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Effect of fin shapes, spacing and height on the heat transfer characteristics of micro fin under natural convection

Navaneetha krishnan P[1], Shine N R[2], Athul KM[2], Muhammad Shaji C P[2], Revathy P[2], Vishnuj S[2]

[1]Asst.Professor, Department of mechanical engineering, Ammini College of engineering Palakkad Kerala, India

[2]Students, Department of mechanical engineering, Ammini College of engineering Palakkad Kerala, India

ABSTRACT

With the miniaturisation of electronic equipment's, removal of heat generated in the microprocessors has become a great problem for research. Nowadays micro fins are extensively used as heat sinks. Therefore the heat transfer analysis of micro fins is an interesting but yet a limited area of research. This paper extends the heat transfer analysis of micro fins under natural convection. It presents the experimental determination of the effect of fin shape, spacing and height on the Nusselt number. A set of six micro fins, with different shape, height and spacing is tested in a standard experimental setup and the Nusselt number for each microfin is determined. Based on the experimental result a correlation is developed connecting nusselt number as a function of the height to space ratio and the shape coefficient. The correlation is validated with the research results in the literature.

Keywords: Micro fin, Nusselt Number

I. INTRODUCTION

The major problem in the electronic equipments is that heat is generating during the working. The heating of the electronic equipment reduces the performance of the equipment. So to avoid this condition we use a heat transfer equipment is called heat sink. The heat sink helps to remove the heat from electronic equipments to the surroundings.

For enhancing the heat transfer characteristics of heat sink, we use a micro scaled heat sink called as micro fin. Micro fin is a surface extended heat exchanger that is use to transfer the heat from the electronic equipment to the atmosphere. The size of the single fin is around 1mm. The major advantages of micro fin over other heat sinks are compact size, lightweight, high heat transfer rate. In this present work, we investigate the effect of fin shape, spacing and height on the heat transfer characteristics of micro fin under natural convection

II. DESIGN AND MANUFACTURING

For the analysis of heat transfer characteristics of micro fin, we select rectangular and triangular shaped

micro fin. The rectangular and triangular micro fin is again classified in to 3 based on their height and spacing of the fin. Therefore, there is 3 rectangular and 3 triangular fin. For the experiment, we use 63.5× 63.5 mm (2.5× 2.5inches) aluminium square plate for the production of micro fin. Aluminium A6063 is selected for the manufacturing of the micro fined square plate. The aluminium alloy A6063 is commonly use for the heat sink manufacturing. The aluminium A6063 has high thermal conductivity (201 W/m.K) and high corrosion resistance, lightweight and low cost. Due to these reasons, we select aluminium A6063 for the manufacturing of micro fin.

The table 1 shows the different geometries and dimensions of the micro fin. In this table the height of the micro fin is varies from 1 to 1.5 mm and the thickness of the micro fin varies from 0.6 to 1 mm The micro fin heat exchanger was designed by using simense PLM software solid edge ST8. We designed 3rectangular and 3triangular micro fin by using solid edge ST8 software. The Figure 1 shows the design of rectangular micro fin.

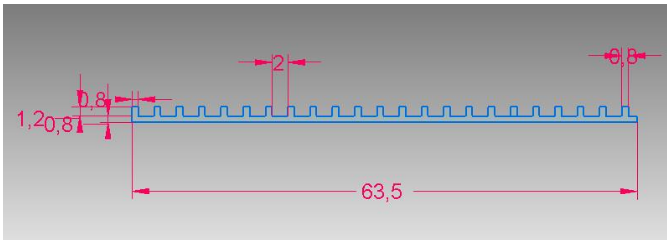

Figure 1: Design of a rectangular micro fin

Sl.No	Fin shape	Spacing (S)	Height (H)
1	Rectangular 1	1 (mm)	1.5(mm)
2	Rectangular 2	2(mm)	1.2(mm)
3	Rectangular 3	3(mm)	1(mm)
4	Triangular 1	1(mm)	1.5(mm)
5	Triangular 2	2(mm)	1.2(mm)
6	Triangular 3	3(mm)	1(mm)

Table 1: dimensions of micro fin

There are several methods used for the manufacturing of micro fin etching, EDM wire cutting etc... In the present work, we use EDM wire cutting. In electron discharge machining, a thin wire is use to fed through the work piece and get the desired shape. The advantages of EDM wire-cutting machining over other methods are any complex shape can machine and good surface finish and very close to the tolerance. However, the main disadvantages of EDM are the material removal is very slow and the power consumption is high. Due to these problems, the cost of the EDM machining is high compare with other manufacturing method

III. EXPERIMENT APPARATUS

For the analysis of micro fin, we have done an experiment. For the experiment, we used six different micro fin geometries. The Figure 2 is representing the triangular micro fin machined by EDM wire cutting. a nichrome wire is used as a heating coil. To provide a constant heat flux a 230 v, 50 Hz AC autotransformer is used. A thermo probe is used to measure the temperature of the micro fin. An insulated chamber is use to cover the experiment setup from the atmosphere. Two holes are provided for the passage of air.

IV. EXPERIMENT SETUP

The heating coil made up of nichrome wire is connected to the autotransformer. The autotransformer is connected to a 230V, 50 HZ Ac power supply. An Ac ammeter and voltmeter is connected to the autotransformer to measure the current and voltage.

Figure 2: Triangular micro fin

For calculating the amount of heat we use the equation $V \times I$. Figure 3 represent the schematic diagram of the experiment setup. Now the autotransformer is adjusted to 30 V and the current is 0.32 A. After the adjustment of the auto transformer, the micro fin is kept on the heating coil. Now the circuit is kept closed and the heating coil is heated. Due to the conduction the heat is transferred from heating coil to the micro fin. Allow one hour time period for the heating of the micro fin. The measurements are taken after one hour time period. After the measurement the micro fin is removed and power off the supply. Provide a time period for the cooling of the experiment setup. When the heating coil reaches the initial temperature, the experiment is repeated for the next fin. The experiment is repeated for all other fins.

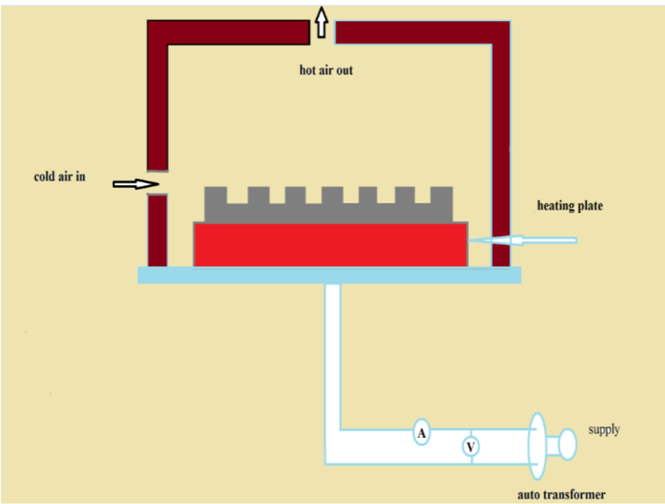

Figure 3: schematic diagram of experiment setup

When the cold air is entering in to the chamber through the two ducts, the air is circulated inside the chamber. When the air is passed over the micro fin plate the convection takes place and the heat is transferred from the plate to the cold air. Now the air gets heated and the hot air is moves up ward direction due to increasing its density. The hot air escaped through the duct where situated above the top of the chamber. Using a thermo probe the temperature of hot air and the micro fin plate is measured at a time.

V. RESULT AND ANALYSIS

From the experiment, we get a result. The table 2 shows the experiment result. In this table the T1 represent the triangular fin 1, and R1 is rectangular fin 1.

Fins	Voltage (v)	Current (A)	Room temperature (°C)	Plate temperature (°C)	Air temperature (°C)	Time (hr)
Rectangular fin 1	30	0.32	31.3	80.5	44.4	1
Rectangular fin 2	30	0.32	31.5	82.8	42.7	1
Rectangular fin 3	30	0.32	31.3	84.4	41.4	1
Triangular fin 1	30	0.32	31.8	80.4	45.1	1
Triangular fin 2	30	0.32	32.2	82.6	41.4	1
Triangular fin 3	30	0.32	31.8	85.9	43.4	1

Table 2: experiment result

From this table, we can see that the atmosphere air temperature in between 31 and 33°C. In rectangular shape fin rectangular fin 1 has more number of fin than other two and the rectangular fin 1 is transferred more heat than rectangular fin 2 than rectangular 3. In rectangular fin 1 the temperature of the cold air or atmosphere air is 31.3°C and after the convection the air is heated and the temperature of the hot air is 44.4°C. The temperature difference between cold air and the hot air is 13.1°c and it is found that the rectangular fin 1 is transfer more heat than other two rectangular fin. Similarly the triangular fin 1 is more number of fins than other two triangular fins. In triangular fin 1the temperature of the atmospheric air 31.8°C. After the convection the temperature of the air is increases and final temperature of the hot air is 45.1°C. The temperature difference between the atmospheric air and the air inside the chamber or the hot air is 13.3°C and we can observe that the triangular fin 1 is transfer more heat to the atmosphere. From this data we can found that when the no of fin is increases then the heat transfer rate is increases. The table show the related data based on the nusselt number. The nusselt number is the ratio of the convective heat transfer to the conductive heat transfer. $Nu = hl/k$. Where Nu is the nusselt number, h is the convective heat transfer coefficient, l is the length of the plate, K is the thermal conductivity. To find the nusselt number first we find the convective heat transfer coefficient h. From the equation $Q = ha\Delta t$ we get the value of the convective heat transfer coefficient.

SL NO	FIN	AREA (m²)	dT (°c)	Q (j)	h (W/m²K)	l (m)	K (W/mk)	Nu
1	T1	0.01359662	35.3	9.6	20.00163822	0.063	0.02779	45.34213
2	T2	0.00748284	41.2	9.6	31.13926767	0.063	0.02765	70.92951
3	T3	0.00565404	42.5	9.6	39.95061106	0.063	0.02791	90.15612
4	R1	0.01000965	36.1	9.6	26.33863	0.063	0.02786	59.54262
5	R2	0.0062992	40.1	9.6	38.00506354	0.063	0.02774	86.28488
6	R3	0.00504825	43	9.6	44.22439736	0.063	0.02763	100.8118

Table 3: Analysis of experiment result

The table shows the nusselt number and the convective heat transfer coefficients of several micro fins. From this table we can found that, the triangular fin 1 has more area over other two triangular fins but the convective heat transfer coefficient and the nusselt number is less than compared with other two. Similarly, rectangular fin 1 has more area over other two rectangular fins but the convective heat trsnsfer coefficient and nusselt number is less than other two rectangular fins. From this data, we can observe that when the number of fins increases then the total area of the microfin plate is increases but the convective heat transfer coefficient is decreases because the convective heat transfer coefficient depending up on the area of the micro fin plate. When the convective heat transfer is decreases then the nusselt number is also decreases.

The table 4 shows the relationship of the nusselt number and the shape factor of the micro fin. It also gives how the space to height ratio is depending upon the nusselt number. From this table we can observe that the shape factor $Z = R/l$ where R is the shape factor coefficient which is given by, $R = 4A/P$ where A is the face area of the fin and P is the wet perimeter. In the equation of shape factor, *l* is the length of the micro fin plate.

Sl no	fin	Nusselt number	S/H	R=4A/P(mm)	Z=R/L
1	Triangular fin 1	45.34213	0.26	0.00058823	0.009263
2	Triangular fin2	70.92957	1	0.0007619	0.0120936
3	Triangular fin 3	90.15612	2	0.00089285	0.0141722
4	Rectangular fin 1	59.54262	0.66	0.0012	0.01889
5	Rectangular fin 2	86.28488	1.66	0.001	0.01574
6	Rectangular fin 3	100.8118	3	0.001333	0.02099

Table 4: Relationship between the S/H ratio and Nusselt Number

When the shape factor is increases and the Nusselt number is increases. Similarly, when the S/H ratio increases also the Nusselt number are increases. When the number of fin increases then the shape factor is decreases and Nusselt number is also decreases. So we can observe that there is a relationship between the shape factor, spacing to height ratio and the Nusselt number. By using the data from the table 4 a general correlation is obtained using a regression analysis

$$Nu = 48.60 + 20.73 * (\frac{S}{H}) - 181.983 * z$$

VI. CONCLUSSION

The investigation of the effect of the fin shape, height, and spacing is done by using an experiment. From the experiment we observed that the number fin increases then the heat transfer is increases. The convective heat transfer and the Nusselt number is depending the spacing of the micro fin. If the spacing is increasing between the two micro fin then the total area of the micro fin is decreasing and convective heat transfer coefficient is increasing also the Nusselt number is increasing. The convective heat transfer coefficient and Nusselt number is depending the spacing to the height ratio. From this relation s, a general correlation is obtained by using regression analysis. The general correlation is

$$Nu = 48.60 + 20.73 * (\frac{S}{H}) - 181.983 * z$$

VII. REFERENCES

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