Thermal Analysis on Different Shaped Heat Sink Profile

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Abstract— finned heat sinks are most widely used as a thermal solution to ensure the reliability of electronic devices with ever increasing power dissipation and circuit density. Among various types of heat sinks, plate-fin and pin-fin heat sinks are widely used owing to their own advantages. The plate-fin heat sink has the advantages of a small pressure drop, a simple design and an easy fabrication. On the other hand, the pin-fin heat sink has the advantages of a high heat transfer rate due to the redeveloping regions and an even thermal performance independent of the direction of the fluid flow. Recently, it has been found that the effective heat sink type between plate-fin and pin-fin heat sinks could be determined depending on the pumping power and heat sink length. In addition to above research activities, there has been a new attempt to combine the advantages of plate-fin and pin-fin heat sinks. Usually, these types of heat sinks have several cut and profile, perpendicular to the direction of the fluid flow. Main purpose of this work is to quantify effects of cross-cuts and profile. An experimental setup will be fabricated to study the pressure drop and heat transfer characteristics of the heat sinks. A comparison between the thermal performance of heat sink without cross-cut and another with single cross-cut.

Key words: Plate Fins, Heat Sink, Performance Analysis

I. INTRODUCTION

heat sink is a component that transfers heat generated within a solid material to a fluid medium, such as air or a liquid. Heat sinks are primarily used to remove heat from a device to keep it from overheating. Examples of heat sinks are the heat exchangers used in refrigeration and air conditioning systems and the radiator (also a heat exchanger) in a car. Heat sinks also help to cool electronic and optoelectronic devices, such as higher-power lasers and light emitting diodes (LEDs). Finned heat sinks are most widely used as a thermal solution to ensure the reliability of electronic devices with ever increasing power dissipation and circuit density. Among various types of heat sinks, plate-fin and pin-fin heat sinks are widely used owing to their own advantages. The plate-fin heat sink has the advantages of a small pressure drop, a simple design and an easy fabrication. On the other hand, the pin-fin heat sink has the advantages of a high heat transfer rate due to the redeveloping regions and an even thermal performance independent of the direction of the fluid flow. Norrman Golldbeg [1] develop a compact forced air heat sink has been designed, fabricated, and tested. It has been studied that narrow channel heat sinks using air as the cooling fluid can keep the temperature below 60°C and thermal resistance can be reduced to about 3-C/W. It has been widely recognized that the heat transfer can be increased by increasing the area of the .heat sink in contact with the coolant, and therefore the use of fins is common coefficient is inversely proportional to the width of the channel. Narrow channel forced air heat sinks have been designed, built, and tested. Amon et al. [2] studied the fluid flow and heat transfer characteristic since communicating channels that have geometry similar to that of cross-cut heat sinks. Selcuk cimtalay and Robert E. Fulton [3] To develop a mathematical model, to optimize and to evaluate a heat sink on chip in electronic assembly. An optimization model has been developed characterize a heat sink at the parameter design stage. Tuckerman and Pease [4] first introduced the micro channel heat sink; many researchers have studied the thermal characteristics of heat sinks and reported optimum geometries of heat sinks C.K. Loh. et al. [5] to evaluate thermal characterization of several fin heat sink systems that may typically be found in portable electronics. Both the thermal characterization and optimum configurations were found experimentally. Also find a theoretical methodology to simulate the natural phenomenon, and have the capability to find the optimum configurations. Hans Jonsson and Bahram Moshfegh [6] tests have been conducted in wind tunnel types of heat sinks including plate fin, strip fin, and pin fin heat sinks. In the case of strip fin, and pin fin heat sinks, both in-line and staggered arrays have been studied. The pin fin heat sinks had circular and square cross-sections. An empirical bypass correlation has been developed for the different fin designs. The correlation predicts the Nusselt number and the dimensionless pressure drop and takes into account the influence of duct height, duct width, fin height, fin thickness, and fin-to-fin distance. Node et al. [7] performed numerical simulations of heat sinks with a cut-fin shape to clarify the effect of a transverse cut on the thermal performance of the heat sinks. Tae Young Kim [8] in the present study, an experimental investigation is performed in order to demonstrate the concept of the scroll heat sink. Average coolant velocities and thermal resistances of the scroll heat sink are measured for various rotating speeds of the moving fins. Experimental measured flow rates of the coolant are almost linearly proportional to the rotating speed of the moving fins. A theoretical model is also developed to estimate the required pumping power and the thermal resistance, and validated using experimental results. The theoretical model shows that optimized scroll heat sinks have lower thermal resistances than optimized plate-fin heat sinks under the fixed pumping power condition. Yue-Tzu Yang [9] also studies thermal performances of the heat sink with un-uniform fin width designs with an impingement cooling were investigated numerically. The governing equations are discredited by using a control-volume based finite-difference method with a power-law scheme on an orthogonal non-uniform staggered grid. Study is to examine the effects of the fin shape of the heat sink on the thermal performance. Dong et.al. [10] in their paper compared thermal performances of two types of heat sinks commonly used in the electronic equipment industry: plate-fin and pin-fin heat sinks. In particular, heat sinks subject to an impinging flow were considered. For comparison of the heat sinks, experimental investigations were performed for

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various flow rates and channel widths. They suggested a model based on the volume averaging approach for predicting the pressure drop and the thermal resistance. By using the model, thermal resistances of the optimized plate-fin and pin-fin heat sinks are compared. Finally, a contour map, which depicts the ratio of the thermal resistances of the optimized plate-fin and pin-fin heat sinks as a function of dimensionless pumping power and dimensionless length, was also presented. The contour map indicates that optimized pin-fin heat sinks possess lower thermal resistances than optimized plate-fin heat sinks when dimensionless pumping power was small and the dimensionless length of heat sinks was large. On the contrary, the optimized plate-fin heat sinks have smaller thermal resistances when dimensionless pumping power was large and the dimensionless length of heat sinks was small.

From the above study, in this field is limited to the quantify effects of cross-cuts, heat transfer and comparison between them. Fins study was not done with reference to the real ship conditions till date.

II. EXPERIMENTAL SETUP

The experimental setup consists of the main duct and test section. The channel is constructed of Acrylic is a Poly (methyl methacrylate) (PMMA) is a transparent thermoplastic of high-grade acrylic include Polycast, Lucite and Plexiglass. Sheet thickness is 3 mm, had an external cross section of 300 mm length, 100 mm width and 125 mm height. There are trapezoidal cross sections at opposite end with pipes at end faces on both sides. The external trapezoid cross section of inner and outer side 125 mm height and outer edge width is 85 mm and inner trapezoidal inner edge width is 100. The length of the trapezoidal section is 140mm and inlet and outlet port is connected with pipes whose cylindrical cross section is 25 mm outer diameter and 19 mm inner diameter with 70 mm length. The total length of the channel is 720 mm. It is operated in forced mode and positioned horizontally.

The duct is made of acrylic material the property of this material like density is 1.15-1.19g/cm^3, Thermal conductivity is 0.86 w/mk, transmissivity is 92% of a visible light (3mm of thickness) and the Co-efficient of thermal expansion is 5-10x10^{-5}m/m^{0C} etc.

The testing heat sinks are made of Aluminium alloy 6061. It has good mechanical properties and exhibits good weldability. It is one of the most common alloys os Aluninium for general purpose use. It is a versatile heat treatable extruded ally with medium to high strength capabilities. In this experimental work we used two type of heat sink having profile 1(without cut in fins surface) and profile 2 (with single cut in fins surface). Specification of heat sink profile 1(without cut in fins surface): length L of the fin is 78mm, width W is 60mm and height of fins H_f, is 40mm, height H_b, of the base of fin is 5mm. width W_W, of fins which are extruded from its base is 2mm having channel width, W_C, is 3mm between the fins. Similarly, the specification of the heat sink profile 2(with single cut in fins surface): length L of the fin is 78mm, width W is 60mm and height of fins H_f, is 40mm, height H_b, of the base of fin is 5mm. width W_W, of fins which are extruded from its base is 2mm having channel width, W_C, is 3mm between the fins. This single straight cut is arranged perpendicular to fins pattern having width L_C, 5mm. It is a well-known fact that if the inter-fin spacing on the base plate decreases, the flow blockage will increase, and thus, the pressure drop along the tested heat exchanger will increase because the aim of the study is to determine the effect on the heat transfer characteristics of perforated plates. The heat sinks with profile 1(without cut in fins surface) and profile 2 (with single cut in fins surface) are shown in fig 1 and fig 2.

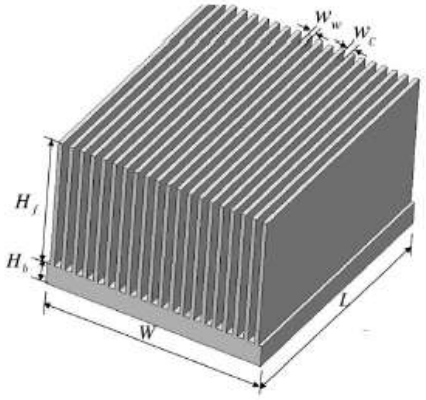

Fig. 1: Heat sink profile 1(without cut in fins surface)

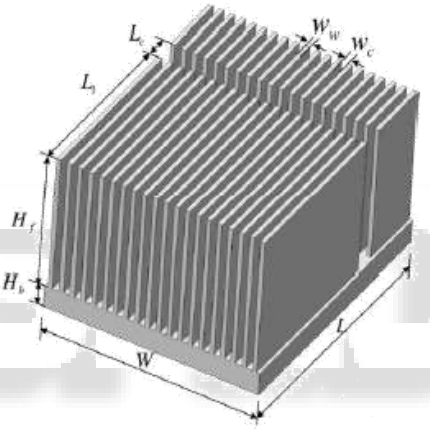

Fig. 2: Heat sink profile 2(with single cut in fins surface)

The heating unit mainly consisted of an electrical heater, a firebrick of 5 mm thickness. The dimensions of the electrical heater placed on the firebrick are square cross section of 75 x 75mm. The heater maximum output power is 120W. The electrical power input to the heater was controlled by a variac (variable AC transformer) to obtain a constant heat flux along the test plate.

The steady state temperature of the base plate was measured by J-type thermocouples inserted into different grooves in the base plate. The readings of the thermocouples are recorded using a voltmeter or computer via a data scanner, and the average of these readings is taken to be the steady state temperature of the test surface. The inlet velocity of the air flow entering the test section is depending on blower specification which is 164.44 m/s. Blower is used to inject the air into the duct. The blower specification is maximum power input is 600 W with 16000 RPM and flow rate is 2.8 m3 per min.

The steady state inlet temperature of the air stream is taken as the average reading of J-type thermocouples that are located at the inlet of the duct which measures the inlet temperature of air. Similarly, second thermocouple located at outlet of the duct which measures the outlet temperature of the air. One is located bottom of the base plate which measures the base plate temperature. These J-type

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thermocouples are made of homogenous material which provides the accuracy in measurement. The measurements are taken in 2 steps with different power input (100W and 120W). Therefore, readings were obtained for profile 1 and profile 2 heat sinks. The average of these readings is taken as the steady state temperature of the air. Whenever thermal equilibrium was reached, the measured data is recorded. The inlet and outlet pressure across the test model is measured using U-tube manometer mounted at the panel of the test section.

III. Result and Discussion

All the experimental readings have been shown in graphical form. Two types of heat sink were used and comparison of the performance of these heat sinks was made on the basis of temperature measurements. Temperatures were measured at an interval of 40 seconds. For a particulate heat input and air flow rate, after 80sec the temperature remains at study. The maximum temperature was observed at heater followed by at heat sink and then at outlet position. Heat inputs were varied from 100 W, 120 W by variac and comparison of temperature between heat sink profile 1 and heat sink profile 2 are shown in fir 3, fig 4.

Fig 5 shows the pressure drop variation for two heat sinks profile 1 and profile 2. It was observed that minimum pressure drop was observed for with cut heat sink as compare to heat sink with profile 2. But the heat transfer variation was maximum for heat sink with profile 2, thus an optimum selection of heat sink is to be made depending upon its industrial application. The less pressure drop leads to its practical use in industry as a cooling solution.

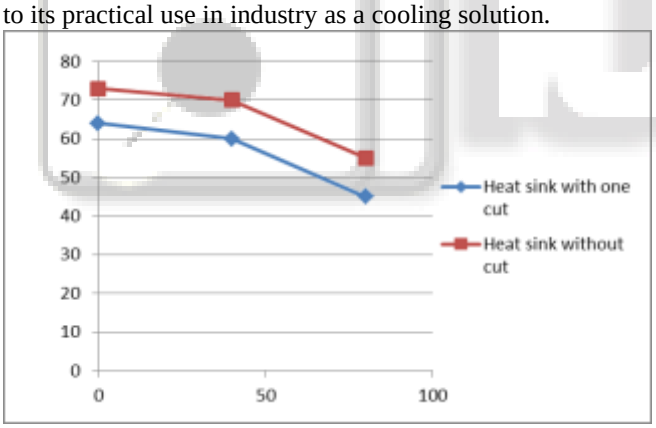

Fig. 3, Comparison of temperature for a heat sink having single cut and without cut under heat input of 100 W

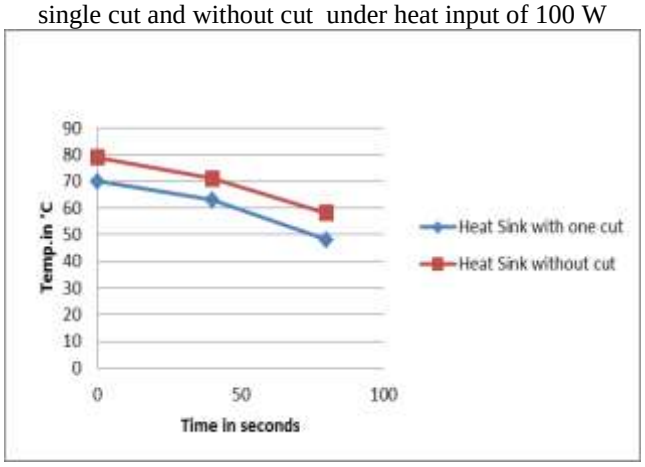

Fig. 4: Comparison of temperature for a heat sink having single cut and without cut under heat input of 120 W

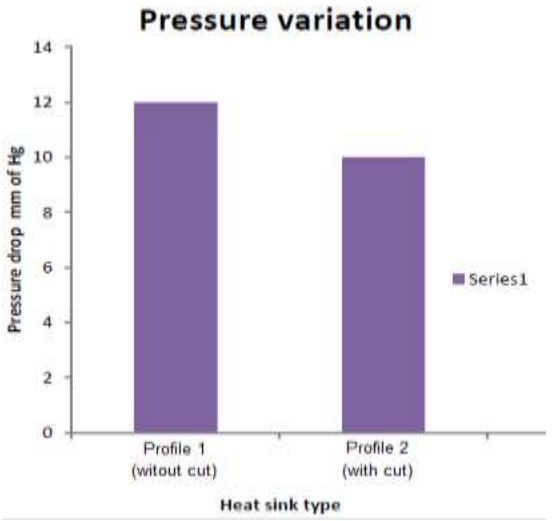

Fig. 5: Pressure Drop Variation for Heat Sink Profile 1 and Profile

IV. Conclusion

Experimental analysis was made for the fluid flow and heat transfer for a heat sink having two profiles. The following conclusions were made throughout the experimentation:

- It was observed that the temperature variation was more for a heat sink with cut as compare to heat sink without cut leading to higher heat transfer.
- Pressure drop was maximum for parallel plate fin heat sink followed by heat sink having with single cut.
- An optimum selection of heat sink is to be made depending upon its industrial application

Similar trends were also observed in for various heat inputs of 100 W and 120 W leading to that heat transfer equations and methodologies hold well for various heat sinks.

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