A REVIEW ON EXPERIMENTAL INVESTGATION OF HEAT TRANSFER OF PIN FIN HEAT SINK

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ABSTRACT

Many engineering systems during their operation generate heat. If this generated heat is not dissipated rapidly to its surrounding atmosphere, this may cause rise in temperature of the system components. This by-product cause serious overheating problems in system and leads to system failure, so the generated heat within the system must be rejected to its surrounding to maintain the system at recommended temperature for its efficient working. The techniques used in the cooling of high power density electronic devices vary widely, depending on the application and the required cooling capacity. The heat generated by the electronic components has to pass through a complex network of thermal resistances to the environment.

Keywords- *Heat dissipation, Overheating, Thermal resistance etc.*

I . INTRODUCTION

The enhancement of heat transfer is an important subject of thermal engineering. The heat transfer from surface may, in general, be enhanced by increasing the heat transfer coefficient between a surface and its surrounding, or by increasing heat transfer area of the surface, or by both. Extended surfaces that are well known as fins are commonly used to enhance heat transfer in many industries. Heat transfer rate is increased by using natural, forced or mixed convection. But now a day's application of natural convection to the cooling of electrical and electronic equipment has received considerable attention over the years. Natural convection doesn‘t require either a fan or a blower, is free of maintenance, has zero power consumption, is low cost, the noise level is reduced and the cleanliness of the system is improved. These features of natural convection cooling play an important role in the electrical and electronic cooling industry; therefore natural convection plays an important role in the design and the performance of the system. Improvements in the design of natural convective cooling systems are required to deal with the increased performance of electrical and electronic systems.

1.1 Modes of Heat Transfer

Heat can be transferred in three different modes:

- Conduction
- Convection
- Radiation

All modes of heat transfer require the existence of a temperature difference and all modes are from the high-temperature medium to a lower-temperature medium.

2. LITERATURE REVIEW

In 1985, E.M.Sparrow and S.B.Vemuri experimentally investigated natural convection and radiation heat transfer pin fin arrays having a pin diameter of 6.35 mm and a pin height of 25.4 mm with a population density ranging from 0.31 to 1.33 pins / cm^2. They found that the ratio of fin diameter to lateral fin spacing was found to play a significant Role and its optimum value was found to be close to 0.5. [1]

Zografos and Sunderl and studied the heat transfer performance of inline and staggered pin fin arrays in natural convection. They found that the inline arrays generally yielded higher heat transfer rates than the staggered ones. Also their investigation showed little influence of inclination when the inclination angle was less than 30 from the vertical.[2]

Aihara experimentally studied 59 arrays with a population density of 1.08–10.58 pins/cm^2. He uses the modified Nusselt and Rayleigh numbers, an empirical correlation for characterized performance heat transfer performance of round pin fin arrays is established. [3]

Fisher and Torrance presented the analytical solutions relevant to the limits of free convection for pin fin cooling. They suggested that the design of pin fin heat sink could be optimized by properly choosing the pin fin diameter and the heat sink porosity. Also, for conventional heat sinks, the minimum thermal resistance was about two times greater than that in an ideal limit according to the model of inviscid flow with idealized local heat transfer. [4]

Maveety and Jung investigated the performance of square pin heat sink with various geometries. They also present comparison between computational and experimental results. They found that cooling performance can be greatly affected by minor changes in fin dimensions. [5]

Kobus and Oshio carried out a comprehensive theoretical and experimental study on the thermal performance of a pin-fin array heat sink. The result of study is the successful development of a theoretical model that has the capability of predicting the influence of various physical, thermal,and flow parameters on the effective thermalresistance of a pin-fin array heat sink. The study shows that for a given fin spacing,thermal performance of a fin array heat sink is only a weak function of fin diameter and it is improved when fin length is increased. It is also pointed out that there seems to be a point of diminishing return with respect to increasing fin length. [6]

Dogruoz and Urdaneta investigated the effect of hydraulic resistance and pin height on performance of heat transfer of in-line square pin fin heat sinks with top by-pass flow. In this investigation pin height is varied from 1.25-2.5 cm. Also the researcher developed a two-branch by-pass model in which a one-dimensional difference approach was used to model the fluid flow through the heat sink and its top by-pass duct. [7]

Sahiti and Lemouedda investigated the influence of pin cross-section on the pressure drop of pin fin arrays and on their overall performance for different six geometries of pin fins. They found that simulation of six different pin cross-sections show that for both comparison criteria of the staggered arrangement the elliptic profile performs better than all other pin cross sections. But manufacturing of that profile is complicated that other profile. [8]

Jeng experimentally studied the pressure drop and heat transfer of an in-line diamond shaped pin-fin array in a rectangular duct by using the transient single-blow technique. He studied pressure drop and heat transfer of an in-line diamond-shaped pin-fin array with various inter fin pitches and developed empirical formula of average fin Nusselt number. He proposed the optimal inter-fin pitch is in between XT=1.414 -1.060. [9]

Balaram Kundu studied the thermal analysis and optimizations of longitudinal and pin fins of uniform thickness subject to fully wet, partially wet and fully dry surface conditions and made a comparative study between the longitudinal and pin fin for a wide range of design parameters. He made a comparative study on the fin performance between the longitudinal and pin fins. The optimization analysis has been presented in a generalized form such that either heat transfer duty or fin volume can be treated as a constraint. The optimality criteria have been derived using the Lagrange multiplier technique. In addition, the method for optimization of partially wet surface fins has also been established. [10]

Jeng et al. experimentally studied the pressure drop and heat transfer of a square pin-fin array in a rectangular channel by using the transient single-blow technique. The study parameters are the relative longitudinal pitch which is XL = 1.5, 2, 2.8 and the relative transverse pitch which is XT = 1.5, 2, 2.8 and the arrangement is in-line or staggered. The performance of the square pin-fins as the cooling devices is compared with that of the circular pin-fins. Also for this result empirical formulas for the pressure loss and the heat transfer are suggested. They found that optimal inter-fin pitches of square pin-fins are XT = 2 and XL = 1.5 for the arrays in in-line arrangements as well as XT = 1.5 and XL = 1.5 for the arrays in staggered arrangements. [11]

Sara studied the drop in pressure and the transfer of heat in rectangular channels with square pin-fins in in-line arrangements. He considered fixed transverse pitch but variable longitudinal pitch. Square pin-fins in staggered arrangements have seldom been investigated, and he also investigated heat transfer on large relative pitches. [12, 13]

Jeng studied experimentally the compact heat sink simulations in forced convection flow with side-bypass effect. He used uses the Brinkman–Forchheimer model for fluid flow and two-equation model for heat transfer. A configuration of in-line square pin-fin heat sink situated in a rectangular channel with fixed height (H = 23.7 mm), various width and two equal-spacing bypass passages beside the heat sink is successfully studied. The pin-fin arrays with various porosities (e = 0.358–0.750) and numbers of pin-fins (n = 25–81) was investigated. After this, he suggested that W/L = 2–3 is the better size ratio of channel to heat sink. [14]

Yang et al. presents the numerical simulation of the heat sink with an un-uniform fin height with a confined impingement cooling. The objective of this study is to examine the effects of the fin shape of the heat sink on the thermal performance, the un-uniform fin height design. They found that an adequate un-uniform fin height design could decrease the junction temperature and increase the enhancement of the thermal performance simultaneously. The results also show that there is a potential for optimizing the un-uniform fin height design. [15]

3. Problem Definition

From the critical discussion on literature survey, very less experimental data are available for the pin fin having various configurations. Very few researches have demonstrated the orientation effect with pin fin. Therefore, the problem statement for the current project is to carry project on analyzing the effect of various pin fin geometries with orientation effect on convective heat transfer in natural convection.

3.1 Objective

The objectives of this work are to:-

1. To construct a test chamber to allow experimental data to be obtained under different conditions.
2. To investigate the flow pattern inside the chamber.
3. To find out the effect of geometrical parameters and orientation effect on convective heat transfer rate.
4. To find co-relation to evaluate convective heat transfer.

3.2 Scope

The scope of the current project is limited to determine the effect of fin geometry on convective heat transfer rate and also orientation effect on pin fin arrays.

3.3 Proposed Work

a) Theoretical Work

1. To Study the theoretical concepts of heat sink.

2. To carry out literature review of various types of heat sink.

b) Experimental Work

1. To develop experimental setup to carryout evaluation of performance of pin fin heat sink.

2. To find out the effect of geometrical parameters and orientation effect on convective heat transfer rate.

3. To investigate the flow pattern inside the chamber.

3.4 Facilities Available-

Library, research, fabrication & test facilities are available at MCOERC COE Nasik

4. Experimental Setup

In this study, a systematic approach is adopted to study the natural convection heat transfer of rectangular pin fin with different orientations. The focus of this study is on developing compact easy-to-use thermal models that can predict the natural convective heat transfer of rectangular pin fin, rectangular walls to the ambient. The fin array problem will be studied, using CFD software, and a relationship for the optimum pin fin array will be developed to obtain the maximum natural convective heat transfer. The new experimental test bed has to be designed and built to verify the developed models and the proposed correlations. Experimental studies with various testing samples at different scales will be performed.

4.1 System Constraints

During the design period of a heat sink the system constraints are to be determined first. System constraints are parameters that are out of control of the designer or investigator.

4.1.1 The thermal conductivity of the fin material is constant.

4.1.2 The heat transfer coefficient is the same over the entire fin surface.

4.1.3 The temperature at the base of the fin is uniform.

4.1.4 Heat to be removed

The most important system constraint is the rate of heat to be removed. It is generally assumed to be a fixed value, which is in fact the maximum heat dissipation rate of the electronic component even if the heat dissipation has a transient manner. The dissipated heat is due to the inefficiency of the electronic component and it is the difference between the input and output electrical power.

4.1.5 Ambient temperature

For closed devices such as a computer chassis, the air inside the chassis will be hotter than the outside air, so average temperature of inside air instead of ambient air temperature must be used for thermal resistance calculations.

4.1.6 Altitude

Elevation of the electronic system to be cooled from sea level also plays a role in heat transfer due to the density variations of air. Since air is less dense at high altitudes than the sea level, its convective capability decreases. This means that higher cooling rates are needed as the altitude increases. These effects may be important for some applications such as aviation electronics.

4.1.7 Sealing

In some cases the necessity for sealing out the dust and sand creates another system constraint. It prevents the use of external fans.

The objective of the experimental study is to investigate the effects of fin length as well as fin spacing on the natural convection heat transfer from the considered rectangular fins. To enable this investigation, new custom-made testbed will be require to designe and built. The numbers of heatsinks with various geometrical parameters are to be prepared. Series of tests will be undertaken. The first series of test is designed to investigate the effect of pin fin length and spacing and their comparison with different orientations. The second series of tests will be to validate the numerical data used for calculating the Nusselt number for the vertical fins.

4.2 Design Parameters

Once the system constraints are determined, design parameters are to be considered. The design parameters include the heat sink material, the number and geometry of the fins and their alignment and the base plate thickness as shown in Fig. 4.1. In order to obtain the minimum thermal resistance and pressure drop, each of these parameters must be designed well.

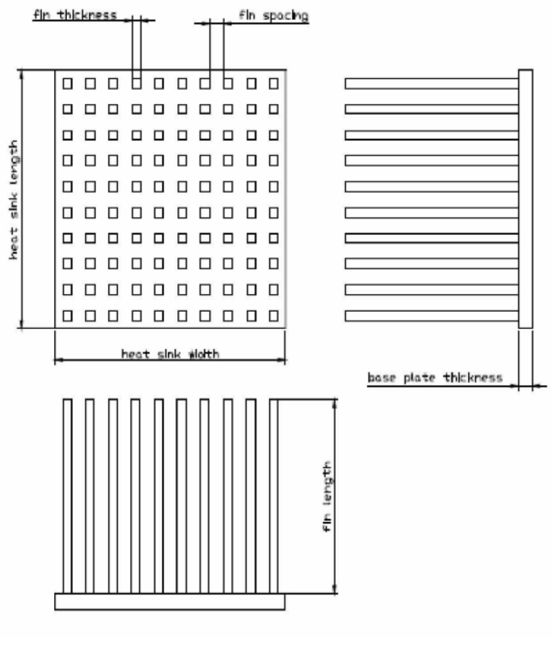

Fig 4.1 Heat Sink Design Parameters

4.2.1 Materials

Heat sink materials are generally metals with high thermal conductivity and relatively low cost are preferred, like aluminum and copper.

4.2.2 The number of the fins

It is one of the most important factors for heat sink performance. A heat sink designed for electronics cooling is a compact heat exchanger for which the ratio of heat transfer area to occupied volume is very large. The heat transfer area is enhanced by use of fins. Therefore increasing the number of fins provides more area for heat transfer. However, it should be noted that increasing the number of fins creates an adverse effect, which is the increased static pressure drop. In order to overcome higher pressure drops, higher pumping powers are needed, which requires the installation of more powerful fans or blowers.

4.2.3 Fin shapes

Different kinds of heat sink geometries are possible. Pin fins, straight fins, fluted fins, wavy fins and fins with non-standard geometry are possible. The most common ones are pin fins whose cross section can be round, square, elliptical, hexagonal or any other suitable geometry. Depending on the spacing among the fins of a heat sink, flow requirements and pressure drops may differ. Design engineers try to achieve the minimum thermal resistance with the pressure drop as low as possible by modifying the fin shapes. Extensive literature is available on this subject.

4.2.4 Pressure drop

Pressure drop is the resistance to the air movement and it is related with flow cross sectional area, fin spacing and fin length. The heat sink should be designed so as to yield a smaller pressure drop than the static pressure of the fan. The heat sink selected or designed changes the total pressure drop of the system, although it is not a very major difference, the operating point which is the intersection of the system impedance curve and the fan impedance curve may shift.

4.3 Testbed Design

Testbed design for rectangular pin fins

A new testbed has to be designed for measuring natural convection heat transfer from the pin finned heat sinks. The testbed will include a heater which will attach to the backside of the fins base-plate, and a data acquisition system.

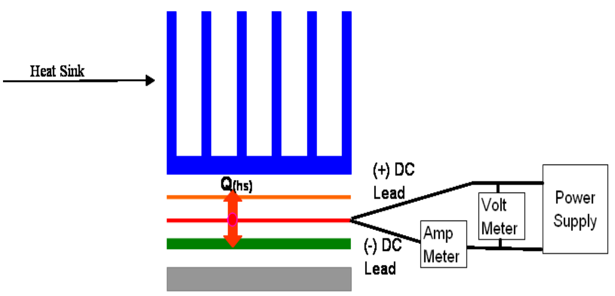

Fig 4.2 Schematic of the Testbed Layout

Thermal paste can be used to decrease the thermal contact resistance between the heater and the heat sink base plate. The voltage and the current of the supplied power can be measured with voltmeter and ammeter respectively.

4.4 Sample Preparation

The rectangular fin samples can be prepared to investigate fin geometric parameters, including length, spacing with different orientation.

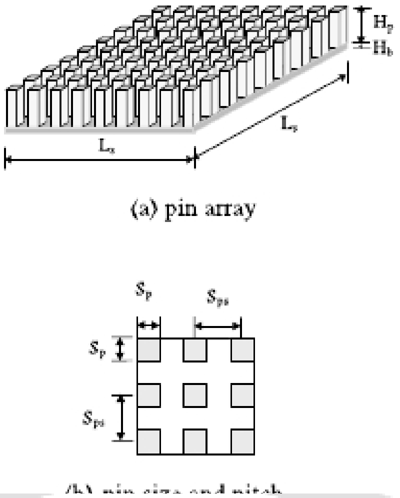

Fig.4.3 Pin Fin Sample Layout

5 Test procedure and data collection

During the experiments, the input power supplied to the heater and surface temperatures will be measured at various locations at the back of the base-plate. Electrical power can be applied using the AC power supply. The voltage and the current will be measured with voltmeter and ammeter to determine the power input to the heater. Thermocouples will be installed in various locations on the surface of the enclosures. All thermocouples are taped down to the inside surface of the enclosure, to prevent disturbing the buoyancy-driven air flow in front of the fins. An additional thermocouple can be used to measure the ambient room temperature during the experiments. Thermocouples are plugged into the DAS. Temperature measurements will be performed at four points in order to monitor the temperature variation on the tested heat sinks. The average of these four readings will be taken as the base plate temperature. For each heat sink, the experimental procedure will be repeated for different power inputs. The base-plate temperature, the ambient temperature, and the power input to the heater considering that the power factor equals 1, will be recorded at steady-state.

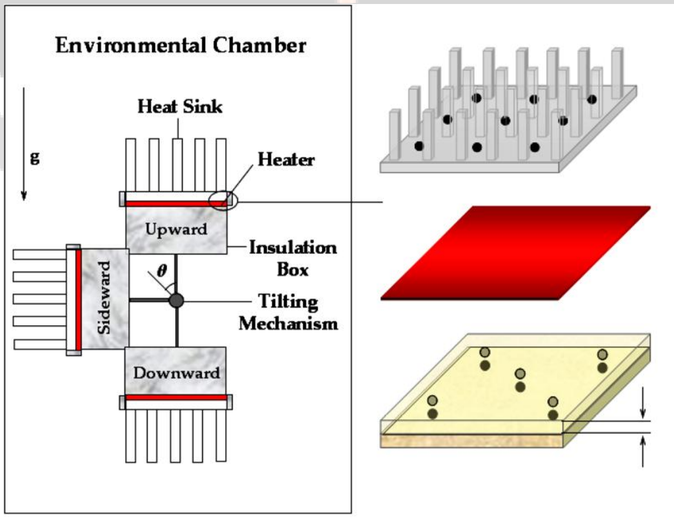

Fig.5.1 Schematic of the Experimental Setup with Different Orientation

The steady state is considered after 60 minutes elapsed from the start of the experiment and the rate of temperature variations with respect to time for all the thermocouples were less than 1^0/hour. In the present study, both vertically and horizontally heated enclosures were considered. The same experimental setup was used and the two orientations were achieved by rotating the enclosure by 90^0. The setup is shown in Fig. 4.4. The above procedure is to be followed for all orientation and for all power inputs

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