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A Performance Study on Heat Transfer using Different Heat Sink by Experimentation and Optimization Method

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Abstract

With the advancement of new technologies, the reductions of size are more in recent electronic devices, which lead to an increase in heat dissipation. Thus, the problem of electronic cooling has become a critical issue in this area. This work is based on the experimental and optimization analysis. The results from the experimental analysis are compared for different shaped heat sinks like concave and congruent made up of copper and aluminium respectively. The experiment is conducted for different heat input and the performance of the heat sink is observed. Results shows that the heat transfer coefficient is more and thermal resistance is less with concave shaped heat sink and this study on experimental performance of different shaped heat sink manifests its application in electronic devices.

Keywords: *Forced convection, Heat sink, Heat Transfer, Optimization, Taguchi*

1.0 Introduction

This is the era which has witnessed the evolution and advancement of electronic gadgets, which leads to the tear down of the components because of improper heat dissipation. To overcome this issue, enhanced heat transfer is required. To achieve this intensified heat transfer, fins are used. Here forced convection air cooling approach is used to remove the heat.

Plate fin heat sink experimental analysis shows that because of the heat losses there is a significant change in optimal heating position. Also one dimensional numerical model helps in finding the optimal trends in thermal resistance and temperature profile [1]. An Experimental investigation on plate fin with different shaped grooves are performed and found that the grooved fin has better thermal performance [2]. Experimentation on pin fin and flat plate heat sink using perforations is performed under forced convection to determine the thermal performance of heat sink From the results it is clear that the perforated fins has more thermal efficiency compared to the solid fins [3]. Experimental forced convection was performed on three finned pipes and a plain pipe with helical fin of different spacing at various speeds. The results obtained are helical fin with 75mm spacing at 400 rpm indicates higher Nusselt number and comparatively the pressure drop

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is more in finned pipe [4]. The results of forced convections shows that metal foams with proper design can improve the cooling capacity of microchannel heat sink. The porosities have larger impact on pressure drop while the thermal performance has the smaller impact [5]. Traditional heat sink is experimentally compared to a new heat sink with one inlet and four outlets. The results showed that the Nusselt number is more in traditional heat sink and comprehensive coefficient can be improved by proper placement of the outlets [6]. Forced convection experiment was performed on solid wire fin in a wire to determine the fin efficiency. The higher fin efficiency is obtained by replacing solid wire fin with oscillating heat pipe. The obtained experimental results agree with the developed model [7]. Pin fin as a passive heat transfer component and piezoelectric translational agitator as an active heat transfer component is used to remove the heat from electronic devices. Thermal performance is obtained from the results of single and multi-channel test [8]. Experimentation is done on a double pipe heat exchanger using cylindrical tubes and conical tubes. Thermodynamic, hydrodynamic and geometrical features are analyzed. The modified geometry shows better performance at optimum condition [9]. Optimal shape of the fin is found experimentally among triangular, trapezoidal, parabolic and wavy shapes. Results obtained are compared to the available literature for validity [10]. The convective heat transfer coefficient is evaluated on grey cast iron plate fins. Numerical approach along with the experimentation is used. The empirical correlation for Nusselt number is found [11]. Simulation is performed using numerical tool for fins of different shaped like rectangular plain and pin fin. The results of hydraulic and thermal behaviour are further compared to trapezoidal fins. Empirical correlation is also found [12]. Finned Surface efficiency and heat transfer coefficient is determined experimentally and numerically on a tube heat exchanger with a plate finned and in line arrangement. The result indicates that increase in air velocity increases the average convective heat transfer. Aluminium and steel fin materials are found to be more cost effective [13].

Experimental investigation is performed on design parameters effect for the heat sink with elliptical fin for both inline and staggered arrangements. For elliptical pin fin empirical correlation is developed [14]. A double pipe heat exchanger is investigated experimentally to find the heat transfer coefficient and pressure loss using perforated circular ring and typical circular ring in the annular pipe. The results obtained are the decrease in thermal performance with the increase in Reynolds number [15]. Forced convection heat transfer is determined on tube which is internally vertically finned using numerical investigation. This investigation results in best heat transfer with the optimum combination of height and number of fins [16]. Experimental and CFD analysis are performed to determine the Optimum shape of perforated fins. The thermal performance is obtained by forced convection using triangular, circular and rectangular perforations. The obtained results are also compared to non-perforated fins and are determined that the significant performance is obtained by perforated fins [17]. A numerical analysis on array set of vertical fins with and without dimples is performed. The heat transfer and the Nusselt number are obtained by varying the Raleigh number. Results show that for arrays with dimples the Nusselt number increases with increase in Raleigh number [18]. Experimental and Numerical analysis of rectangular finned array is performed to determine the heat transfer coefficient and Nusselt number. Geometrical parameter effects are also found. An empirical correlation is drawn for Nusselt number [19].

The above literature works mainly aims at exhibiting the different ways to enhance the heat transfer and reduce the thermal resistance. Some studies also speak about finding the optimal shape of the fin.

The present work is based on experimentation and optimization analysis. This experimental study helps to find the performance of the heat sinks made of copper and aluminum with different new shaped like concave and congruent heat sink. Further this experimental study aid to optimize the heat sink with finer shape. Here forced convection is adopted for the heat removal.

The Novelty of this experiment is to find the optimization of heat sink by varying the shape and also to study the performance of heat sink using forced convection.

2.0 Methodology

Fig.1 shows the heat sink which is concave shaped made up of copper material and Fig.2 shows the heat sink which is of congruent shape and is made up of aluminium material. Six T-type thermocouples are used to obtain the temperatures at different places. An experimental set up is created to perform the forced convection by placing the heat sink in a test duct.

Figure 1: Concave Heat sink

Figure 2: Congruent Heat sink

The required voltage is set using the dimmerstat and the blower is switched ON to induce forced convection. At steady state the readings of voltmeter ammeter and temperatures are noted. This experiment is repeated by varying the dimmerstat reading.

3.0 Results and Discussion

Figs.3 and 4 indicate the variation of temperature difference and surface temperature with the increase in heat flux respectively. The results observed are the increase in temperature difference and surface temperature for both concave and congruent heat sink. Increase in heat input increases the surface temperature with the growth of flow currents. Concave heat sink has greater temperature difference and the surface temperature.

Figs.5 and 6 Show the variation of heat transfer coefficient and effectiveness with the increase in heat flux respectively. The heat transfer coefficient follows the decrease trend with the increase in heat flux because with the rise in heat input, the thermal conductivity increases and in turn leads to the decrease in heat transfer coefficient whereas the rise of heat flux leads to the slight increase of effectiveness. Concave heat sink has higher effectiveness and heat transfer coefficient.

Figs. 7 and 8 show the variation of Nusselt number and Reynolds number with the increase of heat flux respectively. The results show that Nusselt number

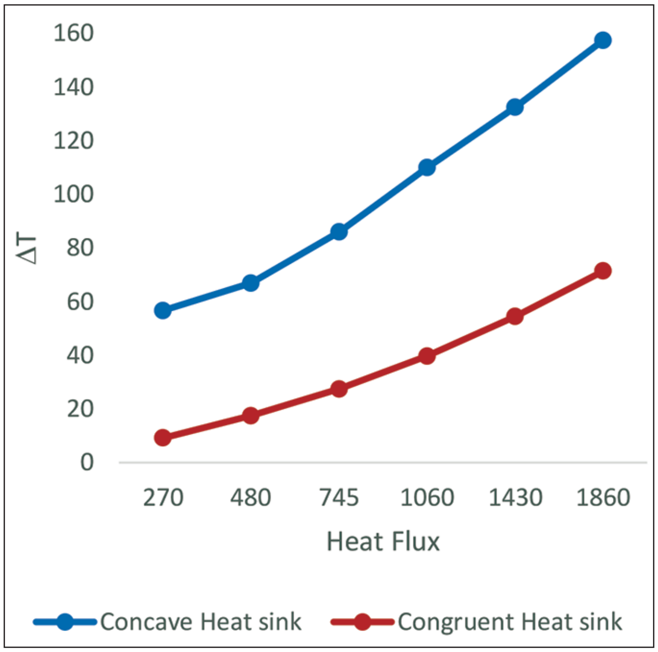

Figure 3: Temperature difference Vs Heat Flux

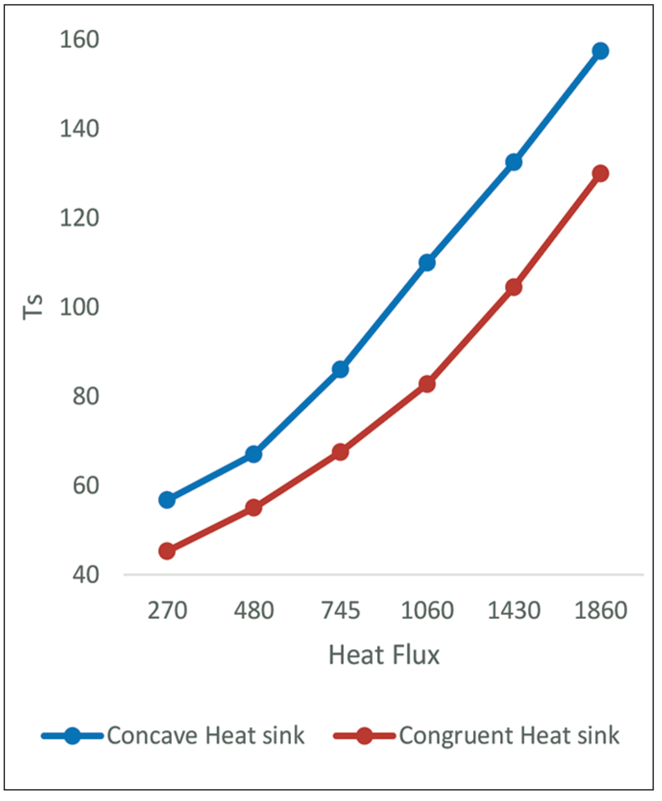

Figure 4: Surface temperature Vs Heat Flux

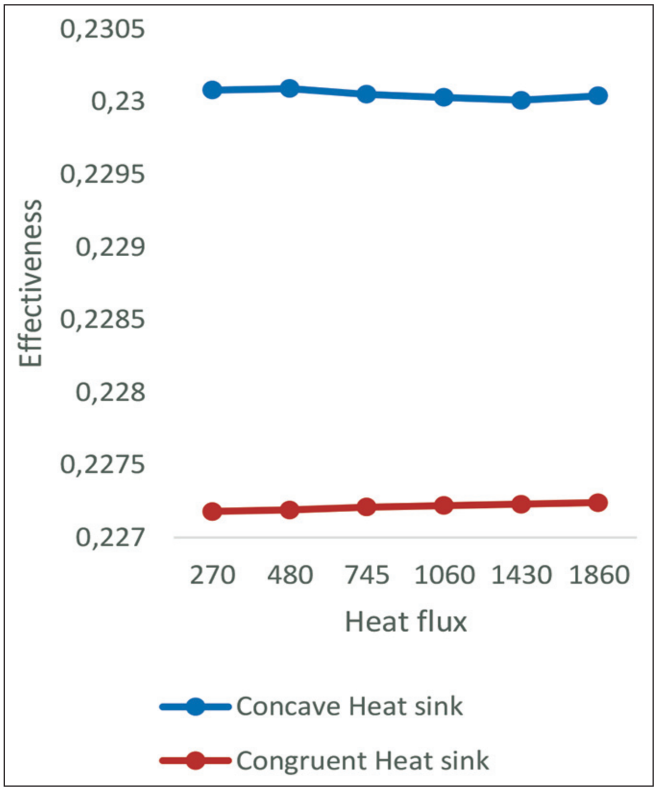

Figure 6: Effectiveness Vs Heat Flux

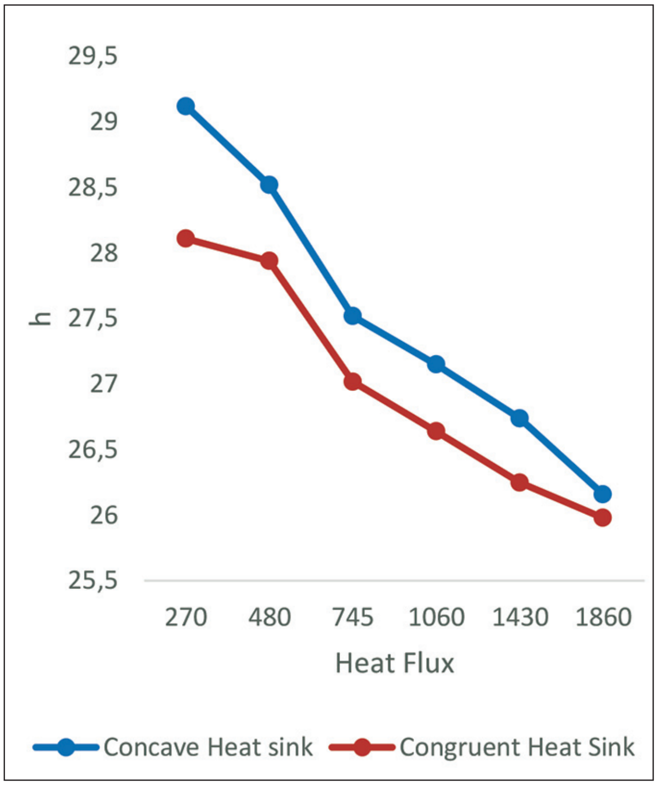

Figure 5: Heat transfer coefficient Vs Heat Flux

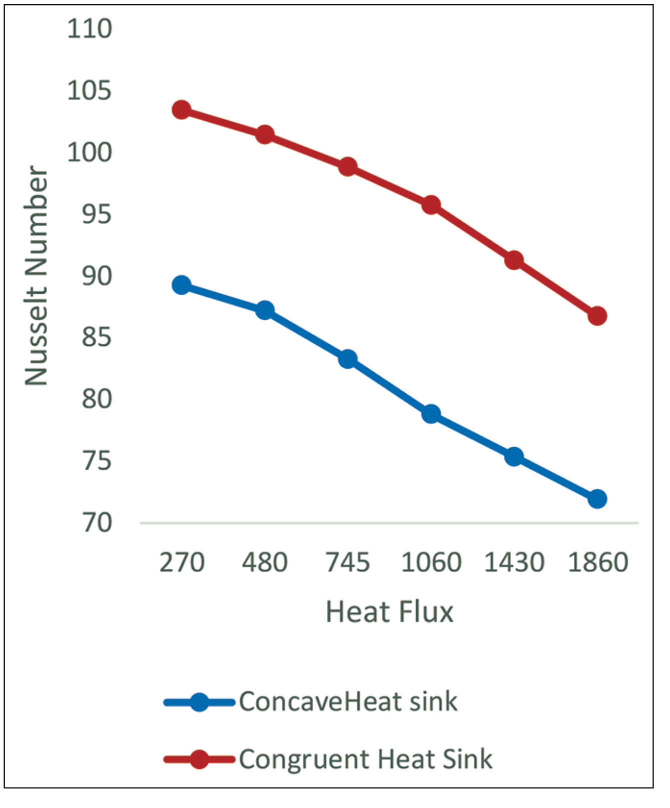

Figure 7: Nusselt number Vs Heat Flux

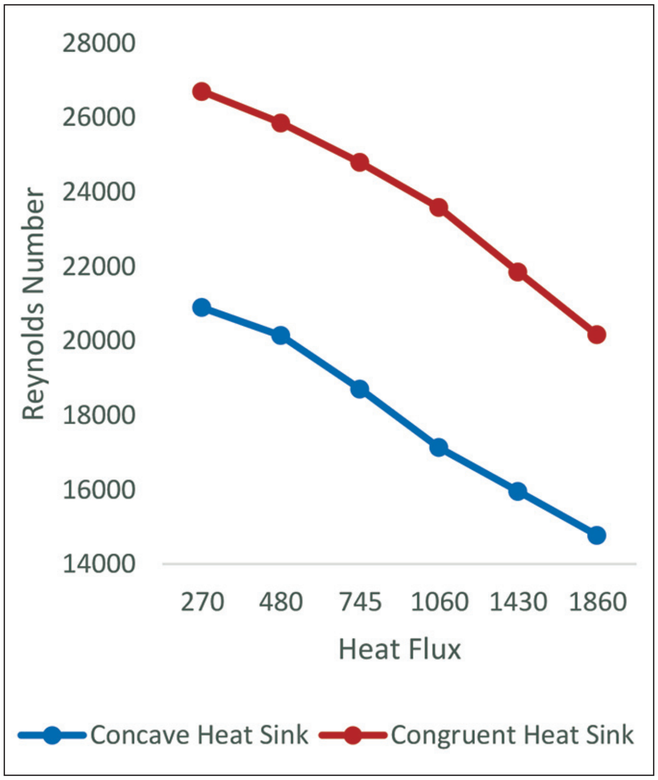

Figure 8: Reynolds number Vs Heat Flux

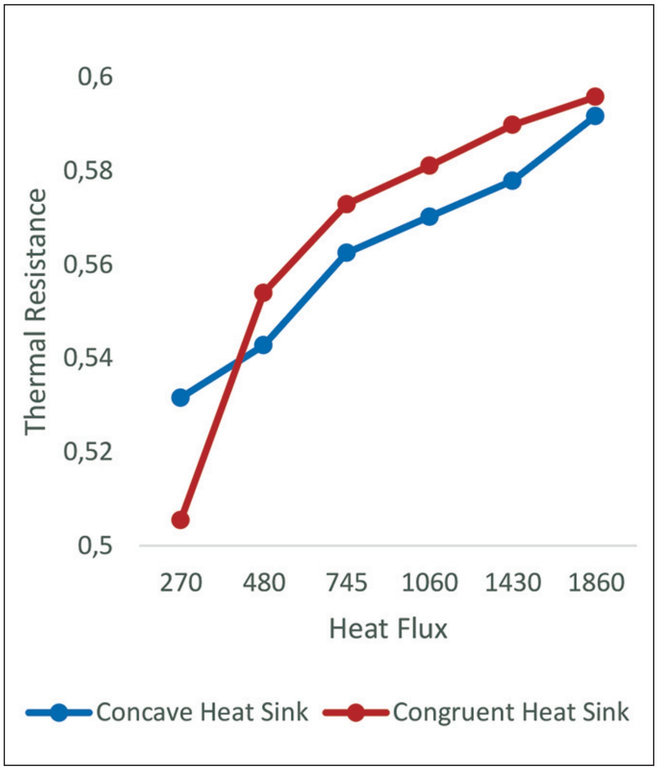

Figure 9: Thermal resistance Vs Heat Flux

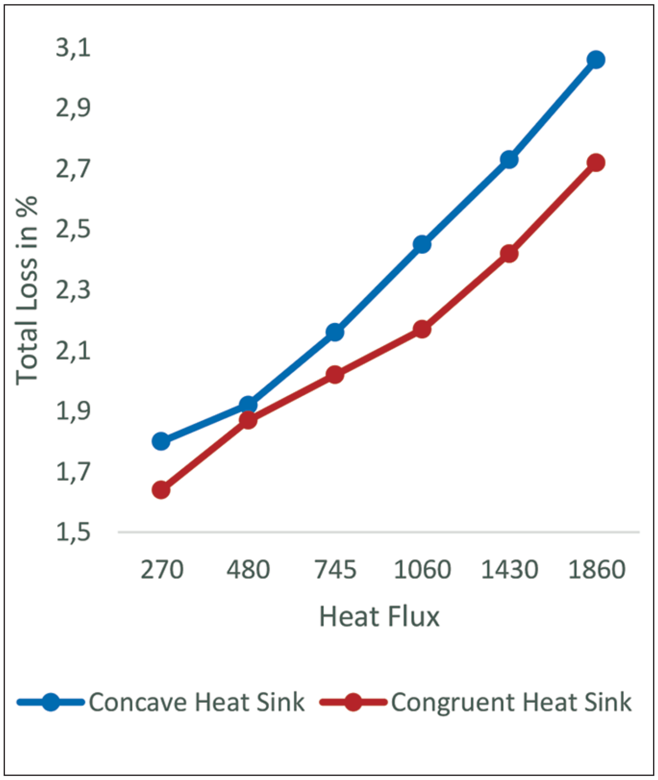

Figure 10: Total Losses Vs Heat Flux

and the Reynolds number decreases with the rise in heat flux because Nusselt number is oppositely symmetrical to Thermal conductivity. Also observed that concave shaped heat sink has comparatively lower Nusselt number and Reynolds number.

Figs.9 and 10 show the variation of Thermal resistance and the total losses for the rise in heat flux respectively. Thermal resistance and the total losses grow with the rise in heat flux. Thermal resistance is slightly more in congruent heat sink compared to concave heat sink whereas total losses are higher for the concave heat sink.

Figs.11, 12 and 13 show the S/N ratio heat transfer coefficient, Nusselt number and thermal resistance respectively. Concave shaped and copper material with lower heat transfer shows the higher heat transfer coefficient. Congruent shaped and aluminium material with lower heat transfer has higher Nusselt number and lower thermal resistance.

Table 1 shows the Taguchi analysis of L8 orthogonal array. It indicates the analysis for Nusselt number, heat transfer coefficient and thermal resistance. From the Taguchi analysis it is clear that heat input parameter acts as the important factor for both heat transfer coefficient and thermal resistance whereas Nusselt number depends more on shape.

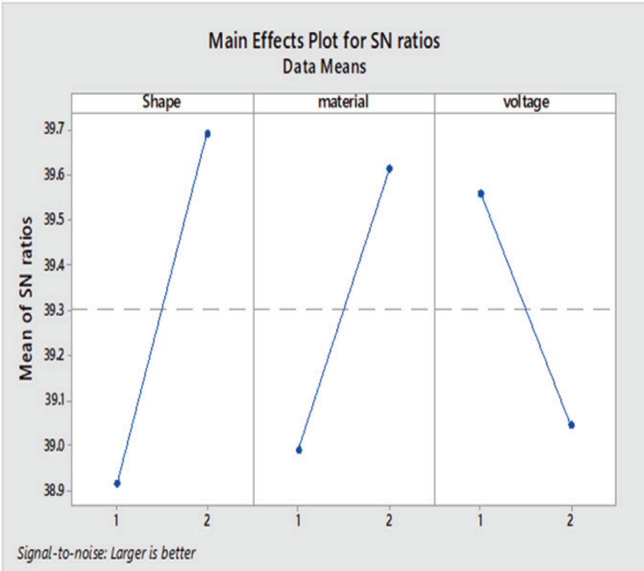

Figure 11: SN ratio of Heat transfer coefficient

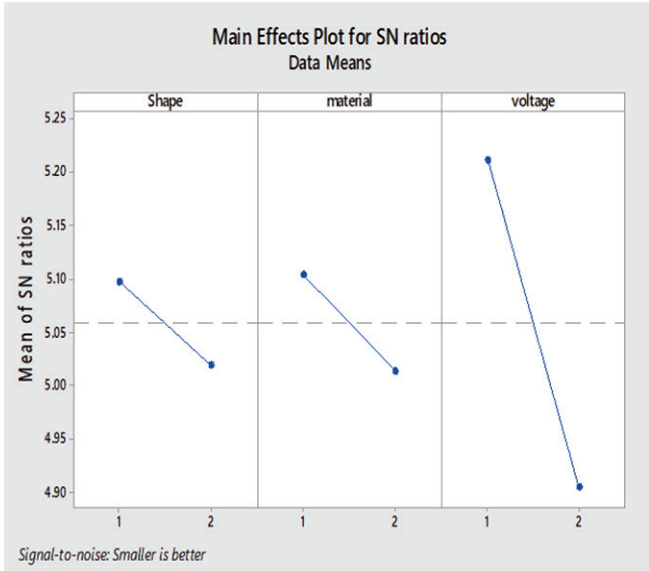

Figure 13: SN ratio of Thermal resistance

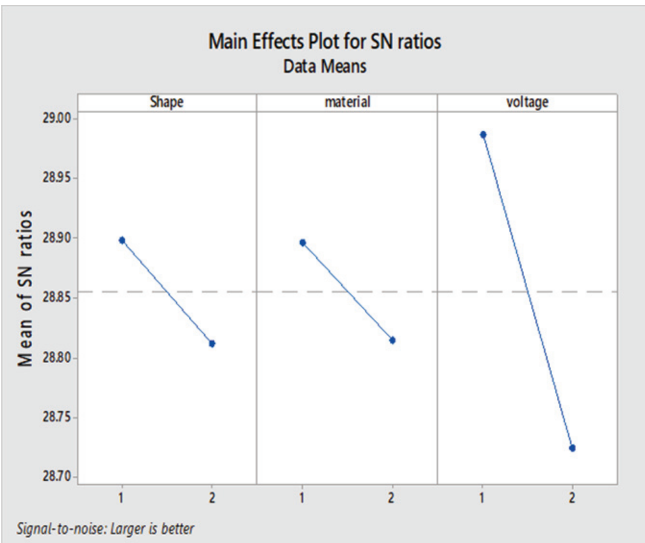

Figure 12: SN ratio of Nusselt number

4.0 Comparison Related to Earlier Studies

Simulation using CFD is performed for Staggered pin fin with different types of perforations like circular, elliptical and diamond cut shapes. The results obtained from the forced convections shows that Nusselt number increases with perforations and Elliptical shaped perforation has higher Nusselt number and maximum pressure drop is achieved in circular shaped perforations [20].

Numerical analysis using Finite volume method is performed on rectangular fins on flat channel, Zigzag fins, Inner Zigzag and outer Zigzag fins. The results obtained from the forced convections shows that Zigzag fins have higher Nusselt number and pressure drop [21].

Table 1: Taguchi Analysis

	Heat transfer coefficient			Nusselt Number			Thermal Resistance		
Level	Shape	material	heat input	Shape	material	heat input	Shape	material	heat input
1	28.90	28.90	28.99	38.91	38.99	39.56	5.097	5.104	5.212
2	28.81	28.81	28.72	39.69	39.61	39.04	5.020	5.013	4.906
Delta	0.09	0.08	0.26	0.78	0.62	0.52	0.078	0.091	0.306
Rank	2	3	1	1	2	3	3	2	1

Numerical simulation for rectangular fins, diamond fins and triangular fins with Trapezoidal, triangle and fan shaped cavities. The results obtained from the forced convections shows that fin shape has more sensitivity than cavity shape on thermal performance. Triangle fin has t friction loss and Rectangle fin has highest pressure drop [22].

Experimental Study is performed on Circular fins, Interrupted rectangular fins and helical ribs. The results obtained from the forced convections show that rectangular fins have maximum enhancement in heat transfer and highest pressure drop. Circular fins have lowest pressure drop [23].

Numerical analysis performed on Triangular, rectangular and trapezoidal shaped fins with square and circular perforations. The results obtained from the forced convections show that Higher heat transfer is obtained from triangular shaped fins. Perforation increases the heat transfer but the results from square and circular perforations are same [24].

Some previous related works are compared to this present experimental work. Different shaped fins are considered for studies through different methods like numerical analysis, experimentation and CFD analysis to observe the variation in heat transfer. It is noticed from the studies that the coefficient of heat transfer and Nusselt number gets larger with the rise in heat input for the majority of the samples.

5.0 Conclusion

Experimentation by forced convection and Taguchi analysis show that the concave shaped heat sink using copper material is superior to strengthen heat transfer in electronic devices. The heat transfer coefficient of copper concave shaped heat sink for 120V of voltage input is more by 1.88% along with decrease in thermal resistance by 1.88% compared to aluminium heat sink respectively. Nusselt number is higher in aluminium congruent shape by 17.7%. Further studies can also be expanded by differing the design of fin parameters like number of fins, spacing of fin and fin thickness. This experimental and optimization study display that the heat throw away is more in copper concave shaped heat sink as compared to aluminium congruent heat sink.

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