

Heat transfer analysis through horizontal rectangular inverted notched fin array using natural convection by experimental method

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ABSTRACT: Geometry and orientation plays an important role in natural convection heat transfer. Fin arrays on horizontal and vertical surfaces are used in variety of engineering applications to dissipate heat to the Surroundings. For horizontal rectangular fin array a chimney flow pattern is developed due to density difference. This flow pattern creates a stagnant zone near central bottom region. That portion does not contribute much towards heat dissipation. This area is removed from fins and they became inverted notched fins. This modified geometry reduces material cost, material weight without hampering heat transfer rate. The purpose of the present study is to investigate thoroughly the possibility of performance improvement of such arrays by providing a notch at the center and suggest for selection of optimum notch dimensions, and spacing by analyzing variety of fin arrangements.

KEY WORD: Inverted Notched Fin, Chimney Flow, Natural Convection, Heat transfer coefficient enhancement, Nusselt number, fin space, Fin height

1. INTRODUCTION

When available surface is found inadequate to transfer required quantity of heat with available temperature gradient, fins are used. Rate of heat dissipation from a fin configuration by convection heat transfer depends on the heat transfer coefficient and the surface area of the fins. The surface area of the fins can also be increased by adding more fins to the base material in order to increase the total heat transfer from the fins. But the number of the fins should be optimized because it should be noted that adding more fins also decreases the distance between the adjacent fins. Using fins is one of the cheapest and easiest ways to dissipate unwanted heat and it has been commonly used for many engineering applications successfully. Rectangular fins are the most popular fin type because of their low production costs and high effectiveness. Configuration of all fins protruding from their bases is popular because they offer economical and trouble free solution to the problem. Natural convection heat transfer is augmented by provision of rectangular fins on horizontal or vertical surfaces in many electrical and electronic appliances

. Because of reduction in surface area available for heat dissipation and low heat transfer coefficient optimization of fin geometry becomes very important in natural convection heat transfer. Now a days in electronic industries microminiaturization of electronic packages are in trend. The thermal design problem is recognized as one of the factors limiting achievement of higher packaging densities. Natural convection occurs due to temperature difference which produces the density difference. Generally in natural convection heat transfer on horizontal fin array, we observe a chimney flow pattern (fig 1) which creates a stagnant zone near the central bottom portion of fin channel. This stagnant zone created becomes less effective or sometimes ineffective for heat transfer, because no air stream passes over this region. To optimize the fin geometry some portion of this stagnant zone is removed in various shapes and sizes and its effect on other parameters are studied in this investigation. Some of the material from that central portion is removed, and is added at the place where greater Fresh air comes in the contact of the fin surface, it would increase overall heat transfer coefficient 'h'. In present study the fin

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flats are modified by removing the central fin portion.

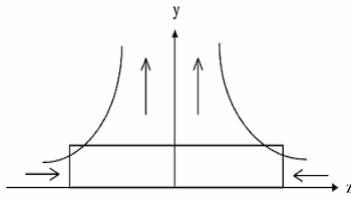


Fig 1. Single Chimney Flow Pattern

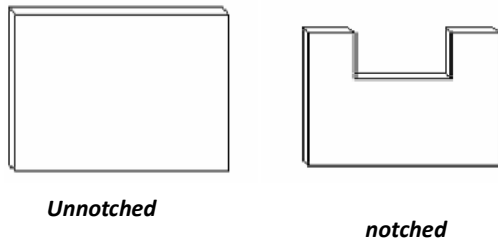


Fig 2. Schematic representation of the unnotched array, notched array and the area compensated notched array.

2. EXPERIMENTAL SETUP

Experimental setup was constructed on the basis of simplicity and practicability. Fin arrays were formed by assembling fin flats and separate spacer pieces and tied together by tie bolts. Fin flats separated by spacers formed fin channels. Fin array under investigation is kept in an enclosure to provide undisturbed natural convection environment. Cartridge heaters of 14 mm diameter were used for heating the array and are kept at the holes provided at the base portion. For temperature measurement of the fins as well as base surface, twelve number of calibrated Cu-Constantan thermocouples are used which are evenly distributed on fin surface and array base for realistic temperature measurement. To reduce the heat dissipated from array by conduction, the array is mounted on a Syporex base. Slot is machined in the block having width equal to width of the array. The depth is provided such that the surface of the fin array responsible for the free natural convection is exposed to surrounding.

2.1 Fin array configurations

Fin array configurations were decided on the basis of development of the single chimney pattern. The main aim of the experimentation is to find out the optimum fin spacing for a fixed L/H. Figure 3 shows the photograph of notched fin array in

position. In this photograph the notched fin array is assembled without the two end fins.

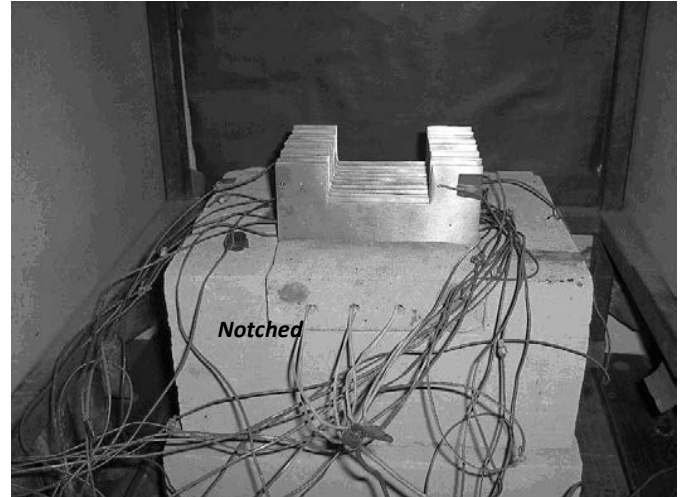


Fig. 3 Photograph showing notched fin array assembled without the end fins.

The unnotched fin array in which the outside exposed surfaces of the end fins are made non conducting is shown in Fig.4.



Fig. 4 Photograph of Unnotched Fin Array in Position

2.2 Table

Various configurations used are as given in the Table 1.

Spacing in mm	No. of fins	No. of channel
6	17	16
8	13	12
10	11	10
12	9	8

Table 1 Configuration table for fin flats used for Experimentation:

Length $L = 150$ mm, Height $H = 50$ mm, Width $W = 100$ mm, h_a = Average heat transfer coefficient
 h_b = Base heat transfer coefficient

2.3 Procedure of experimentation

The predetermined heater inputs were adjusted with the help of dimmer stat. The temperatures of assembled fin array at different positions and ambient temperature were recorded at the time intervals of 30 min. up to steady condition. Generally it takes 4 to 5 hours to attain steady state condition. The heater input was kept constant by adjusting the dimmer-stat, which was provided with stabilized voltage input. Steady state observations were recorded and used for calculation. Parameters used for the study are as given below. Heater input wattage (Q): 20W, 40W, 60W, 80W, 100W Spacing (S) in mm: 6, 8, 10, 12 Area removed: 20%, 30%, and 40%.

3. RESULTS AND DISCUSSION

3.1 Effect of fin spacing on h_a

Fig. 5 shows the effect of fins pacing on h_a with heater input as the parameter for unnotched array. From the figure it is clear that as the fin spacing increases the h_a increases. The increasing trend is steep up to spacing about 9mm. After that there is a gradual rise.

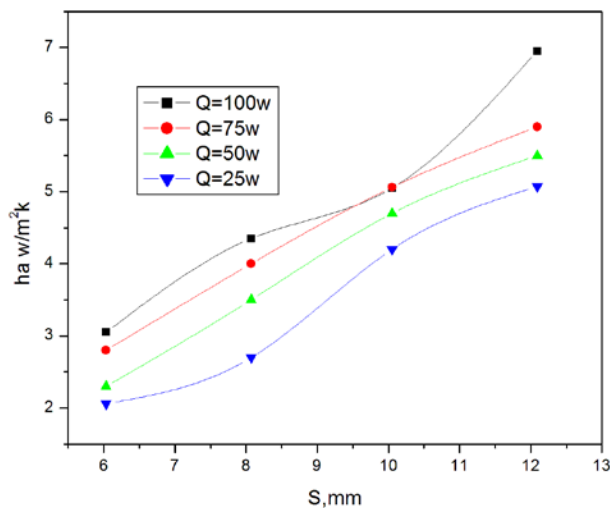


Fig.5 Variation of h_a with S for Unnotched Array

Effect of fin spacing on h_a with heater input as the parameter for 30% notched array is as shown in Fig 6.

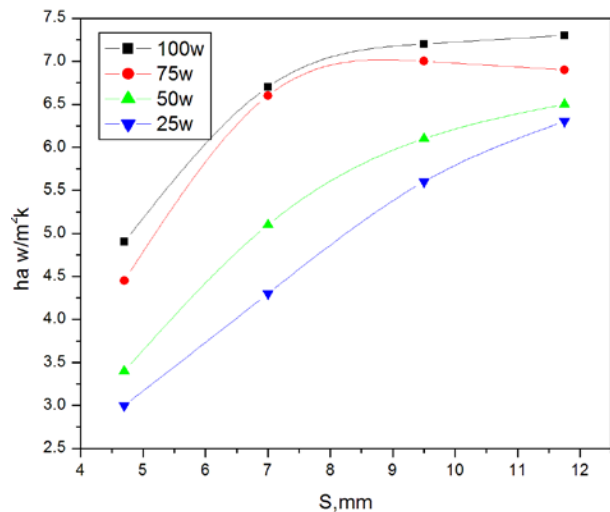


Fig.6 Variation of h_a with S for 30%Notched Array

The trend of increase in average heat transfer coefficient and hence in the Nusselt number with fin spacing is observed in case of the notched array also. Figure 7 shows the relative performance of fin array with 30% notch and that without notch.

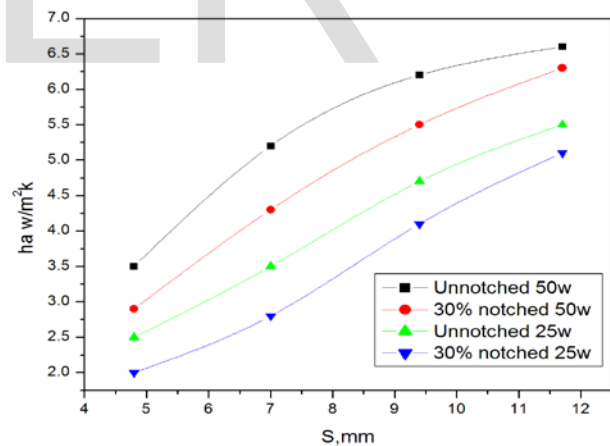


Fig.7 Comparison of average heat transfer

It is evident from the two graphs that the average heat transfer coefficient increases with the heater input. It is clear that for the given heater input, average heat transfer coefficient of notched array is 30 to 40% higher than corresponding unnotched array.

3.2 Effect of fin spacing on nu_a

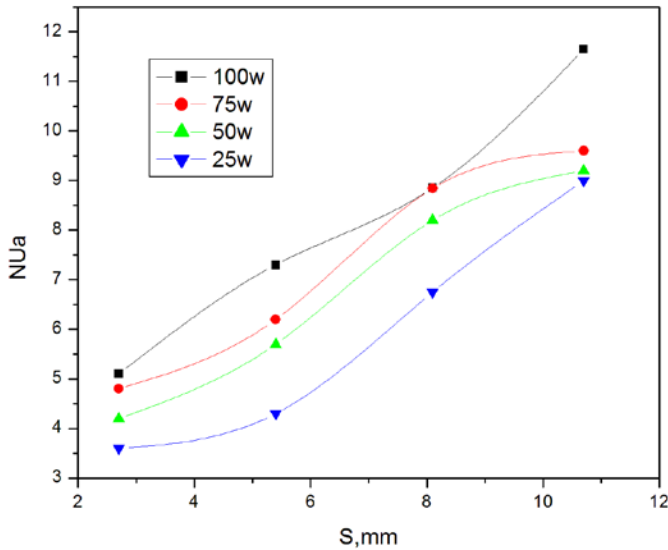


Fig.8 Variation of Nu_a with S for Unnotched Array

It is clear from the Fig. 8 that as spacing increases the average Nusselt number Nu_a increases for the notched array. The increasing trend is steep up to spacing about 8 to 10mm. After that the rise is gradual. The notched configurations yield higher values, thus indicating superiority of notched fin array over normal arrays as shown in Fig. 9.

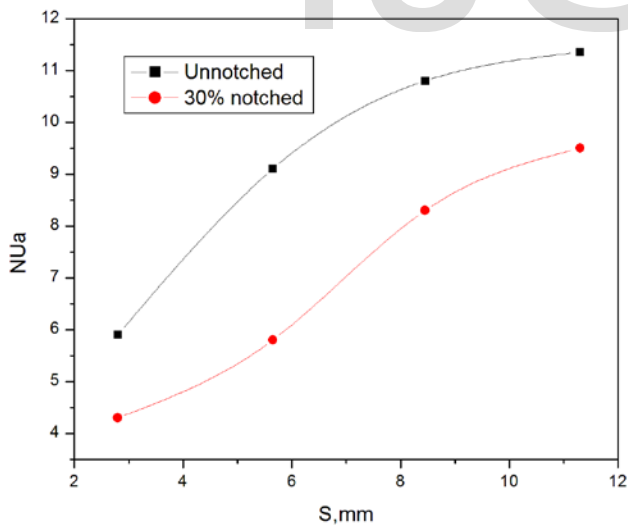


Fig.9 Comparison of Nu_a for Notched and Unnotched Array

In general it is observed that the Nu_a increases with increase in fin spacing, this is due to reason that with increase in spacing, the fluid can flow more freely through the fin channel.

3.3 Effect of fin spacing on h_b

Figure 10 shows the effect of fin spacing on h_b with heater input as the parameter for unnotched fin array. From the figure it is clear that the values of h_b increases as fin spacing decreases. It reaches to its maximum value at a fin spacing about 10mm and again decreases. This may be due to choking of flow at smaller fin spacing

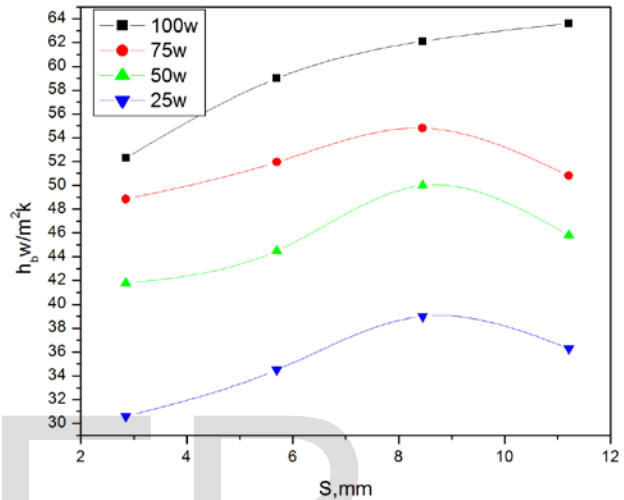


Fig.10 Variation of h_b with S for Unnotched Array

Effect of fin spacing on h_b with heater input as the parameter for 30% notched array is as shown in Fig 11.

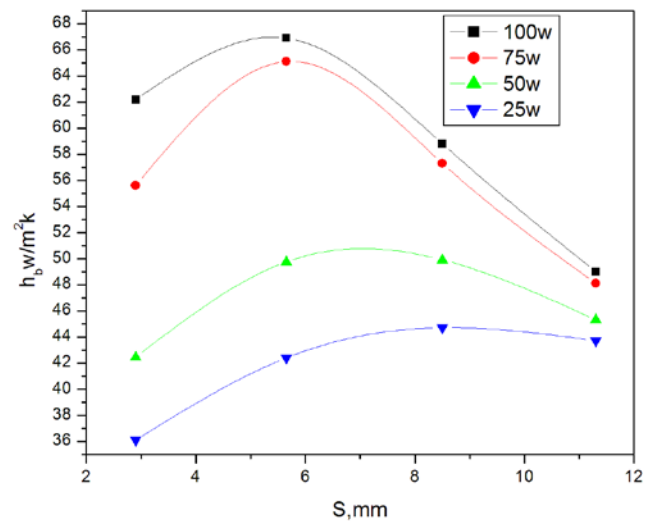


Fig.11 Variation of h_b with S for Notched Array

The trend of increase in base heat transfer coefficient with the maxima at a fin spacing of 8 mm is observed in case of the notched array also. It is observed that performance of notched fin array is better.

3.4 Effect of fin spacing on nu_b

Variation of base Nusselt number with fin spacing for 30%notched array is shown in Fig. 12.

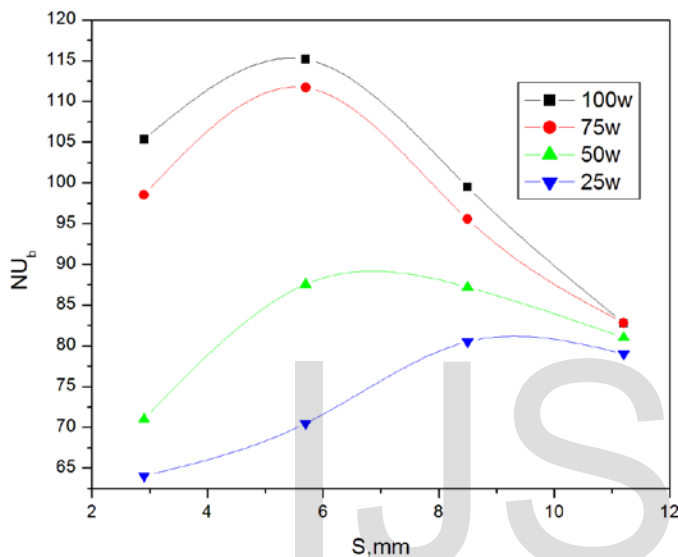


Fig.12 Variation of Nu_b with S for Notched Array

It is clear that as the value of Nu_b increases as fin spacing increases. It reaches to its maximum value and again decreases. The reason for decrement in Nu_b may be due to the choking of fluid flow at smaller spacing. The notched configurations yield slightly higher values, thus indicating superiority over normal arrays.

3.5 Optimum fin spacing:

The results of this experimentation appear to indicate that the value of base heat transfer coefficient is maximum when the single chimney flow pattern just ceases to exist. Thus, the limiting point of the single chimney flow pattern is a point of optimum spacing from heat transfer point of view. This can be explained by considering the heat transfer contribution of the base and that of the fin flat separately. The contribution of base increases with increase in S/H because of relative increase in the base area as compared to fin area.

However, the same logic is not applicable to the contribution of fin flat. At low values of S/H , there is restriction to the flow of air coming into the array, showing end choking effect and dominance of conduction heat transfer. Optimum fin spacing is decided by the highest value of base Nusselt number. It is observed that the optimum fin spacing for the two arrays is in a band of 8 to 10 mm.

4. FLOW VISUALIZATION OF NOTCHED AND UNNOTCHED FIN ARRAYS

In the present work flow visualization study is conducted by using simple smoke technique. Figure 13 shows photographs of flow visualization by using simple smoke technique using dhooop sticks for heater input of 40 W for the unnotched array under study. Figure 14 shows photograph of flow visualization for notched fin array. It is clear from the photographs that the single chimney flow pattern is retained in the notched array as well. The chimney is observed to be broader in case of the notched array. This confirms better performance of notched array in terms of increase in the heat transfer coefficient.



Fig 13 Flow Visualization for Unnotched Array

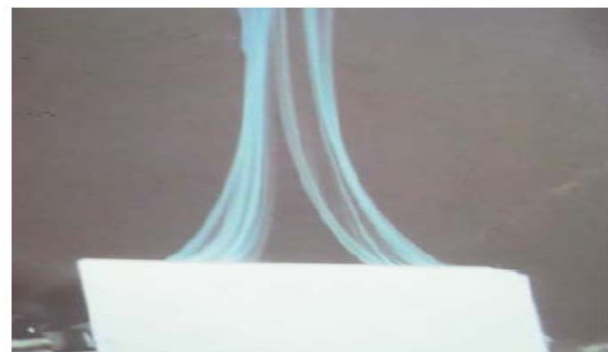


Fig 14 Flow Visualization for Notched Array

5. UNCERTAINTY ANALYSIS

All quantities measured during experiment are subjected to certain uncertainties due to error in measurements (16). The method suggested by Kline and McClintock (17) has been adopted to carry out the error analysis. Errors in temperature difference are $\pm 0.50^\circ\text{C}$. This translates to an error in the heat transfer coefficient of $\pm 4\%$. The uncertainty is calculated for all values and found out to be in the range of $\pm 5\%$.

6. CONCLUSION

Fin geometry and orientation plays a vital role in natural convection heat transfer. Our investigation deals with natural convection heat transfer on rectangular fin array. Here we have tried to optimize a rectangular fin array on the basis of cost and usefulness. In this experimental study, an attempt is made to improve the performance of horizontal rectangular fin array by removing the less effective portion of the fin flat in the form of a rectangular notch. It is observed that total heat flux as well as the heat transfer coefficient increase as the notch depth increases. As area removed from the fin is compensated at the air entry ends of the fin it provides chance to get greater amount of fresh cold air to come in contact with hot fin surfaces. As the air moves inwards along chimney profile, it gets heated and temperature difference between the fin and entering air decreases. When this area is removed and added at place where it is more useful for heat transfer, the heat transfer increases and so does the convective heat transfer coefficient. This analysis reveals that the recommended single chimney flow pattern is maintained for the notched fin arrays. The performance of notched fin arrays is 30 to 50% superior than corresponding unnotched arrays, in terms of average heat transfer coefficient. This innovative concept of modified fin array is reported for the first time by the authors (18, 19). It will be interesting to investigate further the optimization of all geometrical parameters viz. aspect ratio of the fin array, percentage area removal in the form of rectangular notch as well as to find the optimum notch profile for the given heat dissipation.

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