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Experimental Investigation of Heat Transfer Enhancement from Waveform Pin-Fins

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Abstract: The work reported in this paper is an attempt to enhance heat transfer in electronic devices with the use of waveform pin-finned heat sinks. The cooling performance of electronic devices has attracted increased attention owing to the demand of compact size, higher power densities and demands on system performance and re-liability. Pressure drop across heat sink is one of the key variables that govern the thermal performance of the heat sink in forced convection environment. There are several analytical methods to estimate the heat transfer rate, however correctly selecting one that can represent the reality over a range of airflow found in typical electronics cooling application is difficult. In this paper, we propose a modified experimental method to estimate the heat transfer and used it to calculate the thermal performance through different theoretical pressure drop equations. The rapid advancement in technology of microprocessors has led electronics thermal system designer is to pay increased attention to the waveform fin heat sink. The advantages of using a waveform fin heat sink are light weight, low profile and small footprint. There are three manufacturing methods for bonding the waveform fin to the base of heat sink: adhesive bonding, soldering, and brazing.The newly developed comparison method allowed a detailed numerical study of the influence of waveform pin cross-section on the performance of pin fin arrays used in the electronics industry.

Keywords: Waveform pin fins, electronic cooling and natural convection.

I. INTRODUCTION

Rapid development in packaging technology allows portable electronics to gain faster processing speed and enhanced capabilities. However, thermal management in the portable electronics environment is becoming increasingly difficult due to high heat load and dimensional constraints. Proper selection of fans and fin pitch in the heat sink is crucial to ensure the thermal design of the system is optimized.

In the current electronics industry, heat sinks are used extensively to provide cooling for electronics components. The process of making a heat sink is often by extrusion, cold forging, pressed fin, or bonded fins. Even though extruded and cold forged heat sinks require easier manufacturing processes compared to the other two, they have a limited fin aspect ratio due to the manufacturing processes. Whereas the pressed fins or bonded fins techniques offers a higher aspect ratio. Pressed fin is a process where fins are fitted into tapered tip grooves on the base. The fins are pressed by machine to establish contact surface with the base. The disadvantage of this method is that air gaps can exist in the joint which causes higher thermal resistance. However, this problem can be resolved by adding bonding materials, such as adhesive, into the gap. Both pressed fin methods also require grooves to be made on the base before the bonding process. This method is suitable only for thicker fins. However, the waveform fin does not require a grooved base and has no restriction on the fin thickness. This makes waveform fins a highly suitable candidate for future electronics in heat rejection. Methods of attaching the waveform fin to the base include brazing, adhesive bonding and solder bonding.

In this paper, the experimental study of the heat transfer enhancement obtained by employing waveform pins was the main objective of the present work.

II. BASIC INTRODUCTION OF HEAT TRANSFER

Heat transfer is a science that studies the energy transfer between two bodies due to temperature difference. There are three types or modes of heat transfer:

A. Conduction
B. Convection

C. Radiation

A. Conduction

Conduction is a mode of heat transfer that occurs when there is a temperature gradient across a body. In this case, the energy is transferred from a high temperature region to low temperature region due to random molecular motion – diffusion. Higher temperatures are associated with higher molecular energies and when they collide with less energetic molecules the transfer of energy occurs.

The heat transfer rate by conduction can be expressed as:

$$q=-kA\partial T/\partial x \qquad (1)$$

Where,

q – Heat transfer rate (W)

$\partial T/\partial x$- temperature gradient in the direction of the flow (K/m)

k – Thermal conductivity of the material (W/mK)

A – Cross-sectional area of heat path

Equation (1) is known as Fourier's law of heat conduction. Therefore, the heat transfer rate by conduction through the object in Figure 1 can be expressed:

$$q=kA/L\Delta T_{12} \qquad (2)$$

Where,

A – Cross-sectional area of the object

L – Wall thickness

ΔT_{12} – temperature difference between two surfaces ($\Delta T_{12} = T_1 – T_2$)

k – Thermal conductivity of object's material (W/mK)

Analyzing Equations (1) and (2), the heat transfer rate can be considered as a flow, and the combination of thermal conductivity, thickness of material and area as a resistance to this flow. Considering the temperature as a potential or driving function of the heat flow, the Fourier law can be written as:

Heat Flow = Thermal Potential Difference/Thermal Resistance

In other words, defining resistance as the ratio of driving potential to the corresponding transfer rate, the thermal resistance for conduction can be expressed as:

$$R_{contd} = T_1\text{-}T_2/q = L/kA \qquad (3)$$

From the above equations it can be observed that decreasing the thickness or increasing the cross-sectional area or thermal conductivity of an object will decrease its thermal resistance and increase its heat transfer rate.

III.OBJECTIVE AND SCOPE OF PAPER

The Objective of this paper is to increase the thermal performance of waveform straight pin fins and radial pin fins and also increase the heat transfer ability. Observe the operation of waveform pin fins and try to improve the heat transfer rate.

Heat exchangers are widely used in various industrial, transportation, or domestic applications such as thermal power plants, means of transport, heating and air conditioning systems, electronic equipment and space vehicles. In all these applications, improvements in the efficiency of heat exchangers can lead to substantial cost, space and materials savings. Therefore, considerable research work has been done in the past to seek effective ways to increase the efficiency of heat exchangers. The referred investigations include the selection of working fluids with high thermal conductivity, selection of their flow arrangement and high effective heat transfer surfaces made from high-conductivity materials. For both single-phase and two-phase heat transfer, effective heat transfer enhancement techniques have been reported. However, in the present work only the single-phase forced convection enhancement techniques have been considered.

Waveform fins are widely used in the air conditioning, refrigeration and process industries. Generally, heat exchanger containing wavy fins can be encountered in gas to gas and liquid to gas heat transfer applications. The gas-liquid heat exchangers consist of parallel spaced tubes through which water, oil, or refrigerant is forced to flow while air flows across the outside of the tube surface and between the fins. Usually these are known as tube and waveform fin heat exchangers. If the heat transfer rate of the heat exchanger will increase then it will help to increase the pressure drop.

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IV. EQUIPMENT USED

A. *Axial/Radial Blower*

A mechanical fan is a machine used to create flow within a fluid, typically a gas such as air. The fan consists of a rotating arrangement of vanes or blades which act on the air. The rotating assembly of blades and hub is known as an impeller, a rotor, or a runner.

Fig. 1 Axial Blower

B. Venturi Type air flow chamber

In the Venturi Tube the fluid flow rate is measured by reducing the cross sectional flow area in the flow path, generating a pressure difference.

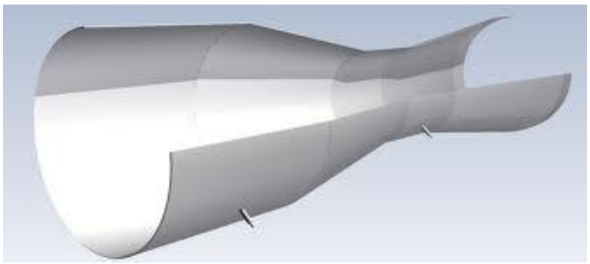

Fig. 2 Venturi Type air flow chamber

B. *Heater (Source)*

Heater is the high temperature reservoir.

C. *Orifice and water tube manometer tube*

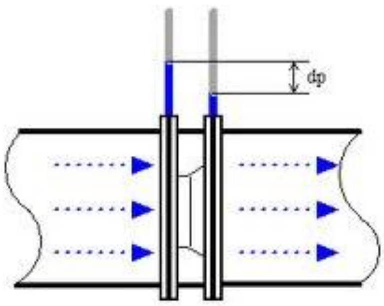

FIG. 3 ORIFICE TUBE

An opening, especially to a cavity or passage of the body; a mouth or vent. The restriction to flow in this case is provided by the insertion of an orifice plate (disc with a hole in it), in one of the pipe flange joints.

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E. J-type thermocouples

A thermocouple consists of two conductors of different materials (usually metal alloys) that produce a voltage in the vicinity of the point where the two conductors are in contact. The voltage produced is dependent on, but not necessarily proportional to, the difference of temperature of the junction to other parts of those conductors.

Fig.4 J-type thermocouples

Naser Sahiti [3] carried out experiment in 2006 on thermal and fluid dynamic performance of pin fin heat transfer surfaces. He had done the experimental and numerical investigation of various aspects of single-phase convective heat transfer enhancement by the use of pin fins is presented. After a brief review of the basic methods used to enhance the heat transfer by simultaneous increase of heat transfer surface area as well as the heat transfer coefficient, a simple analytical method to assess the heat transfer enhancement is presented. The method is demonstrated on pin fins as elements for the heat transfer enhancement, but it can in principle be applied also to other fin forms. In order to check the applicability of the analytical method, experimental investigations of a double-pipe pin fin heat exchanger were carried out.

The order of the magnitude of heat transfer enhancement obtained experimentally was similar to that obtained analytically. The heat transfer and pressure drop results for the pin fin heat exchanger were compared with the results for a smooth-pipe heat exchanger. It was found that by a direct comparison of Nu and Eu, no conclusion regarding the relative performances could be made. This is because the dimensionless variables are introduced for the scaling of heat transfer and pressure drop results from laboratory to large scale but not for the performance comparison. Therefore a literature survey of the performance comparison methods used in the past was also performed. It was found that all proposed methods in the literature offer only an approximate comparison of the performance of heat transfer surfaces. For new developments in heat transfer enhancement methods, it was considered that such methods would fail to predict the performance of new heat transfer surfaces. Hence in the present thesis a more consistent comparison method of the performance of heat transfer surfaces is proposed and its applicability demonstrated.

Fig.5 wavy fins

Wavy fins are widely used in the air conditioning, refrigeration and process industries. Generally, heat exchanger containing wavy fins can be encountered in gas to gas and liquid to gas heat transfer applications. The gas-liquid heat exchangers consist of parallel spaced tubes through which water, oil, or refrigerant is forced to flow while air flows across the outside of the tube surface and between the fins. Usually these are known as tube and wavy fin heat exchangers. In the practical application of wavy channels, two variants are often utilized, namely herringbone and smooth wavy as shown in Fig. 5..

V. EXPERIMENTAL SETUP

The test rig comprises of the following parts:

A. Axial/ Radial Blower : Blower with variable speed to adjust the air flow.
B. Venturi Type air flow chamber : This is developed for enhanced directed flow of air over the test fin structure , so also water tube -manometer arrangement will get the pressure drop across the fin structure, which can be used to determine nature of air flow above the fin structure.
C. Heater (Source): It is 230 Volt, plate type heater having capacity 100 to 125 watt
D. Air flow measurement : Exhaust air flow measurement is done using orifice and water tube manometer tube .
E. Temperature measurement will be done using J-type thermocouples with multi-channel display.

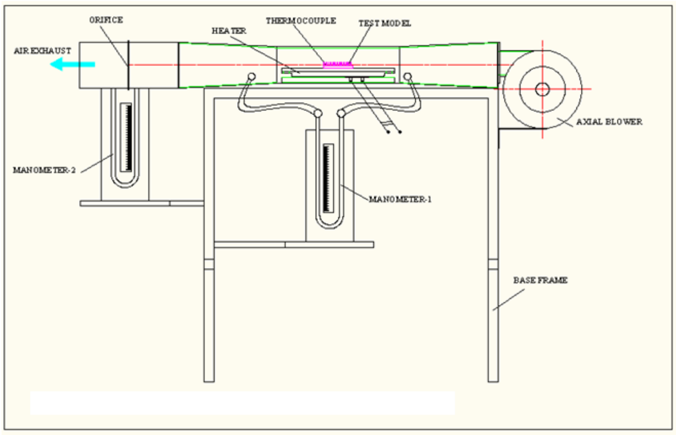

Fig.6 Experimental Setup

VI.PROPOSED WORK

The literature review is carried out in order to see the present research in this area which elaborated the under present status. Further review will be carried out for following purposes by referring journals like, International Journal of Heat and Mass Transfer, International Journal of Heat and Fluid flow, Pressure drop in heat sinks etc.

There are almost no industrial fields in which heat exchangers are not applied. The design of the heat exchanger influences greatly the design of the entire system or process in which they are applied. Many factors influence the design of a heat exchanger, but the most important ones are the heat transfer rate, pumping power required to run the heat exchanger, heat exchanger volume required, heat exchanger weight and heat exchanger production costs. Depending on the application, some of the above factors may have priority but in general the first factors that have to be considered are heat transfer rate, power input and heat exchanger volume. With the exception of a few cases, usually in all kinds of processes high heat transfer rate and small pressure drop within a small heat exchanger volume are required. Particular care in consideration of the last three factors is required for heat exchangers containing gas streams or gas and liquid streams separated by solid walls. In any heat exchanger form, the heat is transferred by all three basic forms: conduction, convection and radiation simultaneously. The intensity of heat conduction is not a challenging problem as usually it can be controlled by the material chosen to build the heat exchanger. Further, radiation is of less concern for heat exchangers operating under moderate temperatures, whereas the intensity of the heat transferred by the convection is the dominant problem particularly on the gas side for the design of the heat exchanger. Based on Newton’s law of cooling, convective heat transfer can be calculated as the product of the heat transfer coefficient, heat transfer surface area and temperature difference between the wall and fluid. The wall to fluid temperature difference is usually adjusted oneself based on the operating conditions and therefore it cannot be used to enhance the heat transfer rate. Hence in order to achieve a high heat transfer rate, one can increase the heat transfer surface area or the heat transfer coefficient, or both of them simultaneously. It was already mentioned in the previous section that interrupted fins in the form of strip or louvered fins provide both a heat transfer surface area increase and heat transfer coefficient increase. Therefore, these are particularly effective in obtaining high heat transfer rates. The mechanism which leads to high heat transfer coefficients of such fins is the periodic interruption of the boundary layer around the fins and in this way also achieving better mixing of fluid streams with different temperatures.

Otherwise the heat transfer surface area increase is achieved by a dense population of the bare surface with such fins and by selecting thin and long fin forms. Similar effects can be expected also in pin fin arrays. Hence they may be considered as a special kind of interrupted fins, although they are not obtained by cutting of continuous fins such as in the case of strip or louvered fins. The analytical and experimental study of the heat transfer enhancement obtained by employing pins was the first objective of the present work.

VII. CONCLUSION

Conclusion thus obtained from testing of various fin structures and discussion will be done as to effectiveness of individual fin structure over other as regards to overall heat transfer coefficient , Heat transfer ability (watt/min), obstruction to air flow, etc and recommendations will be made as to application of the above structures to this experimental setup.

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Biography

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