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EXPERIMENTAL OPTIMIZATION OF HEAT SINK STRUCTURE AFTER NANO-COATING EXERTION UNDER AMBIENT CONDITION

Engineering

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ABSTRACT

Fins are commonly employed to enhance the heat transmission from the source. In order to determine the performance of heat transfer characteristics, an examination into several shapes, including honeycomb, radial, and flared, is conducted. On the basis of free convection, experiments are conducted. There is a determination of the well-known heat transfer characteristics, such as thermal resistance, coefficient of heat transfer, local heat transfer, and Nusselt number. Furthermore, an effort was made to investigate Nano Coating and establish a correlation between shape and heat transfer. The results demonstrated that under constant heating power, the honeycomb form had a lower thermal resistance of 28.88% and a higher free convective heat transfer coefficient of 25.19% when compared to other shapes.

KEYWORDS

Fins, Heat Transfer, Natural Convection, Nano Coatings, Optimization.

INTRODUCTION

Fins are surfaces that protrude from devices to increase the rate of heat transfer. Electronic cooling systems frequently use finned or extended surfaces. Enhancement of heat transfer is a powerful tool used to raise the temperature performance and rate of heat transfer. Increases in the rate of heat transfer are more common in electrical devices and components since they must function at their intended efficiency. Every day, more and more fins with minimal weight and maximum heat transfer are required. Heat transfer from a finned heat sink is dependent on a number of factors, including the fin's size, shape, and composition.

Grooves and perforations improve heat transfer, according to research by Adeel Tariq et al. [1]. Heat transport is still primarily influenced by fin height, fin spacing, and fin length [2–3]. An major factor in enhancing heat transfer is topography and mounting angle [4-5,16]. Heat transport is improved by optimizing variously shaped heat sinks [6–8, 17]. For the purpose of enhancing heat transport, several parameters are computed and relationships are found [9-15]. Heat transport is enhanced in large part by fin orientation [18–20].

A review of the literature revealed that fewer attempts have been made to understand how various geometrical structures, such as honeycomb, radial, and flared, are affected by the parameters that govern heat transport. Using a L9 orthogonal array under free convection, tests are conducted based on Taguchi's Design of tests (DOE). Thermal resistance, the coefficient of heat transfer, and the Nusselt number—three important heat transfer parameters—are ascertained. The experiment was conducted using nano coatings, which also helped to determine the heat sink's performance.

Literature Review

The literature review indicates that a heat transfer model heat sink with grooves and perforations of the plate fin type was studied and it was discovered that the grooves and holes in the plate fin improved the heat transfer coefficient and required less fan power.[1]. A numerical analysis of vertical rectangular fins reveals that the displacement of fin spacing reduces thermal resistance, and that fin length comes in second place for the primary source of thermal enhancement. The effect on fin height and heat flux are found to be negligible.It is discovered that the impact on fin height and heat flux is minimal [2]. The statistical and analytical study finds the ideal fin length, fin material, fin height, fin space and optimum heat design of heat sink and thermoelectric generator in order to improve the performance efficiency [3] Under free convection the performance of heat dissipation on heat sink with mounting angle are tested using experimental and numerical simulation method. With 90º mounting angle the heat sink achieved towering cooling power also cutting of heat transfer stagnation zone improves performance of heat sink [4]. In free convection thermal expansion for heat sinks are done by using the topology method of optimization and are obtained that the heat sink with topology optimization has less thermal resistance and lower mass of material than the normal heat sink [5]. Heat sink with perforated pin fin using staggered and linear arrangements is investigated for the amplification of heat transfer. The perforations are of different shapes like elliptical, diamond and circular. CFD simulation shows the effects on fin shape, spacing and number of perforations. The result found are better heat performance in staggered arrangement also showed pressure drop decrease with increase in perforations. Exergy analysis is also performed [6]. Better results of heat transfer on rectangular fins of radial heat sink using perforated ring are obtained by free convection. Best thermal performance is obtained for upwardly oriented heat sink compared to sideward orientation [7]. Natural convection on internally finned tubes which is oriented vertically and performed analytically to obtain the best geometry by maximizing the convective heat transfer coefficient [8]. 3-D laminar flow using FLUENT determines the heat transfer by natural convection and flow of fluid features of plate finned tube and circular tube heat exchanger. Different correlations are obtained with reference to Nusselt and Rayleigh number [9]. Based on CFD method, a numerical model of natural convection is built. The analysis of distribution on cylinder and fin surface of local Nusselt number are done and found a new correlation with 93% accurate data being in ±10% deviation [10]. The computational analysis on conjugate model with single, rectangular slotted perforated heat sink is done and noticed that with the growth in size of rectangular perforation there is monotonical rise in heat transfer and depletion in pressure drop [11]. A numerical and experimental investigation are done on chimney which is based on radial shaped heat sink using natural convection and the results are compared with the heat sink which is radial and without chimney. Thermal performance is found to be better with 0° and 45° orientation [12]. Rectangular fins heat sink which is of radial type with circular base and concentric ring are exposed to free convection using quantitative and experimental techniques to obtain heat transfer characteristics and a correlation are determined to find the thermal performance [13]. Experimentation and numerical analysis of rectangular fins of radial heat sinks are subjected to free convection with 0° and 180° orientation. Thermal performance is slightly better with 0° orientation [14]. Experimental and CFD examination on perforated pin fin is studied and found that with the increase in number of perforations there is greatly increases in Nusselt number [15]. The study is made on characteristics of heat transfer having impression on the surface of fin. The results are the rate of heat transfer can be enhanced effectively by embossed impressions [16]. A numerical investigation on different shape thin fin array on a horizontal base plate are performed. Radiation heat transfer is also considered along with natural convection. A conjugate analysis is carried and optimum fin shape better than rectangular fins is found [17]. Numerical and experimentational study on the effect on interruptions on rectangular heat fins which are vertically mounted. The increase in heat flux is observed from heat sink with the addition of interruptions [18].

Perforations are introduced to improve the free air flow from the bottom of the fin base and found that the enhancement in overall convective heat transfer with the increasing in total perforation length [19]. Numerical investigation on rectangular cross section vertical plate fins to obtain a validated model which can be used to investigate the heat sinks of inclined orientation. For convective heat transfer a dimensionless corelation is found [20].

The coefficients of heat transfer for short and long fin arrays are larger. The heat flux decreases with decrease in heat transfer coefficient and growth in length [21]. Experimental investigation is accomplished in mixed convection for elliptical and circular pin fin heat sinks in order to examine different parameters. The staggered arrangement has better heat transfer coefficient compared to inline arrangement [22]. An experimentally validated model of heat sink which is finned using inclined plate is numerically investigated and estimated the convective heat transfer rates using scale analysis [23]. Numerical and Experimental study on radial heat sink with rectangular fins and horizontal base are carried out to obtain the consequences of three parameters and found that thermal resistance and coefficient of heat transfer decreases with growth in fin length, height and number [24]. An experimental examination is done to examine the performance parameters like distance from the fin and the fan, the amount of supplied heat to the fin and fan etc. The results showed that the design of heat sink is suitable for thermoelectric applications [25]. Experimental evaluation is performed on spiral fins and found that the perforations are the best way to expedite natural convection. These perforations help to achieve stronger natural convection compared to the solid fin.44% enhancement is obtained in average Nusselt number compared to solid fin.[26] Numerical evaluation is performed on Split hemispherical fins which are placed on base plate. Nusselt number, Pressure drop and Reynolds number are found using thermal and flow analysis. Results shows that the Nusselt number for cylinder fin is around 1.4 times greater than split hemispherical fins which in turn leads to 1.5 times higher pressure drop of cylindrical fin for the given Reynolds number which ranges from 3000 to 5000.[27] It is discovered that the impact on fin height and heat flux is minimal.A numerical analysis of vertical rectangular fins reveals that the displacement of fin spacing reduces thermal resistance, and that fin length comes in second place for the primary source of thermal enhancement.

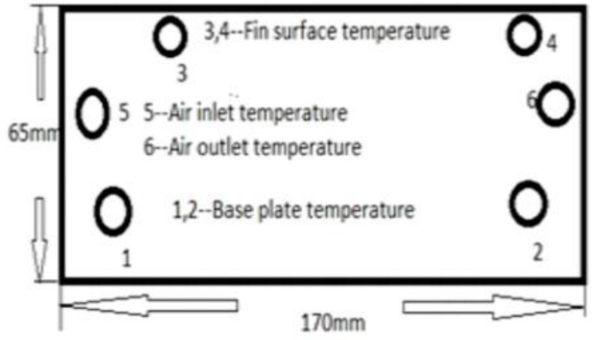
This article helps us understand pinfin heat sinks better. Heat transfer efficiency is influenced by a number of variables, including spacing, geometries, and orientations. Another important component of heat-dissipating systems is perforations.[28] It is discovered that the impact on fin height and heat flux is minimal.A numerical analysis of vertical rectangular fins reveals that the displacement of fin spacing reduces thermal resistance, and that fin length comes in second place for the primary source of thermal enhancement. A variety of simple-shaped fin designs are taken into consideration for optimization, with the option to increase heat dissipation while maintaining a constant fin weight or decrease fin weight while maintaining a constant heat dissipation. With the help of different thermos physical qualities and geometries, heat transport is intended to be enhanced. [29]

Methods

Fabrication process

Figure1: Test Rig

Figure 2: Test rig Instrumentation



A panel with a digital voltage tester, an ammeter, a flow control valve, a dimmerstat, and a gate valve makes up the experimental setup. The test duct is 70 mm by 100 mm by 190 mm. Air is the fluid utilized for convection, and the turbulence flow type is selected. The blower is not operating. Here, a disparity in densities causes convection to occur.

After achieving steady-state readings of current, voltage, and all temperatures, the mains are turned on for free convection. The heater control knob is then turned to determine the necessary voltage. Brass heat sinks with varying shapes are examined using the test apparatus seen in figure 1. The heat inputs are changed to repeat the experiment. After conducting a voltmeter uncertainty analysis, the result was + 0.01 volts.

Further the heat sinks are coated with graphene nano coatings to increase the rate of heat transfer. All the different parameters are calculated. Later the obtained results are compared with the uncoated ones to check its performance.

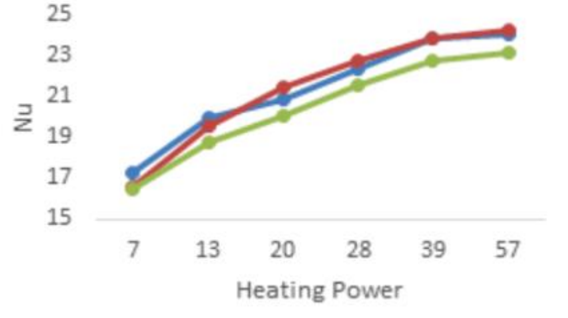


Figure 3: Comparison of Nusselt number

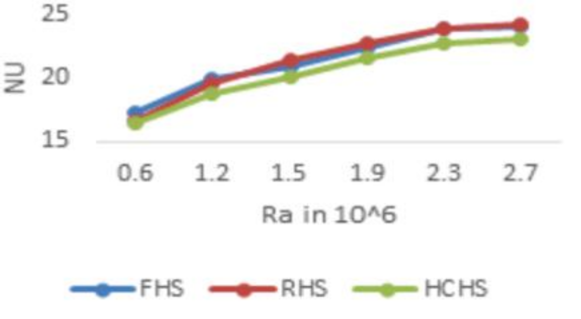


Figure 4: Variation of Nusselt number w.r.t Rayleigh number

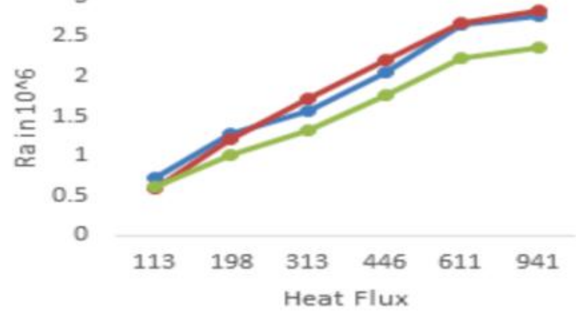


Figure 5: Comparison of Rayleigh Number

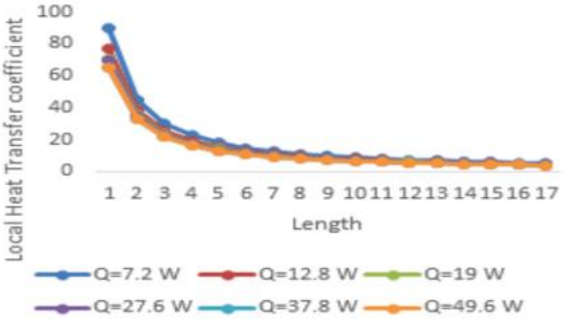


Figure 6: Temperature (steady state) for radial heat sink

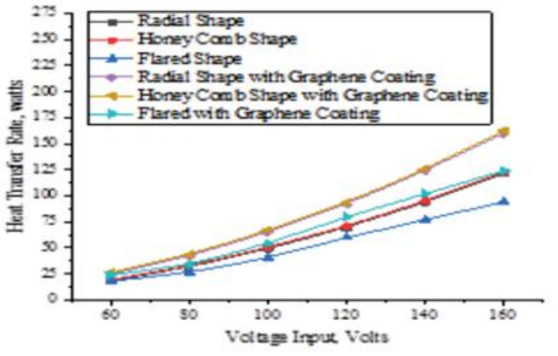


Figure 7: Comparison of heat transfer rate with coating

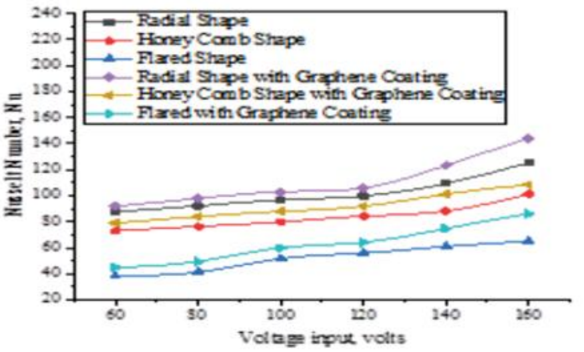


Figure 8: Nusselt number comparison with coating

Figure 3and 4. shows that the Nusselt number rises with the rise in heating power and Rayleigh number for radial, flared and honey comb shaped heat sink respectively. Because of difference in density the fluid's thermal conductivity enhances with the rise in heat transfer from the surface due to which the enhancement of Nusselt number is observed and the variation is as similar [33,34,35]. Nusselt number is calculated using equation 2

Figure 5. shows the increasing trend of Rayleigh number with the enhancement in heat flux for flared, radial and honey comb shaped heat sink. The fluid motion accelerates with the rise in Rayleigh number which increases the convective heat transfer. Rayleigh number is found slightly less with a honeycomb-shaped heat sink compared to flared shaped heat sink and radial-shaped heat sink. This is due to the density difference and the results are in line with the literature [35]

Figure 6. displays the deviation of local heat transfer coefficient with the elevation in length of heat sink for radial shaped heat sink respectively. The local heat transfer for different heat inputs is determined and found that the heat transfer is inversely proportional to length of the heat sink.

Figure 7 shows the comparison of forced convection heat transfer rate with voltage input for the different heat sinks with and without coating. Heat generation is proportional to the power dissipation, and power is defined as voltage times current. From the figure 7 it is noticed that the heat transfer increases with the increase in voltage. Among the different shaped heat sinks radial-shaped heat sink showed higher heat transfer rates compared to Honey comb and flared respectively [40.17% &23.15%]. Further the nano coated radial and Honey comb heat sinks showed higher heat transfer by 57.2% and 61.7% compared to their uncoated ones. This is attributed to the fact that for the same voltage input, the nano-coated surfaces with higher thermal conductivity exhibited higher temperature difference compared to that without coated ones. The similar behaviour is followed by the flared heat sink but however the heat transfer rates were comparatively lower.

Figure 8 shows the variation of Nusselt Number vs voltage input for coated and uncoated heat sinks in forced convection mode of heat transfer. Nusselt number increases with increase in voltage due to increased heat transfer coefficient as is evident in Figure 8. Coated heat sinks showed higher Nusselt number due to enhanced heat transfer rates. Among the heat sinks graphene coated radial showed higher Nusselt number followed by honey comb and flared heat sinks respectively.

Table 6. Comparison of present experiment with the previous work.

Sl. No.	Authors	Shape of the fin considered	Type of Heat transfer and Analysis	Remarks
1	Fengming Wang, JingzhouZhang, SuofangWang	Circular, Elliptical and drop shaped pin fins	Computational and Experimental	Heat transfer is more in pin fin which is of circular shape compared to the pin fin with drop shape. Observed lower specific friction loss with drop shaped pin fin.
2	Hisham H. Jasim	Hybrid model which includes the vertical combination of longitudinal and pin fins	Mathematical modelling using Finite element technique and Analytical modelling using Ansys simulation Natural convection	Drop in temperature profile, drop in thermal resistance and elevation in heat transfer is observed in hybrid model when compared with longitudinal fins.
3	Hyunkyu Moon, Kalyan Boyina, Nenad Miljkovic , William P. King	Optimizedcomplex fin structure, Straight fin design and smooth circular channel	Genetic algorithm and finite element simulation Forced Convection	Optimized complex fin structure has high convective coefficient of heat transfer and reduced thermal resistance.
4	S. Sadrabadi Haghighi ,H.R. Goshayeshi, Mohammad Reza Safaei	Plate fins, Plate cubic pin fins	Experimentation free Convection	Pin fins with cubic plate have higher heat transfer and lower thermal resistance.
5	Thamir K. Ibrahim, Ahmed T. Al-Sammarraie, Manar S.M. Al-Jethelah, Wadhah H. Al-Doori, Mohammad Reza Salimpour, Hai Tao	Square shaped perforation and circular shaped perforation	Experimentation and Numerical Forced Convection	Dissipation of higher heat rates is obtained from the inclusions of more number of square shaped perforations. Square perforations show reduction in friction factor and average Nusselt number is lower compared to circular perforations.

6	Sebastian Unger, Matthias Beyer, Samira Gruber, Robin Willner, Uwe Hampel	Oval tubes with circular plain fins, serrated integrated pin fins, circular integrated pin fins	Experimentation Forced Convection	Results shows that Serrated integrated pin fins has higher Nusselt number and moderate friction factor and low fin efficiency compared with the other pinfins.
7	Tehmina Ambreen, Arslan Saleem, Cheol Woo Park	Square, Circular and Triangle shaped micropinfins	Simulation using Lagrangian-Eulerian model	Circular shaped micro pinfin has higher Nusselt number which is followed by Square and triangle shaped pin fins.
8	E. Buyruk and K. Karabulut	Rectangular fins on flat channel, Zigzag fins, Inner Zigzag and outer Zigzag fins	Numerical analysis using Finite volume method Forced Convection	Zigzag fins have greater pressure drop and Nusselt number

CONCLUSION

In comparison to radial and flaring heat sinks, the Honeycomb heat sink is better at amplifying heat transmission in electronic equipment, according to experiments and optimization techniques. In addition to increasing the free convection coefficient of heat transfer by 23.2% and 25.79%, respectively, the honeycomb-shaped heat sink for 100V of heating power also reduces thermal resistance by 25.18% and 22.81% when compared to flared and radial heat sinks. It turned out that nano coatings were more useful. It is evident from this experimental study that, in comparison to radial and flared heat sinks, the honeycomb-shaped heat sink has more heat dissipation and reduced thermal resistance. Using of different nano coatings to heat sink to increase the transfer of heat can be considered as a suggestion for future studies. Studies can also be extended by varying the fin design parameters like thickness of fins, number of fins and fin spacing.

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