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# HEAT TRANSFER ENHANCEMENT IN NOTCHED FIN ARRAY- A REVIEW

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## ABSTRACT

In this paper we have undertaken the study of heat transfer enhancement in notched fin array. Many times in actual practice we need to increase the rate of heat transfer from smaller areas, in such a cases we need to use the different types of fins. Use of fins also causes the reduction in the temperature driving forces in the system. In this paper the different types and combinations of notched fin arrays were studied with respect to the shape of notches such as rectangular notch, triangular notch, circular notch, etc. Also it is observed that inverted notch fin arrays perform well in comparison with notched fin arrays.

***Keywords***: *Heat transfer enhancement, Notched fin, Nusselt number.*

## I. INTRODUCTION

The advancement of efficient thermal approach has prompted concern in techniques to enhance heat transfer rate. Investigation of improved thermal execution is alluded to as heat transfer upgrade, growth or strengthening. Heat transfer improvement is a way towards enhancing the execution of a heat transfer network. This is a matter of significant enthusiasm for researchers as it prompts sparing energy and cost. By virtue of huge addition in power request all through the globe, both diminishing vitalitylost related with inadequate utilization and intensification of energy in the importance of heat have turned into relentlessly attempted errand for plan and task engineers for many real life applications.

We know that removing heat from the system is very essential therefore heat sink are employed in the systems and they remove heat from that system by exchanging the extracted heat with another fluid or the surroundings.
This can be done by two methods according to Newton's law of cooling-

1) Increasing surface area of heat sink
2) Increasing coefficient of heat transfer

Review of the literature reveals that trial examinations on notched fin arrays with square, triangular, circular and inverted notched fin array have been carried out for the heat exchange enhancement. It is seen that in natural convection, heat transfer rate depends upon variation in orientationand geometry of finned array.Therefore the present investigation has an extraordinary centrality for the advancement of new sorts of compact heat sinks.

## II. REVIEW

**Suneeta Sane et.al [1],**
This paper investigates the trial examination of natural convection heat transfer from horizontal rectangular notched fin arrays. The effect of orientation and the geometry of fin array were identified as the main controlling parameters for the heat transfer augmentation. Four fin configurations having fins 17,13,11,9 of Aluminum having thickness 2mm and Aluminum base plate of dimension 150*100*50 mm is experimentally tested at various input powers 20W, 40W, 60W, 80W, 100W. Another parameter being separation across two fins as 6mm, 8mm, 10mm, 12mm. Slot decrement is 20%, 30% and 40% of complete surface region of un-slotted fin. From this study we concluded as the spacing between fins increments, convective heat transfer coefficient increments. As the slot region increments,

convective heat transfer coefficient increments. For the given input, heat exchange coefficient of notched array is 30% to 40% higher than the relating un-notched one.

**N. A. Nawale and A. S. Pawar [2],**
This paper investigates the experimentation on heat exchange through fins having various notches. In this study, the flat fins are modified by removal of central portion by cutting different types of notches. A set of five fins of Aluminum material with thickness 3mm, are mounted on base plate. Different configurations of fins with un-notched, triangular notched, circular notched, rectangular notched are taken into account to study the effect on heat transfer rate. Experimentation was conducted on two base temperatures $60^0$C and $80^0$C. From this study it is reasoned that the coefficient of convective heat transfer is most astounding for the arrangement of fins with triangular indent. Further investigation was done by varying the height of triangular notch in a fin. The investigation depicts that the set of fins with maximum height for triangular notch has highest convective heat transfer coefficient.

**S. Sadrabadi Haghighi et.al. [3],**
This paper investigates the natural convection heat transfer improvement in new plate-fin heat sinksdesigns. Examination was directed to calculate the convective heat exchange coefficient, and heat execution of plate fins and plate cubic heat sinks under free convection. Setup consists of six combinations of fin configurations of Aluminum alloy 6061 material. In three combinations, rectangular plane fins are used with spacing of 12, 8.5, 5 mm. In remaining three configurations, cubic pin- fin fins are used alternately with respective spacing. Input was varied from 10W to 120W. Results displayed that plate cubic pin fin heat sink indicate twelve percent lower thermal resistance than that of plate pin fin. Further, increment inseparation between the fins lead to decrease in thermal resistance, hence rate of heat transfer increases.

**Abbas Jassem Jubear and Ali A. F. Al-Hamadani [4],**
Paper investigates the heat exchange through free convection from a vertically rectangular fin cluster. There are six fins whose material is aluminum with thickness and fin spacing of 4mm and 10mm respectively. The component demonstrates the length of fin 300 mm, separation 10 mm, thickness 4 mm and heights 10mm, 25mm and 45 mm. The parameter considered for the study is height variation i.e., 10mm, 25mm and 45mm. A Rayleigh number running from 7.6×10−1.5×10 were utilized. The value of power supplied is from 68 W to 716 W in all fin setups. The different values of heat generation were obtained 413, 930, 1680, 2630 and 3792 W/ $m^2$.It was discovered that the rate of heat exchange from fin clusters is high from vertical plate and it's controlled by length, height of fins and base to surrounding temperature contrast. When fin height increases from 10mm to 45mm there is enhancement in heat transfer coefficient.

**Sanjeev Suryavanshi and Narayan Sane [5],**
Orientation and geometry are considered as the main controlling parameters. In this experimentation we are removing this central portion as inverted indent. The parameters considered for the examination are Fin separation, power input, Percentage of region expelled as modified indent. Results are verified with the help of CFD. The conclusions made from the experimentations are

- With increase in fin spacing upto 9 mm, heat transfer coefficient increases after that there is a gradual rise.
- Average heat exchange coefficient for indented fins is 40-50% higher as compared to un-indented fins.
- With increment in power input the estimation of heat exchange coefficient increments.
- As the level of removed region expands, the estimation of coefficient of heat transfers additionally increments.
- Due to decrement in fin separation, the values of Nusselt number decreases upto fin separation of about 6mm after that nub starts to decrease.
- For a specific temperature distinction, inverted fins show higher rate of heat exchange than normal fins.
- It was likewise discovered that 40% of inverted fin array gives higher rate of heat exchange for a specific temperature distinction.
- Values of $nu_b$ are higher for higher power input.

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**Md. Shamim Hossain et.al. [6],**

This paper accentuates the performance and fabrication of pin fins in heat transfer analysis. Both the material of fin and base plate were chosen as aluminum. Seven fins were utilized having diameter 8.2 mm and length 70 mm are organized in line-way. Parameters based on which experimentation was done are as follows-

Coefficient of heat exchange with the expectation for natural convection h=31.6, 35.39, 38 and forced convection h=54.14, 58.85, 64.78.

Efficiency of fin shapes with the expectation of natural convection η=52.87, 60.16, 55.88% and forced convection η= 23.6, 20.84, 16.17%.

The following results obtained are as follows,

- In instance of forced convection the rate of heat exchange through fins increases as the fan speed increases
- Efficiency of fins decrease with increase in heat exchange coefficient for forced convection. It is on the grounds that with increment in fan speed there will be less time of contact with fin and air which will result in decrease in efficiency of fins.
- Whereas in case of free convection efficiency will increase if heat transfer rate increases.

**Anant Joshi and D.G. Kumbhar [7],**

This paper examines the investigation of thermal exchange from horizontal rectangular (square indented) cluster of fins by free convection. This experimentation predicts about the stream of air over the fin cluster and heat exchange due to natural convection. Experimentation was carried out on configuration with 9 fins and fin spacing of 9mm. Dimensions of fin and base plate made of aluminum material are taken as 70mm*40mm*1.1mm & 101mm*70mm*25mm respectively. Heat input was provided as 40W, 60W, 80W along with reduction in square notched area by 10%, 20% and 30%. Result implies that absolute heat flux and the convective heat exchange coefficient increments as the indent depth increments.

**Shyy-Woei Chang et.al [8],**

This paper investigates the heat exchange upgrade of vertical dimpled fin cluster in free convection. Four fin configurations, namely plane rectangular thirteen fin cluster, plane rectangular ninefin cluster, dimpled nine fin cluster, and dimpled seven fin cluster with same base area were experimented and analyzed individually. Rayleigh numbers (Ra) of $10^8$, $7.75 \times 10^7$, $5.5 \times 10^7$, and $3.25 \times 10^7$ were considered for analyzing the free convective flow with fixed Prandlt number of 0.71. The objective employs the comparison of heat transfer between plain thirteen fins and dimpled nine fin array. Results depicted that, as local and average Nusselt number increments with increasing Rayleigh number over each kind of fin surface utilized. As the fin tip has lower fluid densities, air stream rate at tip is larger than that of fin base passage which generates accelerated flow across each segment of fin. With dimpled arrangement, high Nusselt number is obtained due to stronger upward connective flows.

**Akshendra Soni [9],**

In this experimentation comparison between three types of heat sinks are made which are plate fin, pin fin and elliptical heat sink on the basis of their thermal performance in natural convection. Here base plate measurements and fin height is kept constant. Also the examination between vertically situated pin fin and rectangular finned heat sink is done. They are compared on the basis of relentless-state free convection heat exchange and thermal effects. The study of continuous fins is also done and their analytical results were found. After that effects of elliptical fins were found. The 3-D model for researching the distinctive fin geometry impacts is made on ANSYS and SOLIDWORKS software. Results are based on entire heat dissipation under constant volumetric conditions. As indicated by the investigation and experimentation done it was discovered that plate fins perform superior in comparison with pin fins. A region map was made and according to that plate-fin heat sinks performs satisfactory in majority of experimental areas in terms of thermal execution. In case of free convection, elliptical fins are additionally superior than pin fins but they deficit in exposed region available in plate fins. In end it can be concluded that elliptical fins can be utilized as substitution for pin fins yet they are not ready to contend plate fins as bigger exposed region is presented to convection in plate fins.

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**EnchaoYu and Yogendra Joshi [10],**

This paper investigates the heat transfer improvement from enclosed discrete components using pin-fin heat sinks. Various flow patterns, temperature measurements were conducted to look into improvement of heat exchange. Dimensions of enclosure are 25.4mm * 25.4mm and 127mm*127mm*41.3. A pin fin and heat source arrangement was done. Parameters taken into considerations are Length of component, Length of enclosure, Height of enclosure, Thickness of component, Thickness of enclosure wall, Size of pin fin and Porosity. Horizontal and vertical arrangements are done for the enclosure with certain boundary conditions. Fin array material was taken as Aluminum with size 9*9 and 12*12. A single thermo-foil heater is used for heating purpose. For temperature measurement, T type thermocouples having diameter 0.076mm are connected. Result obtained after experimentation are as follows-

- The enclosure walls reduce overall heat transfer due to shrouding.
- Thermal execution of heat source in a closed environment is better than finned array in open space.
- Increase in population of pin fin decrease the improvement of heat exchange.
- In complete enclosure, vertical alignment gives lower thermal opposition.
- For straight enclosure, there are more enhancements in heat exchange by means of pin-fin arrays.

**Qie Shen, Daming Sun, Ya Xu, Tao Jin, Xu Zhao [11],**

In this experimentation study of rectangular heat sink is done which is used in LED (light emitting diode). Under the conditions of natural convection and orientation effects on the fluid flow the numerical and experimental study is done. At all eight orientations are made and their evaluation is done for different rectangular fin heat sink. Heat emission from LED'S is important so as to get higher illumination intensity. There are two types of technologies for cooling which is active and passive cooling. Rectangular fin is the most effective adopted heat sink which is maintenance free and its energy consumption is zero. Denser fins fluctuate significantly with orientation. For orientation from zero degrees to 135 degrees the thermal performance varies little for wide fin spacing heat sink whereas for narrow fin spacing heat sinks fluctuation is quite significant. But 260 degrees orientation is the worst scenario for both types of heat sinks. The trial results, present expectation and past exploratory information are largely comparative. The two overseeing factors that retrograde heat exchange through rectangular fin heat sinks are incompatible between heat exchange area and the free convection flow.

**Mao-Yu Wen and Ching-Yen Ho [12],**

The basic aim of this experiment is to study the elements of fin-and-tube heat exchanger. Examination is basically done on three unique sorts of fins i.e., Plate fin, Wavy fin, and Compounded fin. Discussion has been done on the coefficient of heat exchange, the pressure drop, the Colburn factor (j) as well as Fanning friction factor (f) against Reynolds number and air speed. Stream perception was additionally done to examine the fluid stream attributes. The increment in pressure drop, heat exchange coefficient, j and f variableis appeared by the consequences of wavy fin to the flat fin show. The increment is also shown by the consequences of compounded fins contrasted with the flat fin. To enhance the effectiveness of plate fin heat exchangers and round tube the most effective strategy is to build enhanced fin design. The air flow in compact heat exchangers is complex because there are complicated association between air stream and the fin pattern. Compact heat exchangers are used improve heat transfer aspect and pressure drop during experimentation. Compounded fin is the best amongst these three unique sorts of fins.

**Younghwan Joo and Sung Jim Kim [13],**

In this experiment comparison of pin fin and plate fin heat sinks with a base plate in vertical orientation is done and their thermal performance is measured. Validation of this experimentation is done to advance pin fin heat sinks and connection of its heat exchange coefficient. Two conditions which are kept constant are base plate measurements and fin height. Optimization of heat execution is done by two objectives as complete heat rejectionand heat rejection per unit mass for specific temperature distinction between surface and surroundings. There is larger amount of heat rejection in pin-fin and plate-fin heat sinks in first case and second case respectively. Pin-fin heat sinks are widely adopted because of its uncomplicated design and fabrication. It was discovered that thermal opposition of pin-fin heat sinks is lower than plate-fin heat sinks by about 40%. Under fixed volume condition the comparison of these two heat sinks is done. A region map was made using enhanced heat sinks for each objective function. It depends on

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the objective function that which heat sink will perform better. Improved plate fin and pin fin accomplish better results for targeted functions i.e., absolute heat rejection and heat rejection per unit mass respectively.

**Guei-Jang Huang, Shwin-Chung Wong, Chun-Pei Lin[14],**

Investigation was done for improvement of natural convection heat exchange from horizontal rectangular fin arrays with perforations in fin base. Perforations are made on the fin base to improve ventilation. Two combinations of fin array of Aluminium material with lengths 104 mm and 380 mm are used. Fin height, thickness and spacing are 38 mm, 1mm and 10mm respectively. Parameters taken into consideration are low flow velocity, temperature of air flow, Heat exchange improvement might be acquired by improving ventilation in inward locale of fin cluster.Heat transfer improvement may be gained by improving ventilation in inner region of fin arrays. Temperature contrast is 55K between base of fin and surroundings and an unsteady model is adopted. Perforation length is taken as L/2 or L/4. Results obtained are -

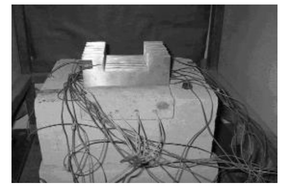
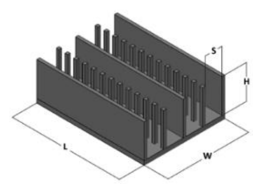
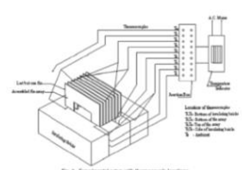
- There is 16.7% enhancement in heat transfer rate.
- More ventilation and heat transfer coefficient is observed when perforations are provided in inner region is higher in case with fin arrays with L= 380mm.
- Overall heat transfer coefficient of perforated fin array are found in two ranges w.r.t imperforations fin array and vertical parallel plates.
- When uniform heat is supplied on bottom surface at mid par, heat transfer rate is increased by a factor of 1.77.

**Viswanatha Sharma Koradaa, Mark Ovinis, Suhaimi B Hassan [15],**

Investigation was done on natural convection-radiation from a vertical base-fin array with Emissivity Determination. Experimentation was done to find emissivity for black chrome coated and uncoated aluminium plate fins. 22 fins having spacing of 10mm are placed on fin array of size 70mm * 70mm. Temperature range is $60^0$C to $110^0$C. Radiation contributes more than 20% of total heat dissipation. The setup consists of Strip heater, aluminium plates of size 100mm * 200mm * 4mm, wooden box, a control box (components – ammeter, voltmeter, temperature indicator, dimmerstat, selector switch). Three heaters are mounted having power of 400W Plates are held in vertical position with apoxy resin plate having thickness of 5mm and track wool is placed between resin plates. Enclosure is used for dissipation of heat by natural convection method. The size of enclosure is 530mm* 360mm* 140mm with threshold temperature of $120^0$C. Enclosure consists of 6 rows, each contains of 22 vertical square having 5mm thickness, 70mm length and 70 mm*10 mm of vertical base. Results obtained are as follows –

- With increase in radiation parameter, heat dissipation is increased which results in higher value of h.
- Increase in temperature ratio gives high value of free heat exchange coefficient.
- Increase in convection parameter states that there is more heat loss by convection. Estimated value of heat loss with temperature with emissivity of 0.7
- Heat drop from 22 fins with separation of 10mm and 6 rows in experiment range – $38<Q<99;33.4<T_b<37.8;3.93<\Psi<8.17$

*Table 1.Summary of literature review results*

| NAME OF AUTHOR | MODIFICATIONS | PARAMETERS STUDIED | ENHANCEMENT ACHIEVED | GEOMETRY |
|---|---|---|---|---|
| SuneetaSen [1] | • Horizontal rectangular notched fin array.<br>• Number of fins- 17, 13,11,9.<br>• Thickness- 2mm. | • Fin spacing- 6, 8, 10, 12 mm.<br>• Notch area reduced- 20%, 30%, 40%. | • Fin spacing increases, heat transfer rate increases.<br>• Coefficient of heat exchange of indented array is 30%-40% more than corresponding un-indented array. |  |
| N.A Nawale [2] | • Fins having different notches (circular, triangular, rectangular).<br>• Number of fin- 5.<br>• Thickness – 3mm. | • Height of triangular notch is varied. | • Heat transfer rate is maximum for triangular notch.<br>• Set of fin with maximum height of triangular notch has highest heat transfer coefficient. |  |
| S. Sadrabadi Haghighi [3] | • Cubic pin fin are used alternatively with plain rectangular fins. | • Number of fins- 5, 7 and 9.<br>• Spacing between fins – 12mm, 8.5mm , 5mm. | • Thermal opposition of plate pin fin is 12% more than plate cubic pin fin.<br>• Rate of heat exchange increments with increment in separation among fins. |   Fig. 2. Studied fins. |
| Abbas Jassem Jubear [4] | • Vertical rectangular fin array.<br>• Number of fins- 6.<br>• Thickness- 4mm.<br>• Fin spacing- 10mm. | • Height considered are – 10mm, 25mm, and 45mm. | • When fin height increases from 10mm to 45mm, there is enhancement in heat transfer coefficient and Nusselt Number. |   |
| Sanjeev D. Suryavanshi [5] | • Horizontal rectangular inverted notched fin array. | • Fin spacing varied upto 9mm.<br>• Percentage of region expelled in form of inverted indentation. | • With increase in fin spacing, rate of heat exchange increases.<br>• Average heat transfer coefficient for indented fin is 40% - 50% higher than un-indented.<br>• $Q_{inverted} > Q_{normal}$ |  |

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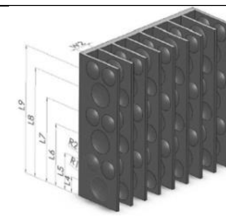
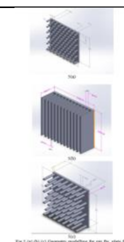
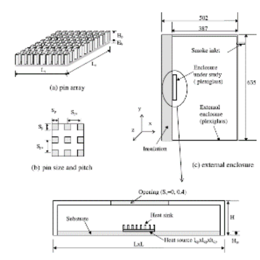
|---|---|---|---|---|
| Md. Shamim Hossain [6] | • Pin fin array.<br>• Number of fins -7<br>• Diameter of pin fin- 8.2mm.<br>• Length – 70mm | • Heat transfer rate<br>• Fin efficiency of Pin fin shapes | • Fins efficiency decrease with increment of heat exchange coefficient for forced convection whereas in case of free convection, efficiency increases with increment of heat exchange coefficient. |  |
| Anant Joshi [7] | • Horizontal rectangular (square notched) fin array.<br>• Number of fins – 9.<br>• Spacing – 9mm | • Reduction in square notched area by 10%, 20%, 30%. | • Total heat variability and convective heat exchange coefficient increments with indentation depth. |  |
| Shyy-WoeiChang[8] | • Vertical dimpled fin array.<br>• Four fins configuration, plane and dimpled are used. | • Rayleigh number (Ra) of $10^8$, 7.7 $\times10^7$ , 5.5$\times10^7$ and 3.25$\times10^7$ are used<br>• Prandtl number (Pr) of 0.71 is considered. | • Local and average Nusselt number increments with augmentation in Rayleigh number over each sort of fin surface.<br>• By using dimpled configuration, high Nusselt number is obtained. |  (a) |
| AkshendraSoni [9] | • Pin fin, Plate fin and elliptical fin heat sinks (vertically orientated base plate). | • Type of fin. | • Heat exchange rate of, Pin fin < elliptical fin < plate fin heat sink. |  |
| EnchaoYu [10] | • Pin fin array configurations of 9×9 and 12×12 are considered | • Length and thickness of component.<br>• Length and height of enclosure.<br>• Thickness of enclosure wall. | • Thermal effects of heat sink in closed surroundings are superior as compared to open surroundings.<br>• For horizontal enclosure, there was more enhancement in heat transfer using pin-fin arrays |  |
| Qie Shen [11] | • Rectangular fin heat sink mounted on LEDs | • Orientation (Angle variation from $0^0$ to $260^0$) | • For wide fin spacing heat sink, thermal performance varies a little for orientation from $0^0$ to $135^0$ whereas for narrow fin spacing heat sink fluctuation is quite significant<br>• 260 degrees orientation is the worst scenario for both types | |

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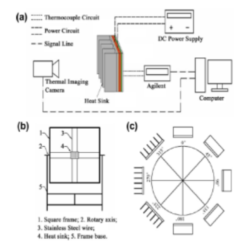
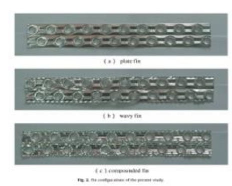
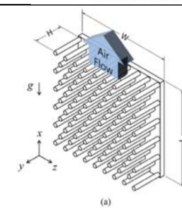
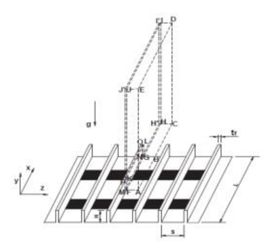
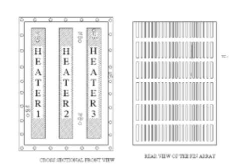
|---|---|---|---|---|
| | | | of heat sinks. |  |
| Mao Yu Van [12] | • Fin and tube heat exchanger with improved fin design (plate fin, wavy fin and compounded fin) | • Pressure drop of air side<br>• Colburn factor<br>• Fanning friction factor. | • Enhanced fin design is key factor to increase the effectiveness of round fin. |  |
| Younghwan Zoo [13] | • Plate- fin and pin fin heat sink | • Total heat rejection.<br>• Heatrejection per unit mass | • Thermal resistance of plate fin heat sinks is higher than pin fin heat sinks by 40%<br>• Enhanced plate fin accomplish better result than enhanced pin fin heat sink. |  |
| Gui Jang Huang [14] | • Horizontal rectangular fin array with perforations on base of fins.<br>• Perforation lengths- L/2 or L/4. | • Low flow velocity.<br>• Temperature of airflow in fin channel and fin spacing. | • Perforations in inner portion provide more ventilation which in turn gives more heat transfer.<br>• If uniform heat is supplied at middle part of fins base, heat transfer is enhanced by a factor of 1.77. |  |
| Vishwanatha Sharma Korada [15] | • Vertical base fin array.<br>• Number of fins – 22.<br>• Fin spacing – 10mm. | • Temperature range – $60^0$C to $110^0$C.<br>• Radiation ( which contributes more than 20% of total heat dissipation) | • With increase in radiation parameter, heat dissipation is increased which results in higher value of heat transfer coefficient.<br>• Increase in temperature ratio gives high value of heat exchange. | <br>Figure 1. Schematic diagram of the experimental setup |

## III. CONCLUSION

From the above, it is presumed that in structuring the heat sink one can get the basic understanding about the different parameters such as geometry and orientation of fin. The rate of heat transfer increments with increment in fin separation and fin height. It is also observed that 8 to 10mm fin spacing gives the optimum rate of heat transfer. Moreover, it is fully justified that inverted notched fin gives more rate of heat transfer than normal fin. Triangular notched fin gives more rate of heat transfer when compared with rectangular and circular notched fin array.

The performance of notched fin arrays is highly competitively to normal fin arrays. Hence, the literature review gives provident evidence about plate fin heat sink being most adopted in comparison with pin fin and elliptical fin heat sink in terms of real life applications of heat transfer. This extensive study is useful for the future research in design of heat sinks.

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