To Verify Heat Transfer Through Solid Pin Fin And Perforated Pin Fin By Analytical And Experimental Method

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Abstract- *Increasing miniaturization of high speed multifunctional electronics demands ever more stringent thermal management. If the heat is not transferred properly, the equipment may result into severe damages or sometimes failures. Development of super heat exchangers requires fabrication of efficient techniques to exchange great amount of heat between surface such as extended surface and ambient fluid. Heat transfer inside flow passages can be enhanced by using passive surface modifications such as rib tabulators, protrusions, pin fins, and dimples. The heat transfer through solid pin fin can be greatly enhanced by the use of perforated pin fin. Normally a fan is used above the sink to enhance the heat dissipation. The surface area enhancement and cross flow heat dissipation is planned though use of through hole in fins in direction of air flow. Also the heat transfer coefficient can be improved by creating swirling effect to the motion of fluid which can be done by providing twist to the rectangular fin.*

Keywords- Heat transfer enhancement, Rectangular fins , Perforated pin fin, Twisted fin

I. INTRODUCTION

There are various equipment where the unutilised heat energy is required to be dissipated to the surroundings. If this heat is not dissipated, the system will fail due to overheating. The design of heat sink device is decided upon optimizing the opposite demands of increasing thermal dissipation rate and minimizing the pressure drop across the system. One of the most common solutions is to apply pin fin array onto a heat sink design which depends upon the relative fin height (H/d), the velocity of fluid flow, the thermal properties of the fluid, the cross-sectional shape of the pin-fins like perforation, the relative inter-fin pitch, the arrangement of the pin-fins like in-line, staggered arrangement and others [1]

Extended Surface (Fins) is used in a large number of applications to increase the heat transfer from surfaces. Typically, the fin material has a high thermal conductivity. The fin is exposed to a flowing fluid, which cools or heats it, with the high thermal conductivity allowing increased heat being conducted from the wall through the fin. Fins are used to enhance convective heat transfer in applications like IC engine cooling, heat removal from nuclear reactor, cooling of electronic components, motor, compressor, refrigerator, integrated circuits, transformer etc. [2]

Heat sink is a device which enhance heat dissipation from a hotter surface, to a cooler medium, generally air. For the following discussions, air is assumed to be the cooling fluid. A heat sink lowers the temperature by increasing the surface area that is in direct contact with the cooling fluid. This results into more heat dissipation and reducing the device operating temperature. The size of the device is a constraint due to the fact that the device is to be used as a portable device hence has to be compact. The study is focused on design development and testing of heat sink with rectangular fins that have a three layer of concentric triangular layout of fins. The surface area enhancement and cross flow heat dissipation is planned through use of perforation in fins in direction of air flow.

Thus the objective is to increase the heat transfer rate from the surface so that the temperature of solid surface is maintained in permissible range to prevent breakdown. This can be achieved by adding the perforations to the fin structure

II. METHODOLOGY

2.1 Types of test models:

Rectangular fin channel: Rectangular channel with solid rectangular pin fins arranged in a triangular staggered arrangement is used as shown in the below figure.

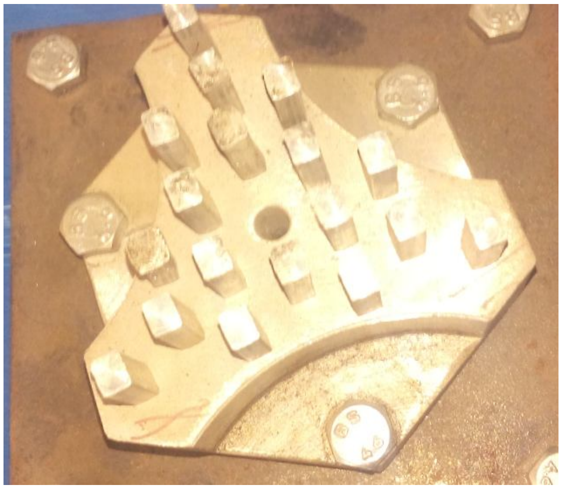


Fig. 1: Solid staggered pin fin array

Perforated pin fin channel: Rectangular channel with perforated rectangular pin fin arranged in a triangular staggered arrangement is used as shown in figure below.

Fig. 2: Perforated staggered pin fin array

2.2 Experimental set up:

The experimental set up consists of a base frame, blower, rectangular channel, heater, thermocouple, manometers and orifice etc. The base frame is used to support the experimental set up. A rectangular channel is mounted on the base frame. The blower is attached to the one end of the rectangular channel. With the help of blower, air is blown through the channel. The assembly of test model, thermocouple, heater and orifice is arranged inside the channel. The heater is used to heat the test model and thermocouple is used to measure the temperature of the test model. A manometer is used to measure the pressure inside the channel before and after the test model. The difference between manometer readings will give the pressure drop across the channel. The orifice meter is placed at the exit of the channel to measure the flow rate of air. Various readings are taken by changing the flow rate, test model and temperature.

Fig. 3: Experimental set up

2.3 Experimental procedure

1. Adjust the flow of the blower by using regulator for which the reading is to be taken.
2. Temperature will keep on increasing continuously. When steady state is reached note all the temperature for staggered pin fin array having solid pin fin.
3. Note down the temperature for different flow rate and pressure drop from manometer.
4. Repeat the procedure by replacing the solid pin fin staggered array with the perforated pin fin staggered array.

III. PERFORMANCE TESTING

3.1 Design of Pin fin array.

The pin fin array is arranged in a triangular staggered layout. The fins are rectangular in cross section with size as 4mm and 15mm high. These fins are mounted over a hexagonal base frame having holes to mount the test model inside the rectangular duct.

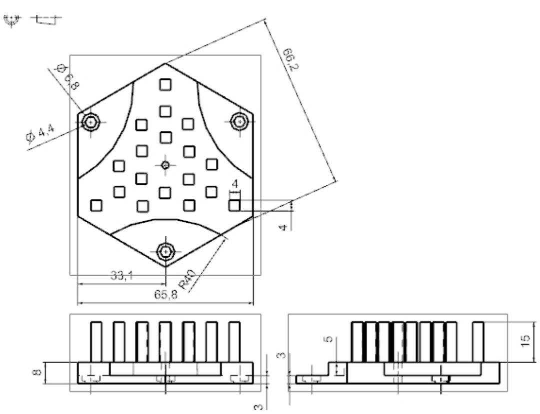


Fig. 4: Design of solid staggered pin fin array

The perforated pin fin array is having the identical arrangement as that of the solid pin fin array but with perfotations. The hole diameter is kept 2.5mm. Two equidistant holes are drilled per fin. Since the height of fin is 15mm, pitch of the hole becomes 5mm.

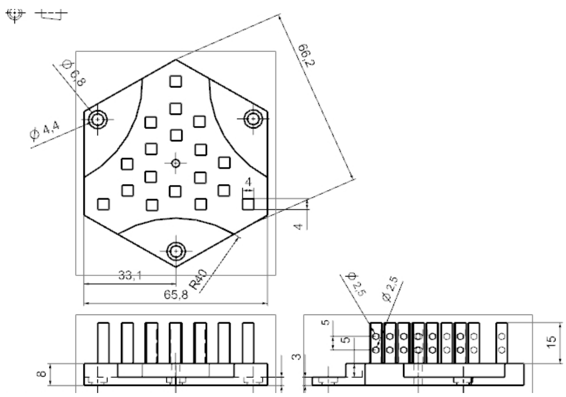


Fig. 5: Design of perforated pin fin array

3.2. Calculations of Heat Transfer Coefficient (Q)

$$Q = U \times A \times \Delta Tm = m \times Cp \times \Delta T$$

IV. ANALYSIS OF SOLID PIN FIN ARRAY

The test model of solid pin fin array is analysed by using ANSYS software to calculate the temperature distribution and heat flux through the pin fin array

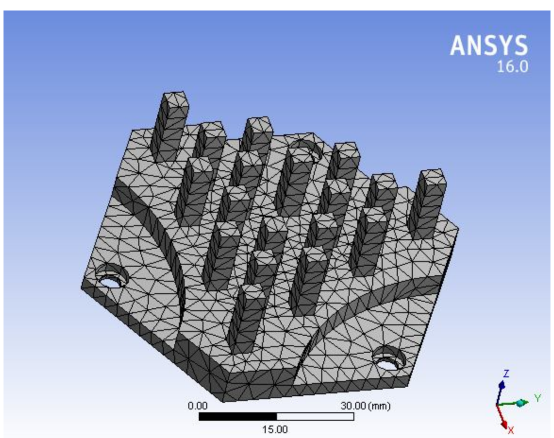


Fig. 6: Meshing of solid pin fin array

4.1 Mesh parameters:

Statistics	
Nodes	10106
Elements	5303
Mesh Metric	None

4.2 Temperature distribution: Temperature of the base frame was maintained at 600 C. As the distance from the source point increases, temperature of the fin is reduced. Temperature at the tip of fin is found about 300C.

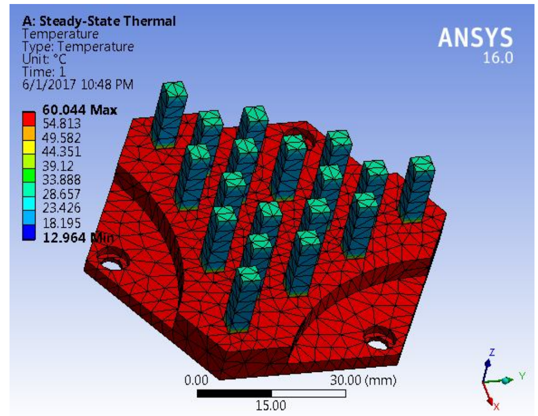


Fig. 7: Temperature distribution of solid pin fin array

4.3 Heat flux distribution: Air blows from the entry to the rectangular duct in unidirectional way and heat is carried with the air. Maximum heat flux is 2.64 W/mm2

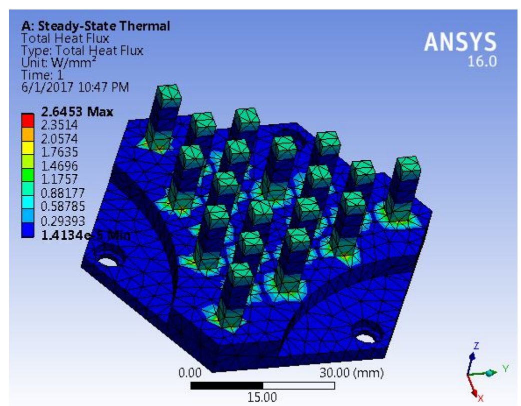


Fig. 8: Heat flux distribution of solid pin fin array

V. ANALYSIS OF PERFORATED PIN FIN ARRAY

The test model of solid pin fin array is analysed by using ANSYS software to calculate the temperature distribution and heat flux through the pin fin array.

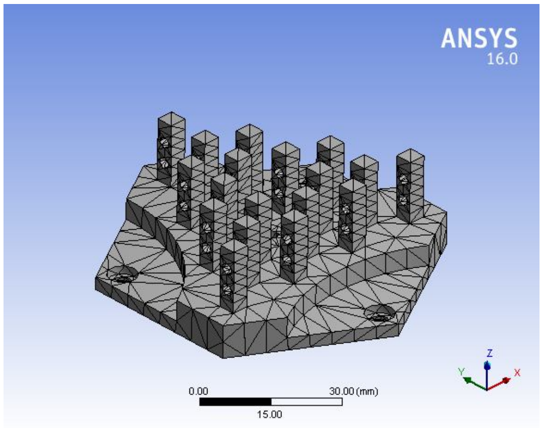


Fig. 9: Meshing of perforated pin fin array

5.1 Temperature distribution:

Temperature of the base frame was maintained at 600 C. As the distance from the source point increases, temperature of the fin is reduced. Temperature at the tip of fin is found about 220C. This temperature is very much less than that of the solid pin fin array.

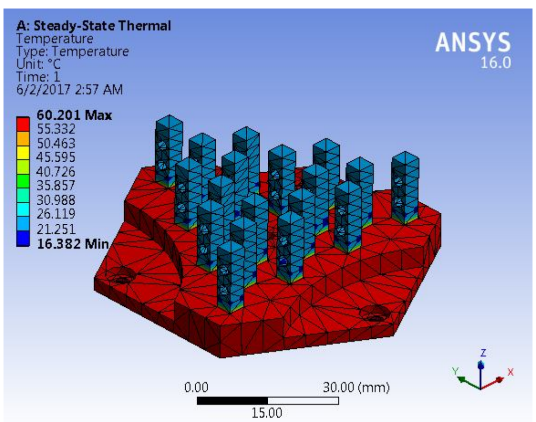


Fig. 10: Temperature distribution of perforated pin fin array

5.2 Heat flux distribution:

Heat flux through perforated pin fin: Maximum heat flux possible is 3.378 W/mm2

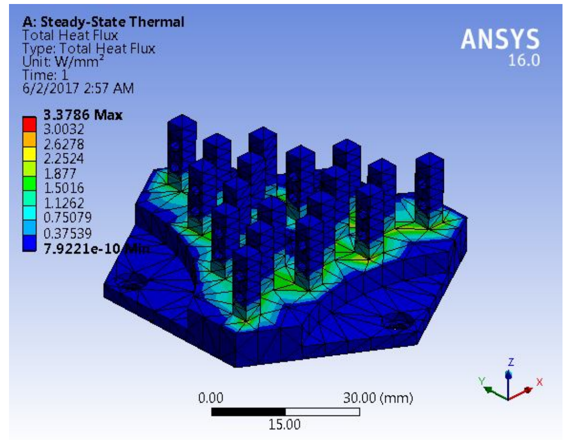


Fig. 11: Heat flux distribution of perforated pin fin array

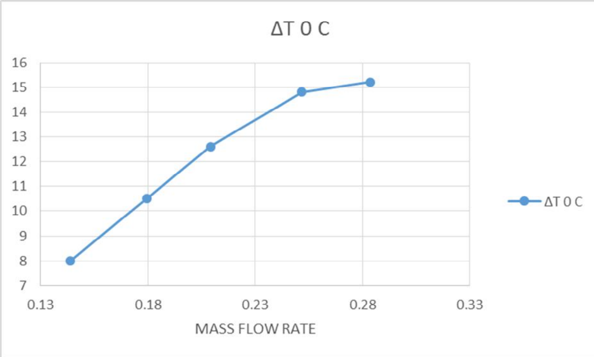
VI. RESULT AND DISCUSSIONS

Table 1: Calculation of Pressure drop, Temperature gradient, Heat flux and overall heat transfer coefficient of solid pin fin array

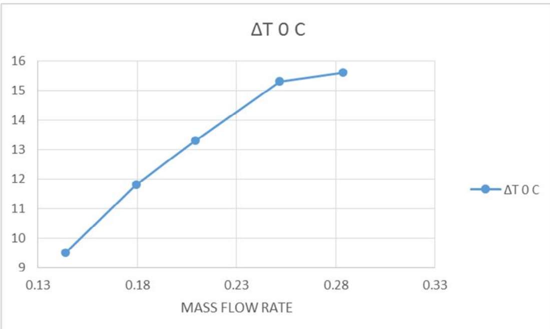
Sr. No.	Pres sure drop (CM)	Temp gradient ΔT 0 C	Heat flux (Watt)	Overall heat transfer coeff .
1.	0.2	8	1163.52	31.56
2.	0.37	10.5	1908.9	39.45
3.	0.76	12.6	2672.46	46.03
4.	1.01	14.8	3766.89	55.23
5.	2.51	15.2	4360.97	62.26

Table 2: Calculation of Pressure drop, Temperature gradient, Heat flux and overall heat transfer coefficient of perforated pin fin array

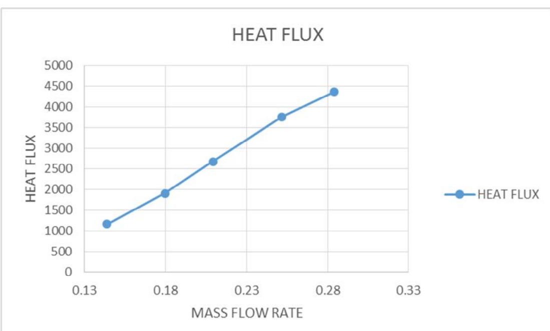
Sr. No.	Pres sure drop (CM)	Temp gradient $\Delta T\ ^0 C$	Heat flux (Watt)	Overall heat transfer coeff .
1.	0.21	9.5	1372.47	34.40
2.	0.37	11.8	2129.11	42.95
3.	0.73	13.3	2795.6	50.04
4.	0.97	15.3	3870.57	60.23
5.	2.45	15.6	4449.44	67.91



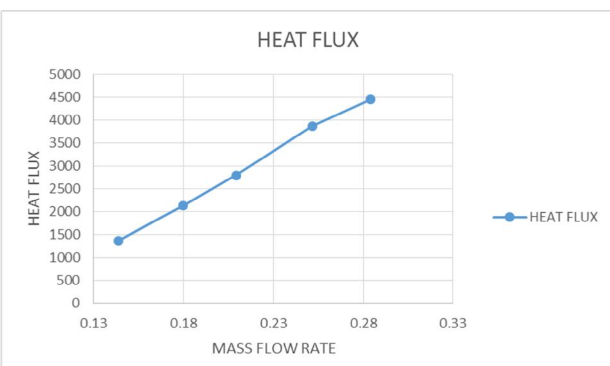
Graph 1: Temp. gradient Vs Mass flow rate of air solid pin fin array



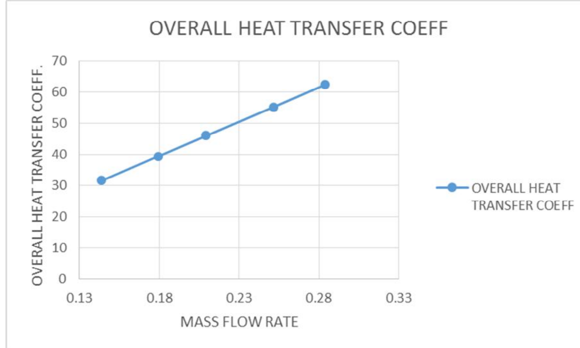
Graph 2: Temperature gradient Vs Mass flow rate of air perforated pin fin array



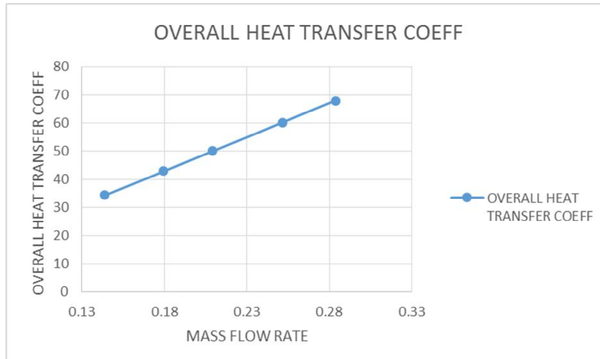
Graph 3: Heat flux (Watt) Vs mass flow rate of air (kg/sec) solid pin fin array



Graph 4: Heat flux (Watt) Vs mass flow rate of air (kg/sec) perforated pin fin array



Graph 5: Overall heat transfer coeff. Vs mass flow rate of air solid pin fin array



Graph 6: Overall heat transfer coeff. Vs mass flow rate of air perforated pin fin array

VII. CONCLUSION

From the analysis and experimental readings of Solid pin fin array and perforated pin fin array, we can conclude that Heat transfer through perforated pin fin array is more than that of solid pin fin array.

The temperature distribution is uniform along the fins. It is maximum at the base and reduces as it approaches the tip. It’s maximum value is 60.2oc, whereas maximum 3.378 watt of heat flux per unit area is possible. Temperature gradient increases with increase in mass flowrate up to a particular limit then becomes stable over a range. Hence optimal mass flow rate will be 0.25 to 0.3 kg/sec

Heat flux increases with increase in mass flow rate. Overall heat transfer coefficient increases with increase in mass flow rate

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