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Experimental Comparison of Natural Convection Heat Transfer from Blackened Horizontal Fins and Blackened V-Fins on a Vertical Plate

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ABSTRACT

Convection is usually the dominant form of heat transfer in liquids and gases. Although sometimes discussed as a third method of heat transfer, convection is usually used to describe the combined effects of heat conduction within the fluid (diffusion) and heat transference by bulk fluid flow streaming. Convective heat transfer is the transfer of heat from one place to another by the movement of fluids, a process that is essentially the transfer of heat via mass transfer. Bulk motion of fluid enhances heat transfer in many physical situations, such as between a solid surface and the fluid. This paper refers to the convective heat transfer from a V-Fin Array whose surface is made black and the fins are sticked to it to form horizontal fin array and in form of V-Fins to form V-Fin array.
Keywords : Heat Transfer, Natural Convection, V-Fins, Vertical Plate

I. INTRODUCTION

Free, or natural, convection occurs when buoyancy forces that result from density variations due to variations of temperature in the fluid cause bulk fluid motions (streams and currents). Forced convection is a term used when the streams and currents in the fluid are induced by external means—such as fans, stirrers, and pumps—creating an artificially induced convection current.

Natural or free convection is observed as a result of the motion of the fluid due to density changes arising from the heating and cooling process. Natural convection represents an inherently reliable cooling process. Further, this mode of heat transfer is often designed as a backup in the event of the failure of forced convection due to fan break down.

Fins are commonly applied for heat management in electrical appliances such as computer power supplies or substation transformers. Fins are used to enhance convective heat transfer in a wide range of engineering applications, and offer a practical means for achieving a large total heat transfer surface area without the use of an excessive amount of primary surface area. Other applications include Internal Combustion engine cooling, such as fins in a car radiator. Feasible and practical means to improve natural convection heat transfer is by the use of finned surfaces.

II. METHODS AND MATERIAL

A. Literature Review

Starnar and McManus [1] determined average heat transfer coefficients for four arrays positioned with base vertical, at 45° and horizontal. It was found that vertical arrays performed 10-30 % below the similarly placed parallel plates. The arrays at 45° performed 5-20 % below the vertical arrays and horizontal fin arrays performed lowest. Flow visualization tests were conducted using smoke technique. Baskaya et al. [2] carried out parametric study of natural convection heat transfer from the horizontal rectangular fin arrays. They investigated the effects of a wide range of geometrical parameters like fin spacing, fin height, fin length and temperature difference between fin and surroundings, to the heat transfer from horizontal fin arrays. However, no clear conclusions were drawn due to the various parameters involved. Wankhede et al. [3] developed an

experimental setup to carry out the investigation on horizontal rectangular fin array with and without inverted notch under natural and forced convections. The objective of the work was to determine the heat transfer characteristics experimentally, and further to find out the enhancement in heat transfer in the case of notched fin arrays over normal fin arrays, and analyzed the effect of different parameters like length, height, spacing of fins on heat transfer coefficient (h).
Karagiozis [4] experimentally investigated the problem of free convection from isothermal vertical base rectangular fin arrays, the fin cross-section being rectangular and triangular. He studied two different orientations of fins: viz. vertical and horizontal and also studied the arrays with blocked ends with both fin orientations. He also carried out experiments to determine the radiation contribution.

Prasolov et al. (1961) [5], Heya et al. (1982) [6], Bhavnani et al.(1990) [7] suggested that the roughness elements whose height is less than the boundary layer thickness will have no appreciable influence on the heat transfer of natural convection and these elements will work as flow retarder rather than the heat transfer promoter. An interferometric technique was used to determine local heat transfer coefficients for surfaces with repeated ribs and steps.

Barhatte et al. (2012) [8] did the study on heat transfer rate through different types of notches in the fin. He used different notches such as rectangular, circular, triangular and trapezoidal. He compare without notch and notch fin array by supplying different heat inputs. The dimensions of fin were fixed. They concluded that more heat is transfer through triangular notch fin.

Tsuji et.al. (2007) [9] conducted an experimental study on heat transfer enhancement for a turbulent natural convection boundary layer in air along a vertical flat plate has been per-formed by inserting a long flat plate in the span wise direction (simple heat transfer promoter) and short flat plates aligned in the span wise direction (split heat transfer promoter) with clearances into the near-wall region of the boundary layer.

B. Summary of Review

From the above literature review, it is seen that,

i. Very few researchers have worked on Vertical Plate with V-Fins
ii. Less work is carried out on Vertical Plate with V-Fins
iii. No any work has been carried out on V-fins with Blackened surfaces

C. Experimental Setup

Enhancement of heat transfer under natural convection conditions can be achieved by attaching the horizontal surface fins to the base plate. The arrangement will be vertical and the fins will be attached to the surface of the base plate. From the literature survey, it is found that very few investigators have worked on the problems related to this type of arrangement. Hence, it is decided to carry out an experimental work to find the enhancement in heat transfer by a special V-fin arrangement. The basic consideration will be, the total length of rectangular fins will be equal to the total length of V-fins. Therefore, the surface area during both conditions will be equal. In order to ascertain the characteristics of V-fins, the rectangular fins will be sticked to form V-fins on the base plate. Therefore, same height of both fins will be there and the enhancement in heat transfer for both conditions can be carried out. The base plate is divided into four equal parts. The heaters are placed between the base plate at an equal length from each other for effective heat distribution to the base plate. The enclosure used is for the development of undisturbed natural convection condition.

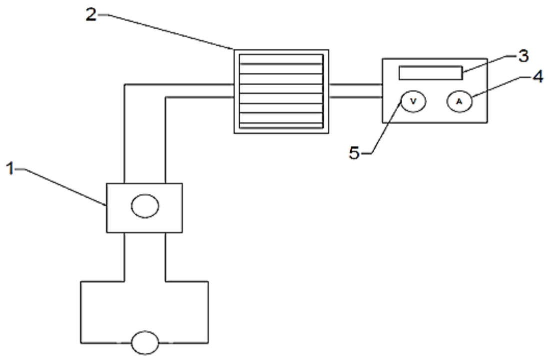


Figure 1. Experimental Setup

i. Dimmerstat
ii. Fin Array
iii. Temperature Indicator
iv. Ammeter
v. Voltmeter

D. Development of System

The system is designed and developed for the measurement of heat transfer parameters for which the details are as follows:

The base plate used for experimentation work is made up of aluminium and of dimension 200mm X 200mm X 25mm. Several markings are done on the base plate to identify the positions of rectangular fins as well as V-fins. The hooks are attached to the base plate with the help of screws. The strings will be attached to the hooks for positioning the base plate right at the mid center of the enclosure. The rectangular fins are arranged in such a way that they look like a V-fin.

Figure 2. Plate with V-Fins

The cartridge type heater of dimension Ø 5mm X 200mm was used. The heaters were placed in the holes inside the base plate symmetrically. The rated power output was 260 Watts. Enclosure is used to obtain an effective natural convection condition. The setup is hanged at the top side of the enclosure. The enclosure is covered with acrylic sheets from all the four sides for observation purpose. The enclosure is 1m x 1m x 1m in dimension.

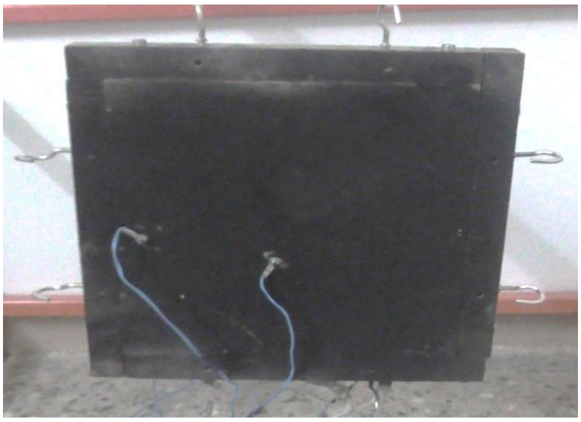


Figure 3. Plain Blackened Vertical Plate

Figure 4. Plain Blackened Vertical Plate with Fins

Figure 5. Plain Blackened Vertical Plate with V- Fins

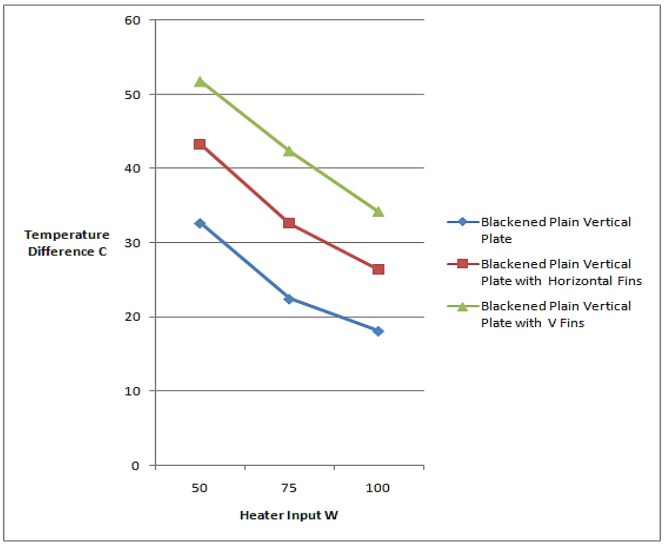
The experimental procedure carried out is as follows: Initially, the enclosure is opened from two sides. This is in order to hook the test plate to the enclosure from inside end. After that, the sides of the enclosure are closed by acrylic sheets. The connections of the thermocouples were made at required positions. The remaining electrical connections are checked i.e. connections of heater, wattmeter and dimmerstat etc. The heater is heated by supplying a.c.current through dimmerstat and wattmeter. After checking all the connections, the switch of temperature indicators and dimmerstat is turned ON. The temperatures at different points were read by the digital temperature indicator and were recorded at a time interval of 30 minutes. The heater input was kept constant by varying the dimmerstat to account for voltage fluctuations. The final reading was recorded when steady state is reached.

III. RESULTS AND DISCUSSION

After certain series of observations and calculations, the results found are as follows:

Table 1. Results of Temperature Difference

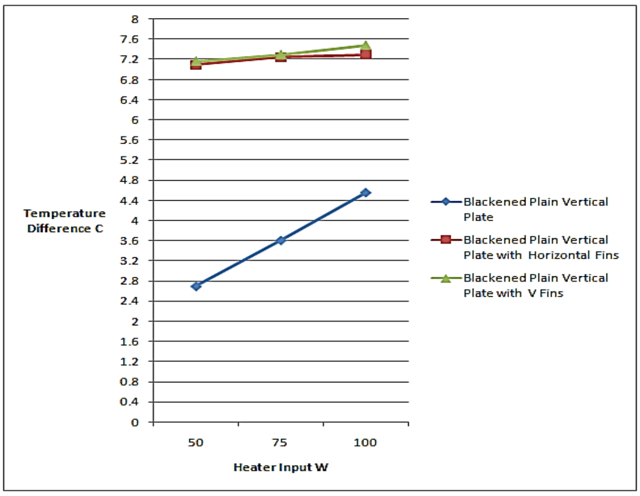
Sr.No.	Heater Input Q (W)	Temperature Difference Δ T (°C)		
		Blackened Plain Vertical Plate	Blackened Vertical Plate with Horizontal fins	Blackened Vertical Plate with V-Fins
1	50	32.65	22.39	18.06
2	75	43.28	32.62	26.37
3	100	51.80	42.36	34.16



As the whole surface being black, the radiation increases thereby reducing the temperature at all the nodes. For Blackened surface, the lowest temperature difference is found out to be for V-fins with apex facing downwards configuration.

Table 2. Results of Average heat transfer coefficient

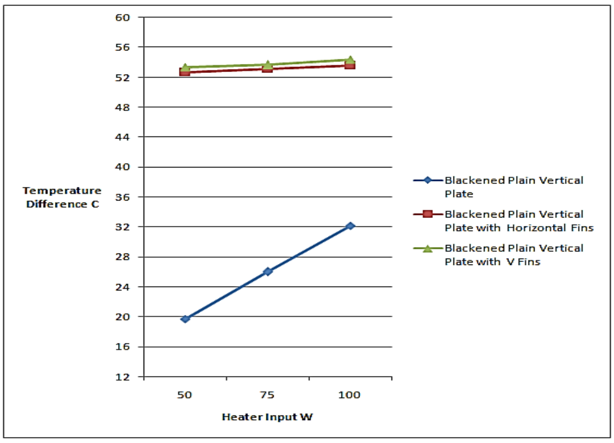
Sr.No.	Heater Input Q (W)	Nusselt Number Nu		
		Blackened Plain Vertical Plate	Blackened Vertical Plate with Horizontal fins	Blackened Vertical Plate with V-Fins
1	50	19.71	52.67	53.34
2	75	26.00	53.14	53.67
3	100	32.18	53.56	54.35



From the graph, it has been observed that the average heat transfer coefficient for V-fins with apex downwards configuration has the highest value and thereby has more better performance in comparison with the other configurations.

Table 3. Results of Nusselt Number

Sr.No.	Heater Input Q (W)	Average heat transfer coefficient h - W/m² K		
		Blackened Plain Vertical Plate	Blackened Vertical Plate with Horizontal fins	Blackened Vertical Plate with V-Fins
1	50	2.69	7.09	7.16
2	75	3.60	7.24	7.29
3	100	4.55	7.39	7.48



From the graph, it has been observed that the value of Nusselt Number for V-fins with Apex facing downwards is higher than the other configurations. As Nusselt Number is higher, this type of configuration will give better performance as compared to other fin configurations.

IV. CONCLUSION

1) In case of V-Fins with Apex facing Downwards configuration, the average heat transfer coefficient is in the range of 7.16 – 7.48 W/m2 K which is the highest value of average heat transfer coefficient for any other configuration. This concludes that V-Fins facing downwards give better performance than Plain Vertical Plate, Vertical Plate with Horizontal Fins.
2) As the heater input increases from 50W to 100W, the temperature difference also increases, and it is observed that for V-Fins with Apex facing downwards configuration, the temperature difference is in the range of 18.06 – 34.16ºC, which is the lowest as compared to any configuration. This means that this configuration gives the better performance.
3) Nusselt number value for V-Fins with Apex facing downwards configuration is in the range 53.34 – 54.35, which is the highest as compared to other configurations.
4) The V-Fins arrangement has good heat transfer performance than a plain vertical plate because it acts as a flow disturber to heat flow over the plate.

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