclination angle: 0<o<45. t. Their results show significant augmentation in heat transfer and pressure drop by increases the perforation area due to disorganizing the thermal traps between the ribs.

Giovanni Tanda [11], studied heat transfer and pressure drop experiments were performed for a rectangular channel equipped with arrays of diamond-shaped elements. Both in-line and staggered fin arrays were considered, for values of the longitudinal and trans verse spacing's, relative to the diamond side, from 4 to 8 and from 4 to 8.5, respectively. The height-to-side ratio of the diamonds was 4.0. Liquid crystal thermography was used to determine the heat transfer coefficients on the surface of the channel (endwall) on which th e fins were mounted. Local

variations in heat transfer coefficients induced by the arrangements of the diamond -shaped elements were measured and discussed. Correlations giving the average Nusselt number for each configuration as a function of the Reynolds number were developed. Thermal performance comparisons with data for a rectangular channel without fins showed that the presence of the diamond-shaped elements enhanced heat transfer by a factor of up to 4.4 for equal mass flow rate and by a factor of up to 1.65 for equal pumping power.

Yatendra Singh Tomar, M. M. Sahu [12], studied that the thermal resistance and pressure drop are considered as the multiple thermal performance characteristics. he effects of geometric parameters, fin height, fin diameter fin material and base-to ambient temperature difference on the heat transfer performance of fin arrays and the optimum fin separation value has been determined. The studies have shown that the convection heat transfer rate from fin arrays depends on all geometric parameter, fin material and base-to-ambient temperature difference. Heat transfer increases with the increase in approach velocity, pin diameter, and number of pins. The effect of fin density on the heat transfer performance is examined Heat transfer also increases with the thermal conductivity of the material and with the pin height. In line arrangement gives higher heat sink resistance and lower pressure drop than the staggered arrangement. Heat transfer models for in-line and staggered arrangements are suitable in designing pin-fin heat sinks. The effect on Re on the behavior the channel are also studies.

Abdullah H. AlEssa, Mohamad I. Al-Widyan [13], studied heat transfer enhancement from a horizontal rectangular fin embedded with triangular perforations under natural convection. The fins heat dissipation rate compared to that of an equivalent solid one. Geometrical dimensions and thermal properties of the fin and the perforations are the parameters considered. Their study shows that the heat dissipation from the perforated fin for a certain range of triangular perforation dimensions and spaces between perforations result in improvement in heat transfer over the equivalent solid fin. The heat transfer enhancement of the perforated fin increases as the fin thermal conductivity and its thickness are increased.

Wadhah Hussein[14], conducted experimental study to investigate heat transfer by natural convection in rectangular fin plates with circular perforations as heat sinks. The pattern of the perforations included 24 circular perforations for the first fin, and the perforations were increased as 8 for each fin to 56 in fifth fin. They distributed the perforations in 6-14 rows and four columns. They observed that the temperature along the non-perforated fins was from 30 to 23.7^{o} at lower power 6 W. They observed that the drop in temperature between the fin base and the tip increased as the diameter of perforations increased. The temperature drop at t he highest power of 220 W was from 250 to 49^{o}C for non-perforated fins. They concluded that the heat transfer rate and the coefficient of heat
transfer increased with increased number of perforations.

A. A. Kanaskar, V. M. Kriplani, P.V. Walke [15], studied to enhance the heat transfer between the primary surface and surrounding fluid, extended surfaces (fins) are frequently used as heat exchange devices . The fins are widely used for various industrial applications. Various types of fins such as rectangular, square, annular, tapered or pin fins or combination of different geometries have been used. Pin fins which are commonly used may be cylindrical or any other shaped attached to the wall of heat transfer fluid passing cross flow to the pin fins. Short fins are widely used in gas turbines blades, electronic cooling, and aerospace industries. Long fins have applications where attainment of high heat transfer is major concerned. Fins provide large total surface area without the use of a large primary surface area. This paper contains literature survey which involved thermal enhancement from heat sinks by using perforated fins.

Amol B. Dhumne, Hemant S. Farkade [16], studied the experimental analysis of on heat transfer enhancement and the corresponding pressure drop over a flat surface equipped with cylindrical cross –sectional perforated pin fins in a rectangular channel. The channel had a cross sectional area of 250-100 mm2. The experiments covered the following range: Reynolds number 13,500–42,000, the clearance ratio (C/H) 0, 0.33 and 1, the inter-fin spacing ratio (Sy/D) 1.208, 1.524, 1.944 and 3.417. Nusselt number and Reynolds number were considered as performance parameters. Correlation equations were developed for the heat transfer, friction factor and enhancement efficiency. The experimental implementation shows that the use of the cylindrical perforated pin fins leads to heat transfer enhancement than the solid cylindrical fins. Enhancement efficiencies vary depending on the clearance ratio and inter-fin spacing ratio. Both lower clearance ratio and lower inter-fin spacing ratio and comparatively lower Reynolds numbers are suggested for higher thermal performance.

R. Karthikeyan , R. Rathnasamy [17], studied that the heat transfer and friction characteristics of convective heat transfer through a rectangular channel with cylindrical and square cross-section pin-fins attached over a rectangular duralumin flat surface. The pin-fins were arranged in in-line and a staggered manner. Various clearance ratios (C/H=0.0, 0.5&1.0) and inter-fin distance ratios (Sy/d and Sx/d) were used. The experiments are conducted for various mass flow rate of air (Re ranges from 2000-25000). The experimental results showed that the use of square cross-section pin-fins may lead to an advantage on the basis of heat transfer enhancement. For higher thermal performance, lower inter fin distance ratio and clearance ratio and comparatively lower Reynolds numbers should be preferred for in-line and staggered arrangement. The results of the in-line configurations were also compared with the results of the staggered arrangements for the two types of pin-fins and the average Nusselt number increased with increasing Reynolds number the average Nusselt number increased with decreasing clearance ratio and inter-fin distance ratio. For a given Reynolds number, the pin-fin array with smaller inters fin distance gives higher performance than those with higher inter fin distances. the friction factor increased with decreasing clearance ratio and inter-fin distance ratio. the staggered pin-fin array significantly enhanced heat transfer as a result turbulence at the expense of higher pressure drop in the wind tunnel. Square pin -fin array performance is slightly higher than the cylindrical array with the penalty of pressure drop.

K. Kumar, Vinay et.al. [18], they performed thermal and structural analysis of tree shaped fin array. They had taken tree shaped fin with slots and tree shaped fin without slots for their analysis. They also studied the effect of material on the results for the same geometries by taking aluminum alloy, structural steel and copper alloy for the same. The results obtained showed that the capabilities of the slotted tree fins are better than without slotted tree fins. According to material the copper fins with slots was best for heat transfer among all the fins. The aluminum slotted fin was found most effective as it has effective heat transfer without deformation among all the fins taken for the study.

Mehedi Ehteshum et al.[19], the paper review that in designing heat exchanger equipment heat removal and reduction of fin size becomes major task. The present paper focus on experimental analysis to evaluate the turbulent heat transfer performance of rectangular fin arrays, both solid end circular perforation along the length of the fins. Experiment carried out with variation in the size and number of circular perforation in a horizontal wind tunnel with force draft fan. the Reynolds no is taken between 6×10^{4} through 25×10^{4} .Thermal performances and effectiveness of perforation compared with solid fin arrays have been evaluated result in remarkable heat transfer augmentation, lower thermal resistances, pressure drop and higher efficiencies ,effectiveness for perforated fin with increasing the perforation number in addition to the considerable reduction in weight compared to solid fin arrays.

M. R. Shaeri et al. [20], in this paper a 3-D array of fins with rectangular perforation are arranged in lateral surface of fins in which the fluid flows and conjugates conduction-convection heat transfer are studied numerically. Investigations are carried out using Navier-Strokes equations and RNG Reynolds number of 2000-5000 for solid and gas phases are computed. With previous experimental studied has been validated by numerical model and good agreements were observed, with a valid model. To find fluid flow and temperature distribution for various
arrangement numerical solutions is conducted. Determination is done for each type, fin efficiency of perforated fins and compared with equivalent solid fins. It result in higher heat transfer with new perforated fins and there is considerable weight reduction compared to solid fins.

Monoj Baruah el at. [21], they carried out the computational investigation to assess the heat transfer and pressure drop characteristics of elliptical pin fins arranged in a rectangular duct in a staggered manner. They considered solid as well as perforated elliptical pin fins with three perforations. The heat transfer and pressure drop characteristics along the computational domain are presented and the overall performance, which they defined as the heat transfer per unit pressure drop of the heat exchanger. The results show that the perforated elliptical pin fins perform better than the solid pin fin both in terms of heat transfer and pressure drop characteristics. They claimed that by changing the solid elliptical fin into the perforated elliptical pin fin, the pressure drop decreases by an average of 12% and heat transfer increases by 23% by introducing perforations and this performance may be further improved by increasing the numbers of perforations in elliptical pin fin.

Cheng-Hung Huang et al.[22], in this paper a 3-D inverse design problem is studied, the work employing general purpose commercial code CFD-ACE+ and Levenberg-Marquardt Method. The analysis includes of three cases. In design #1, Using 5 design variables to approximate the optimal perforation diameters and the aim are to reduce ambient temperature and pressure drop of the pin fin array. In design #2, four design variables to define the optimal perforation diameters depend on the minimization of ambient temperature and pressure drop. In design #3, all the perforation diameter are decided identical and use only one parameter to define optimal perforation diameter depending on the reduction of ambient temperature and pressure drop. The numerical design concluded that, for all six design considered here the design optimal heat sinks result in the lowest average base plate temperature decreasing from 6.3% to 7.3% when compared with solid pin fin array.

H. Saadat, et.al.[23], Studied In this study, an experimental investigation is conducted in order to analyze heat transfer characteristics of a new type of perforated fins. according to the results, they found that the temperatures of the fin at thermocouple locations are decreased by increasing flow Reynolds number, the fin surface temperature increased in the streamwise direction with the maximum surface temperatures correspond to the middle location of the fin. The average convection heat transfer coefficient increased with increasing flow Reynolds number and some improvements of heat transfer performance are observed with the current perforation arrangement in comparison with previous study.

CONCLUSIONS

The researchers investigators have studied the problems concerned with various fin geometries, extensively both theoretically and experimentally. Out of which the interrupted fins to improve the convective heat transfer under forced convection. Based on the studies undertaken in literature review it can be said the following:

The fin efficiency of perforated fin is greater than the solid fin. Perforated fins are light in weight, so decrease the manufacturing cost. so, weight reduction is remarkable and this economical benefit is Salong with more enhancement heat transfer rate.

A proper selection of interruption length leads to a higher thermal performance.

Extended surfaces are the better method of enhancement heat transfer.

The perforated materials can have better strength. In case of perforated fins there is higher contact area with fluid in comparison with solid fins result in average friction drag force for perforated fins compare to solid fins and also increase by adding perforations. There is drop in temperature from fin base to fin top surface increases with number of perforations .Increasing perforations.

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