Experimental Investigation on Performance of Perforated Plate Fin Heat Sink for CPU Cooling

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Abstract—The various types of heat sinks are used to cool the computer processor units (CPU). Due to advancements in the high speed processors, making it more powerful and compact, it becomes further challenging to cool these units effectively. The rate of heat dissipation from the heat sink decides the allowable density of the transistors on the processor. Therefore, it is essential to design the heat sink with increased rate of heat transfer to the ambient for the safe working of CPU.

In the present work, the experiments are conducted to determine the thermal performance of the perforated heat sink and it is compared with that for the normal heat sink without perforations. For the investigations of heat transfer performance, existing heat sink of Pentium IV processor is used in the work. Additionally, the effect of number of perforations on the temperatures of the heat sink is studied for varying mass flow rates of air. It is found that the six perforations in the heat sink gives the optimum heat transfer performance. Therefore, the use of perforated heat sinks can be recommended for the effective cooling of processors.

Key words:*Heat Sink; perforations; heat transfer rate; CPU.*

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I. INTRODUCTION

The heat sinks are widely used in electronic devices for cooling the processor. It is essential to keep the case temperature of the processor within the permissible limits for its safe operation. The design of heat sink depends upon the capacity of the processor. There are various types of heat sinks used for effective cooling of integrated circuits or computer processor units (CPU). The heat extraction capacity of the heat sinks distinguishes them from one another. Heat sinks with heat pipe and vapor chamber technology which can handle higher heat loads are available and are known as second generation heat sinks. In CPU cooling, heat sinks are coupled with a fan above them, which sucks the air, inturn increases the flow of air around the hot fins of the heat sink for better cooling by force convection. Usually, the heat sinks are made up of either aluminum or copper. The heat sinks of copper are compact in size due to its relatively higher thermal conductivity; however, these are costly than that of aluminum heat sinks. The fin thickness is minimum which ensures higher surface area per unit volume of the heat sink. The spacing between the fins should be optimum so as to accommodate more number of fins. However, higher or lower number of fins than the optimum number may degrade the performance of the heat sink.

In order to improve the thermal performance of the extended surfaces either its surface area can be increased via perforations without altering its operational space required or the turbulence can be increased at the cost pressure drop. The perforations in the heat sinks increases the wetted surface area of the heat sink leading to enhanced convective rate of heat transfer.

Many researchers reported experimental and theoretical studies on the heat transfer analysis of the perforated heat sinks. Amer Al-Damook et al. [1] conducted experiments on pin fins with multiple perforations. The study showed that perforations in the pin fin heat sink lead to increase in heat transfer and decrease in pressure drop across it. Sahin and Demir [2] presented experimentalstudy on the heat transfer and the corresponding pressure drop over a flat surface with square cross-sectional perforated pin fins in a rectangular channel. The effects of the flow and geometrical parameters on the heat transfer and friction characteristics were determined. Rao Yu et al. [3] reported experimental study on hydraulic and thermal performance of stagger-arrayed short pin fins for transitional airflow in a rectangular channel. Their studydemonstrated that there was considerable enhancement in theheat transfer performance of the pin fins, while there was significant increase in the flow frictional resistance. It was found that there was increase in the convective heat transfer performance by 68% in the case of transitional flow region. On the other hand, in the fully turbulent flow region, the heat transfer performance of the pin fin decreases with the increase in Reynolds number (Re > 6000). Zobaer and Mohammad Ali [4], compared the thermal performance of perforated and solid fins, numerically. The lateral perforations of square and circular shape were used in rectangular solid fin for the study. They found that the perforated fins have higher efficiency than the solid fins due to increased surface area. The thermal performance of circular and square perforated fins was almost the same; however, the pressure drop found to be significantly less in the case of circular perforated fins than that of square perforated fins.

Shaeri M. R. et al. [5] studied the fluid flow and conjugate conduction-convective heat transfer from a three-dimensional array of rectangular perforated fins with square windows that are arranged in lateral surface of fins numerically. Computations were carried out for Reynolds numbers in the range of 2000–5000 based on the fin thickness and $P_r = 0.71$. Their results showed that perforated fins have higher heat transfer and considerable weight reduction in comparison with the solid fins. They also noted that the turbulence in the flow increases with increase in the number of perforations. Gupta et al. [6] also carried out the simulation and thermal analysis of rectangular plate fin and circular cylindrical pin fin type heat sinks for the cooling of CPU with a commercial software. From the CFD analysis, it was concluded that heat transfer rate of rectangular plate fins is greater than cylindrical pin fin. There are many other papers [7-9] available in the literature which suggests that the perforated pin fin type of heat sinks are studied extensively. However, the work on the perforated plate fin type of heat sink is a scarce.

The objective of the present work is to investigate the effect of perforation on the performance of the parallel plate heat sink used in the Pentium IV processor. The experiments are conducted on plate fin heat sink with and without perforations keeping flow of air parallel to the fins of the heat sink. Additionally, the effect of number of perforations on the thermal performance of the heat sink is studied at various operating conditions.

II. EXPERIMENTAL SET-UP

Usually, the cooling system of CPU consists of a fan mounted on the heat sink. The fan gives constant flow rate and sucks out air from the sink. In the present work, the experimental setup is designed to provide a steady flow of air over the heat sink using blower as shown in Fig. 1 (a) and (b). It consists of a blower, control valves to regulate the flow of air, an orifice meter along with manometer to measure the air flow rate and a rectangular test section in which the heat sink is placed. In this arrangement, the flow of air is parallel to the fin surfaces of the heat sink.The circular channel for the air flow is made up of plastic pipe of diameter 40 mm. Two valves are used to control mass flow rate of air; one is connected in the channel tocontrol the flow of air to the rectangular test section through orifice and the other is used to by-pass the air to the atmosphere.

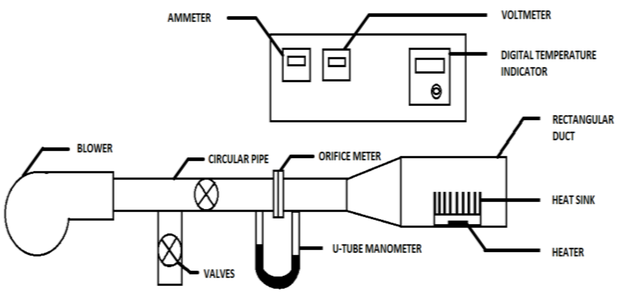

Figure 1 (a). Schematic diagram of experimental set-up

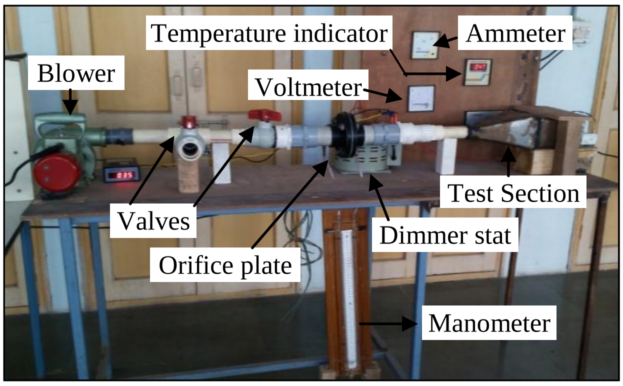

Figure 1 (b). Experimental set-up of plate fin heat sink

The orifice meter is mounted at the center of the whole section to measure the mass flow rate of air. A blower is mounted at the end of channel which maintains the air flow through the channel over the heat sink. The heat sink coupled with a heater is placed at the baseof a rectangular test section. The rectangular duct test section has dimension (10 x 15) cm and is made of up mild steel. The rectangular duct has divergent section (length 20 cm) so as to set up fully developed flow in the test section.

The heater is used as a source of heat for the heat sink. It consist of the nichrome wire wounded around the mica sheet at 2.5 mm spacing to reduce the load in extended wire. The asbestos sheet is bonded over it to avoid heat losses. Both mica and asbestos are class B insulators which can sustain temperature of about 130 °C. The heater coil has resistance of 40 **Ω**. A single phase 230 V dimmer stat is used to provide and vary the voltage across the heater coil. AC ammeter (0-5) A and Voltmeter (0-300) V is used to measure current and voltage, respectively. The heat input is determined from the voltage and current drawn by the thin film heater with heat output. The heater is tested for leakage of current to the heat sink and power wattage. For that the electric bulb in series was used along with the tester. The power dissipated by the heater for a particular voltage applied to it, is also tested. As the resistance of the heater is constant, it draws the same current every time when a particular voltage is applied to it. The *K*-type thermocouples are bonded at different places to record the temperatures at the base as well as at the tip of the fins. Digital temperature indicator is used to measure the temperatures using thermocouples. All the thermocouples and orifice plate are calibrated. The value of coefficient of discharge, C_d for the orifice meter is found to be 0.8. The details of calibration are available in [10]. The temperature readings are noted once it is ensured that the steady state is reached for all the experiments.

III. RESULTS AND DISCUSSION

The experiments are conducted to obtain thermal performance of the heat sink under varying mass flow rate of air at constant power input for all the cases of perforations made in the heat sink and for the solid heat sink. The shape of the perforations in the heat sink is circular with the diameter of 5 mm and number of the perforations are varied from 2 to 8. During the experiments, the effect of variation in the ambient temperature is observed to be significant on the performance of the heat sink. Therefore, in the present case, variation in the

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temperature difference between the fin and ambient with respect to mass flow rate of air over the heat sink is analyzed. The range of Reynolds number corresponding to the measured mass flow rates of air is 4131 to 10975.

Fig. 2 shows the variation in the difference between the temperatures at the base of the fin, Tb and ambient, Ta with respect to mass flow rate of air. Usually, the processor operates at around 100 W capacity. Therefore, the heat input is maintained constant at 107 W for all the tests on the heat sink. It is clear from the figure that the temperature difference decreases with the increase in the mass flow rate of air for all the cases of perforations in the heat sink and the case of without perforation. This is due to the fact that the rate of heat dissipation increases with the increase in Reynolds number. It is also noted that the temperature difference is more for the case of two perforations and lowest for the case of six perforations at any value of mass flow rate of air. It can be seen from the figure that the temperature difference is lowest at 32 °C for the air mass flow rate of 1.22 kg/min. The temperatures at the base of the heat sink with eight perforations for all the values of mass flow rate of air are greater than those for the heat sink with six perforations.

Fig. 3 shows the variation in the difference between average temperature at the tip of the heat sink, T_p and ambient temperature,$T_a$with respect to variation in the mass flow rate of air for the constant heat input. It is noted from the figure that the temperature at the tip of the fins decreases with the increase in mass flow rate due to high rates of heat transfer. It also reveals that the temperature difference is lower for the case of heat sink with the six perforations at all the values of mass flow rate of air. It means that the rate of heat transfer is relatively higher for the heat sink with six perforations as compared to other cases of perforated heat sinks and the heat sink without perforations. It can be observed from Fig. 2 and 3 that the temperatures of heat sink with eight perforations from its base to the tip are higher than that for the heat sink with six perforations. It indicates that the rate of cooling of the heat sink decreases with the increase number of perforations beyond the six perforations. From the present study, it is observed that the number of perforations in the heat sink considerably affects the thermal performance of the heat sink. The use of perforated heat sink also reduces the weight of the heat sink.

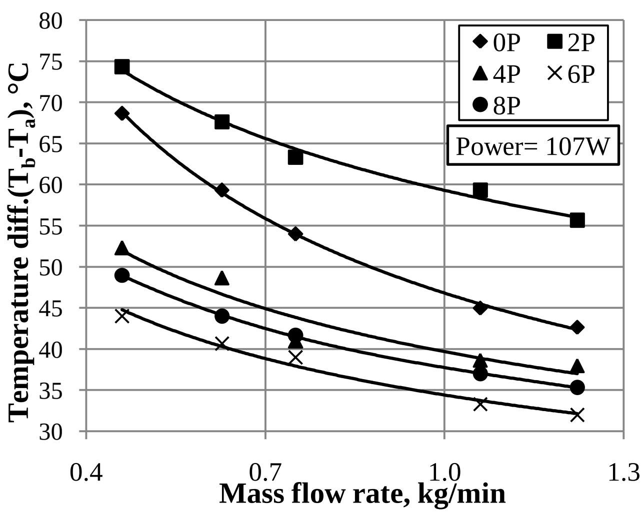

Figure 2. Effect of mass flow rate of air on base temperature

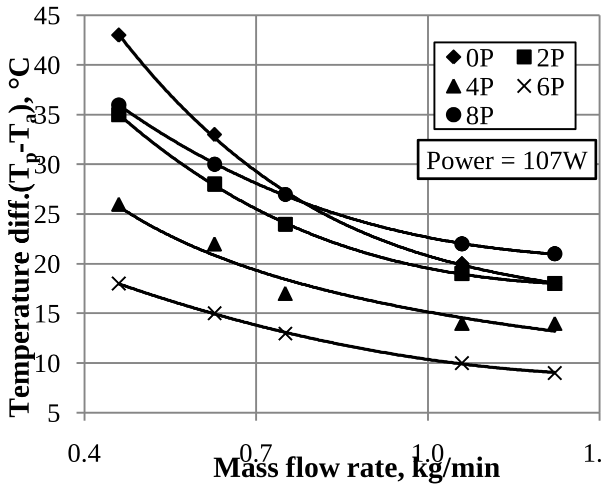

Figure 3. Effect of mass flow rate of air on tip temperature

IV.CONCLUSIONS

The design of effective heat sink with high rate of heat transfer for miniaturized processor units is the key challenge. The perforated type of heat sink gives better thermal performance as compared to solid heat sink. In the present work, the experiments are conducted to study the effect of number of perforations on the heat transfer performance of the heat sink at different operating conditions. The temperature difference between the base of the heat sink and surrounding air is lowest for the six perforations. It can be concluded that heat sink with six perforations demonstrates the higher rate of cooling as compared to solid heat sink and other cases of perforations for the operating conditions considered in the present study. However, the pressure drop in the air due to perforations may affect the overall performance of heat sink which may be studied further.

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