Research on a Blackened Aluminium Plate with V-fins under Natural convection heat transfer conditions

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Abstract

This paper deals with the experimentation of a vertical aluminium plate on which fins are attached. The fins are attached in such a way that they form a V-fin array The entire Plate is blackened in order to also find the radiation heat transfer. The heat transfer performance parameters like average heat transfer coefficient and Nusselt number are calculated and compared. The rectangular fins are arranged to form a v-shape and are tested for various heater inputs like 50W, 100W, 125W and so on. As per the results it is concluded that the blackened v-fins arrangement with apex downwards is the best arrangement as compared to rectangular arrangement.

Keywords

Blackened Plate, Heat Transfer, Natural Convection, Rectangular Fins, V-fins

INTRODUCTION

Free, or natural, convection occurs when bulk fluid motions (streams and currents) are caused by buoyancy forces that result from density variations due to variations of temperature in the fluid. 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 back up in the event of the failure of forced convection due to fan break down.

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. Fins are commonly applied for heat management in electrical appliances such as computer power supplies or substation transformers. 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. Vertical plate fins have been conventionally adopted to enhance the heat transfer from a vertical heated plate. The main function of these fins is not to increase the heat transfer rate itself, but to enlarge the effective heat transfer area. In order to obtain a high level of heat transfer performance with these fins, the surface area of the fins should be far larger than that of the base plate. Such a large fin area can only be achieved by the use of high fins.

LITERATURE REVIEW

The influence of various surface roughness on natural convection of water and spindle oil along with a vertical cylinder was studied by **T.Fujii and M.Fujii [1]**. The work on the effect of horizontal partition plate attached to a vertical plate was reported by **Misumi and Kitamara K [2]**. This was followed by the same authors **Misumi and Kitamara K.[3]**, where they have studied the effect of partition plate and V-plate. They also compared the performance of V-plate array with conventional vertical fin array and obtain better performance. **Starnar and McManus [4]** 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. Vertical arrays and arrays at 45° showed predominant flow in vertical direction with some inflow from the front of fin channel. In addition to the above mentioned flow pattern, for horizontal arrays they observed single chimney flow pattern when the ends were kept open and down and up flow pattern when the ends were closed.**N.K.Sane and J.G.Kulkarni [5]** carried out study on free convection heat transfer from vertical tapered fin arrays. Fins both with upward and downward taper have been investigated. Also arrays formed by changing the fin spacing have been tested at different power input values. Similar experimental work is carried out with rectangular straight fins with the same fin flat areas. Experiments were conducted by varying the fin spacing from 6.2mm to 24.8mm in four steps. The results were obtained for the average value of heat transfer coefficient based on the total surface area of fin array and base heat transfer coefficient based on base area only. They found that downward tapered fins are more effective than straight and upward tapered fins over the values of fin spacings which fall in the range of optimum spacings. **Baskaya et al. [6]** 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. [7]** 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 [8]** 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.

SUMMARY OF LITERATURE

From the above literature survey, it is found that -

1) Several studies are carried out on heat transfer through rectangular fins by variation in height of fins and number of fins.
2) More study has been focused on the use of Partition plate for V-Fins between the base plates.
3) To the author’s knowledge, it has been observed that very less work has been carried out on blackened V-Fins for the heat transfer enhancement.

EXPERIMENTAL WORK

The experimental work is related with the blackened plate to which the fins are attached the total surface area of the plate with fins is kept constant. The enhancement of heat transfer will take place due to the attachment of fins arranged in V-form to the vertical base plate. From the literature survey, it is found that very less work has been carried out on blackened plate with V-fins. The basic arrangement will be, the total surface area of rectangular fins will be equal to the total surface area of V-fins. The whole system is kept under natural convection conditions under an enclosure and the readings are taken at steady state conditions. The experimentation is carried out by varying the power input with the help of a dimmerstat while the total surface area remaining constant in each case.

DEVELOPMENT OF SYSTEM

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

The aluminium base plate used for research work having the dimensions as 200mm X 200mm X 25mm. The base plate is divided into equal parts in order to locate the position of both, rectangular and V-form fins. The vertical plate will be hanged by hooks which are provided at the top side of enclosure The base plate also has hooks at its far end on every side. The base plate will be hanged at the mid centre of the enclosure with the helps of a nylon string. The base plate has three cartridge heaters inserted throughout at equal distances. The aluminium base plate is shown in Figure No.1 below:-

Figure 1. Plain Aluminium Plate

The figure no.2 shows the blackened V-Fins attached to the base plate and the plate hanged at the centre of enclosure.

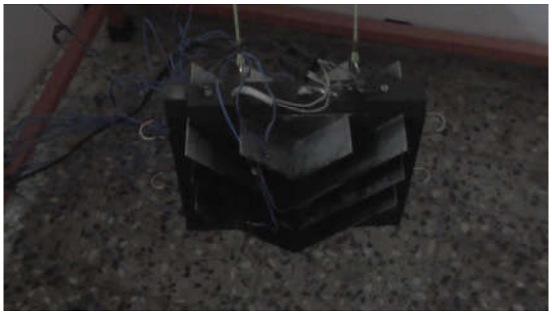


Figure 2. Plain Aluminium Plate with V-fins fins

The figure no.3 shows the vertical Rectangular fins attached to the base plate and the plate hanged at the centre of enclosure.

Figure 3. Blackened Plain Aluminium Plate with Rectangular Fins

RESULTS AND DISCUSSION

The below mentioned are the observation tables for various arrrangements –

Sr. No	Heater Input (W)	Base Plate Temperatures (°C)				Enclosure Temperature(°C)
		T1	T2	T3	T4	Tamb.
1	50	58.2	60.9	60.5	58.6	26.9
2	75	67.2	72.4	71.8	69.7	27.0
3	100	76.4	80.2	81.5	77.5	27.1
4	125	83.5	88.8	89.5	89.6	27.2
5	150	93.8	97.1	97.6	99.6	27.3
6	175	105.1	108.5	106.5	106.1	27.4
7	200	113.9	116.5	115.5	114.3	27.6

Table no.1 – Observations for Blackened Plain Vertical Plate

Sr. No	Heater Input (W)	Base Plate Temperatures (°C)				Fin Array Temperatures (°C)					Enclosure Temperature (°C)
		T1	T2	T3	T4	T5	T6	T7	T8	T9	Tamb.
1	50	47.0	52.3	52.1	51.2	41.5	40.1	42.5	43.5	41.3	27.3
2	75	57.6	60.2	61.2	62.5	47.5	45.4	50.2	54.1	48.2	27.5
3	100	66.0	72.2	72.5	71.5	51.3	50.1	59.2	60.5	54.6	27.8
4	125	74.5	83.5	84.6	83.2	55.6	54.2	64.9	67.5	60.2	27.8
5	150	81.5	91.2	93.4	94.1	59.2	59.7	73.5	75.9	66.6	28.1
6	175	93.5	100.1	104.2	102.5	63.5	64.2	79.5	81.4	70.1	28.3
7	200	101.4	110.2	113.5	114.2	69.8	70.1	87.5	87.5	79.2	28.4

Table no.2 – Observations for Blackened Vertical Plate with Vertical Fins

Sr. No	Heater Input (W)	Base Plate Temperatures (°C)				Fin Array Temperatures (°C)								Enclosure Temperature (°C)
		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	Tamb.
1	50	48.8	49.5	51.3	50.8	43.6	43.1	41.0	45.2	43.2	43.4	47.8	46.2	28.1
2	75	62.4	63.2	65.6	64.2	50.2	49.2	47.6	51.2	48.2	50.2	51.4	51.4	28.2
3	100	74.7	78.3	76.5	72.3	58.1	56.8	51.2	58.1	54.2	56.2	55.8	56.1	28.2
4	125	84.3	88.5	90.0	85.5	64.2	63.7	59.5	64.2	58.6	60.8	59.2	61.2	28.3
5	150	97.2	100.1	98.3	94.1	70.9	69.6	65.2	70.3	65.2	64.5	64.1	65.8	28.3
6	175	108.2	111.4	107.6	103.2	75.2	76.2	70.3	76.2	73.1	69.8	69.3	69.8	28.5
7	200	118.2	120.4	116.8	113.4	82.6	82.2	78.5	83.2	78.2	76.4	75.5	75.6	28.6

Table no.3 – Observations for Blackened Vertical Plate with V-fins

The average heat transfer coefficient is based on the total surface are including that of the extended surfaces. It is observed that the heat transfer coefficients increases with increase in heater input thereby increasing the temperature difference for all configurations. The average heat transfer coefficient for blackened plain vertical plate was found in the range of 2.69 to 5.35 W/m^2 K. For Blackened Vertical Plate with Vertical fins, the value was in the range of 6.96 to 7.50 W/m^2 K. The value of average heat transfer coefficient for Blackened Plate V-fins with apex facing downwards comes out in the range of 7.16 to 7.73 W/m^2 K. From the results, it was observed that the average heat transfer coefficient for V-fins with apex facing downwards configuration is higher as compared to the other configurations, thereby giving better performance

Sr. No.	Heater Input (W)	Enclosure Temperature $T_{amb.}$ (°C)	Average Surface Temp. Ts (°C)	Temp.Difference Δ T (°C)	q (radiation) W	q (convection) W	Average heat transfer coefficient h - W/m² K
1	50	26.9	59.55	32.65	36.39	13.61	2.69
2	75	27.0	70.28	43.28	50.85	24.15	3.60
3	100	27.1	78.90	51.80	63.49	36.51	4.55
4	125	27.2	87.85	60.65	77.64	47.36	5.04
5	150	27.3	97.03	69.73	93.28	56.72	5.25
6	175	27.4	106.55	79.15	110.82	64.18	5.23
7	200	27.6	115.05	87.45	127.52	72.48	5.35

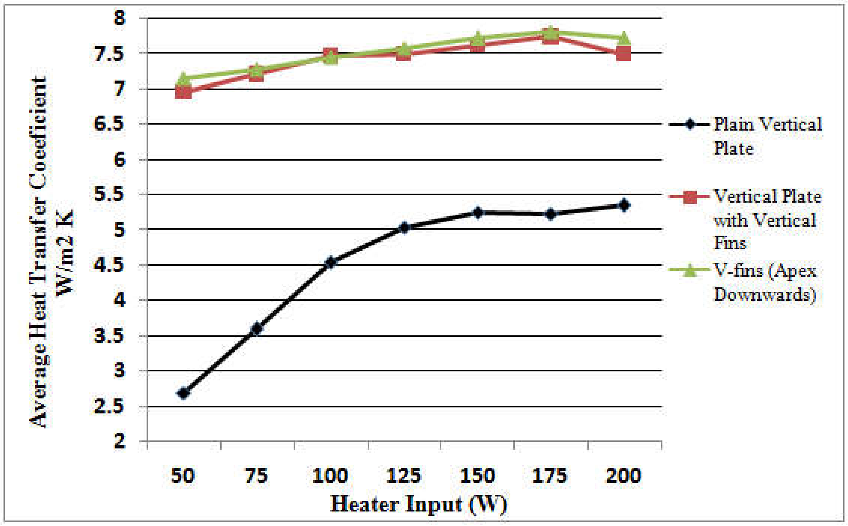
Table no.4 – Results for Blackened Plain Vertical Plate

Sr. No.	Heater Input (W)	Enclosure Temperature $T_{amb.}$ (°C)	Average Surface Temp. Ts (°C)	Temp.Difference Δ T (°C)	q (radiation) W	q (convection) W	Average heat transfer coefficient h - W/m² K
1	50	27.3	45.72	18.42	19.22	30.78	6.96
2	75	27.5	54.10	26.60	28.95	46.05	7.21
3	100	27.8	61.99	34.19	38.72	61.28	7.47
4	125	27.8	69.80	42.00	49.41	75.59	7.50
5	150	28.1	77.23	49.13	60.00	90.00	7.63
6	175	28.3	84.33	56.03	70.86	104.14	7.74
7	200	28.4	92.60	64.20	84.49	115.51	7.50

Table no.5 – Results for Blackened Vertical Plate with Vertical Fins

Sr. No.	Heater Input (W)	Enclosure Temperature $T_{amb.}$ (°C)	Average Surface Temp. Ts (°C)	Temp.Difference Δ T (°C)	q (radiation) W	q (convection) W	Average heat transfer coefficient h - W/m² K
1	50	28.1	46.16	18.06	18.95	31.05	7.16
2	75	28.2	54.57	26.37	28.85	46.15	7.29
3	100	28.2	62.36	34.16	38.83	61.17	7.46
4	125	28.3	69.98	41.68	49.18	75.82	7.58
5	150	28.3	77.11	48.81	59.62	90.38	7.72
6	175	28.5	84.19	55.69	70.44	104.56	7.82
7	200	28.6	91.75	63.15	82.84	117.16	7.73

Table no.6 – Results for Blackened Vertical Plate with V-Fins



Graph no.1 – Comparison of Average Heat transfer coefficient

The Nusselt number for Blackened Vertical Base plate is in range from 19.71 to 35.74. For Blackened Vertical Plate with Vertical fins, the value was in the range of 51.96 to 54.77. The value of Nusselt number for Blackened Plate with V-fins comes out in the range of 53.34 to 55.19.

Sr.No.	Heater Input (W)	Enclosure Temperature $T_{amb.}$ (°C)	Average Surface Temp. Ts (°C)	Mean Film Temp. Tm (°C)	Nusselt No. Nu
1	**50**	26.9	59.55	43.23	19.71
2	**75**	27.0	70.28	48.64	26.00
3	**100**	27.1	78.90	53.00	32.18
4	**125**	27.2	87.85	57.53	35.10
5	**150**	27.3	97.03	62.16	35.74
6	**175**	27.4	106.55	66.98	35.11
7	**200**	27.6	115.05	71.33	35.29

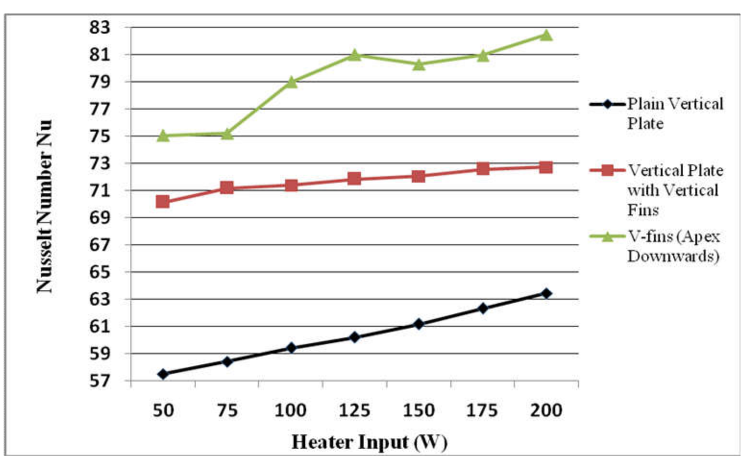
Table no.7 – Results for Plain Vertical Plate

Sr.No.	Heater Input (W)	Enclosure Temperature Tamb. (°C)	Average Surface Temp. Ts (°C)	Mean Film Temp. Tm (°C)	Nusselt No. Nu
1	**50**	27.3	45.72	36.51	51.96
2	**75**	27.5	54.10	40.80	53.10
3	**100**	27.8	61.99	44.89	54.33
4	**125**	27.8	69.80	48.80	53.98
5	**150**	28.1	77.23	52.67	54.33
6	**175**	28.3	84.33	56.32	54.77
7	**200**	28.4	92.60	60.50	52.61

Table no.8 – Results for Vertical Plate with Rectangular Fins

Sr.No.	Heater Input (W)	Enclosure Temperature Tamb. (°C)	Average Surface Temp. Ts (°C)	Mean Film Temp. Tm (°C)	Nusselt No. Nu
1	**50**	28.1	46.16	37.13	53.34
2	**75**	28.2	54.57	41.38	53.67
3	**100**	28.2	62.36	45.28	54.35
4	**125**	28.3	69.98	49.14	54.63
5	**150**	28.3	77.11	52.70	55.15
6	**175**	28.5	84.19	56.35	55.19
7	**200**	28.6	91.75	60.18	53.98

Table no.9 – Results for Vertical Plate with V-Fins



Graph no.2 – Comparison of Nusselt No.

CONCLUSION

1) For Blackened V-Fins with Apex facing Downwards configuration, the average heat transfer coefficient is in the range of 7.16 – 7.73 W/m^2 K. As this value is higher as compared to the other values, it is concluded that this arrangement is best as compared to the other arrangements.

2) The Nusselt number value for Blackened V-Fins with Apex facing downwards configuration is in the range 53.34 – 55.19, which is the highest as compared to other configurations.

3) The Blackened V-Fins arrangement has good heat transfer performance than a plain vertical plate because it disturbs the flow and due to this the flow of heat becomes turbulent, thereby increasing the heat transfer rate.

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