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Review on Heat Sink Design and Material

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ABSTRACT

The heat sinks are used in various electronic devices for heat dissipation. Proper design of heat sinks is essential for good heat dissipation. The current research reviews the various researches conducted to improve the existing design of heat sink using both experimental and numerical methods. The optimization methods involved to modify the existing design are also studied. The outcome of various researches has shown suitable methods and designs which could be incorporated in existing heat sinks.

KEYWORDS: *Heat sink, Design optimization, temperature*

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1. INTRODUCTION

With the rapid development in electronic and mechanical devices (such as conditioning equipment, turbines, and electronic equipment), the need for efficient heat sinks with less size and weight has increased. The excess heat generated by these devices becomes a major problem which can cause damages in their parts. Furthermore, traditional cooling methods have become ineffective due to their limitations. The demand for developing effective ways to dissipate heat turns into a serious challenge. Therefore, researchers have been developing new effective techniques to solve the problem of high temperature. The heat transfer enhancement focuses on increasing the heat transfer rate between the hot surfaces with surrounding by raising the heat transfer coefficients or increasing the heat transfer area. Using extended surfaces (fins) is considered as a good technique which is widely used to enhance the heat transfer in various types of heat sinks [1, 2]. Different designs have been investigated in order to obtain optimized fin geometry. Interruption, slots, and perforation are examples of geometrical modifications that have been improved the thermal performance of fins or to reduce their weight or cost [3, 4]. A heat sink with working fluid which is called micro-channel heat sink is another technique in which the flow characteristics have an impact on the thermal performance. The fluid that fills the heat sink channels has a great influence on the heat removal rate [5, 6]. Various geometries have been utilized to increase the heat transfer rate in micro-channel heat sinks such as using circular, rectangular and trapezoidal cross-sections. Because the surface area of the microchannel is small, different modifications were used in order to maximize the heat transfer efficiency such as using rough surfaces, twisted tap and rib [7, 8, 9, 10]. Moreover, many researchers reported different shapes by using waves, zigzag and curves structures in which structures affect the flow characteristics in micro-channel heat sink [11, 12]. Another approach that introduces optimizing the geometry of a heat sink without predefining the shape or configuration of the final design is topology optimization [13, 14, 15]. Topology optimization can be defined as a mathematical science approach which has been used in designing a heat sink due to its geometric freedom. In this approach, the computational domain is divided into a large number of elements. Each element has a relative density that determines whether the element is occupied by solid material or not. Therefore, the distribution of the relative density within the computational domain determines the heat sink geometries. In fact, there are many review articles that summarize the work previously performed by other researchers like [16, 17, 18, 19]. This paper mainly illustrates various designs of heat sinks and their geometrical parameters which have been designed by previous researchers during the last five years. It mainly focuses on the pins and flat surface fins heat sinks under free and forced convection due to their wide range of applications in industry and the modern design of microchannel heat sink. Besides, the effective topology optimization methods which are used in designing heat sinks. Most of the heat sinks designed with fins which are attached to the heat sink base to increase the heat dissipation area. There are two main techniques for heat transfer enhancement active and passive [20, 21]. Due to their excellent heat transfer performance, pin fins have a wide range of applications in industries [22, 23]. Cylindrical, square, triangular and elliptical pin fins are examples of shapes used by many researchers to investigate their performance with the aim of increasing their efficiency [24 - 28].

2. LITERATURE REVIEW

Mao-Yu and Cheng-Hsiung [29] examined experimentally and numerically the heat transfer rate for two different pin fin heat sinks under natural convection. The first was flat and solid heated base, while, the other had a hole in its heated base. The influence of the base plate, fin height, holes diameter in the base plate and the heat sink porosity on the heat transfer performance was also studied. The heat sink made of aluminum and the heated element was fitted into a copper block while attached to the heat sink. The results showed that the heat transfer coefficient for hallow heated base heat sink is higher than that of the unhallow one due to greater acceleration and velocity in the circulation region. As the fin height, holes inside-outside diameter and input heat increases, the thermal performance increases. Finally, the hollow heat sink has a higher heat transfer coefficient than the solid heat sink when its porosity is ≤ 0.262.

Sing [30], analyzed the thermal performance of a heat sink under natural convection by designing a model with ANSYS software. The ordinary circular pin fin with 32mm length was used then the diameter of the pin was modified by an angle of expansion of 1 degree, 2 degrees and 3 degrees outward. In this work, it was found that the 2 degree of expansion is the best modification as it dissipates more heat from the heat sink than other geometries.

Effendi et al. [31], predicted Nusselt number correction for a heat sink with round hollow hybrid fin (HHFHSs) under natural convection. CFD software has been used to generate a 3D-thermal model as shown in Fig. 3. 108 cases were studied, which include 36 arrangements with a different base temperature (50, 70 and 90°C). The numerical results have been experimentally validated. The developed Nusselt number correlation which is based on the fin height, Raleigh number, fin wall thickness, and external fin diameter, was shown to have reasonable accuracy with less than 20% difference compared to the complicated numerical correlation.

Baldry et al [32] adapted a numerical 3D model by using COMSUL CFD program to design a heat sink that is used in thermoelectric cooling cap under natural convection. This study examined 19 configurations of pin fin heat sink with 6 different pin fin parameters which are number, diameter, height, wetted area, center to center spacing and arrangements. The results were experimentally validated with the traditional pin fin heat sink. This research developed a pin fin heat sink with base temperature equals 44.4 C and 10.9 kW-1 thermal resistance which meets the efficiency requirement for dissipation the waste heat from the cooling cap.

Al-Damook et al. [33], investigated experimentally and computationally the effect of perforation on the pin fin thermal performance and the pressure drops across a heat sink under forced convection with different flow rates. Two aluminum heat sinks were designed; the first with solid pin fin while the second with perforated pin fin (the same work done by [34]). The pin is 12 mm long with 2 mm diameter fitted with a regular array into a base plate with 6.5mm spacing between each two-pin centers. The perforated pins have holes with 1mm diameters with different locations. The results showed that the Nusselt number (Nu) for the perforation pin is 11% higher than that in the corresponding solid. As the perforation increases, the pressure drop increases to reach its maximum value when using 5 perforations. In contrast, the location of the perforation was shown to have a less enhancing influence on the thermal performance in the heat sink.

Mao-Yu and Cheng [35] conducted simulation studies by using COMSOL multiphysics software to examine the thermal performance under forced convection for the heat sink designed in their previous research [29]. Reynolds number (Re) range from 6468 to 45919 was studied and data obtained were compared with experimental data from other investigators. The results showed the highest heat transfer performance gained when a small hollow (Dh/Db) < 0.15 is used in the base plate heat sink.

Maji et al. [36] studied numerically the heat transfer through a pin fin with different numbers, shapes, and sizes of perforation under forced convection by using inline and staggered arrangements. All the perforated fin heat performance and pressure drop were compared with the corresponding solid fin under the same conditions. ANSYS 14 fluent software was used to design the system models. Heat flux of 5903 w/m2 was applied at the bottom of the base plate which has an area of (0.1 × 0.1) m2 and a thickness of 3mm, where the fins are mounted either in inline of staggered.. The results showed that all perforated fins had higher thermal performance than the solid fins, especially with a staggered arrangement. The Nu number increases and the pressure drop decreases as the perforation number and size increase. The maximum heat transfer rate obtained by using elliptical fins with elliptical perforation is higher by 40.5 % than that of the solid circular fin.

Maiti and Prasad [37], carried out a computational study on the heat transfer performance and the pressure drop in a fin heat sink under forced convection. Solid cylinder, slotted cylindrical, and kidney fin geometries were designed. Reynolds number ranged from 2000 to 11000. The results obtained were validated with experimental results from previous work, and they found that the higher heat transfer rate acquired by using slotted kidney fin shapes with a staggered arrangement. Moreover, the decrease in pressure drop associated with the slotted fin was higher than that associated with the solid fin for both geometries, cylindrical and kidney.

Khonsue [38], conducted an experimental study to calculate the heat transfer rate and pressure drop of mini pin-fin heat sink under forced convection to make a guide for the design and development of electronic devices. They used 63 aluminum pin fins with three different configurations, Rectangular, cylindrical and spiral pin-fin configurations. The experiments were carried out under a constant heat flux ranging from 9.132 to13.698 kW/m2 and the air Reynolds number range was from 322 to 1982. The results showed that the spiral pin fins had the highest heat transfer coefficient and Nusselt number compared to the other configurations. On the other hand, the minimum pressure drop was obtained when the rectangle pin fin was used.

Tijani and Jaffri [39], investigated numerically and experimentally the influence of circular configuration on thermal performance, pressure drop and temperature distribution of two finned heat sink geometries under forced convection. The experiments were performed with a constant heat flux of 50 W. The heat sink was placed inside a channel where air flowed through with a velocity range from 1 m/s to 3 m/s. solid and perforated pin fin and flat plate were designed together and compared in this work. The results showed that perforated pin and flat fin enhanced the heat transfer coefficient by 8.3% and 6.3% more than the corresponding solid fins respectively. Also, the Nusselt number was increased by 2% to 4% when perforated pin fin was used instead of a solid pin fin. The perforated fin had a smaller pressure drop in the experiment. Many researchers enhanced flat fin heat transfer performance by making holes, interrupted and rough surface, etc. [40].

Awasarmol and Pise [41], carried out an experimental study to investigate the thermal performance of a perforated fin in a heat sink with different holes diameters and angles of inclination under natural convection. The perforations diameters ranged from 4 to 12 mm, the input powers supplied ranged from 15 to 35 W, and the angles of inclination ranged from 0° to 90°. The effect of these parameters was studied and the results are compared with the corresponding solid fins under the same conditions. The results obtained showed that the fins with 12 mm perforation diameter and 45 ° angle of inclination had a higher heat transfer coefficient with 32% enhancement over the solid fin. Also, perforation fins saved about 30% in the material by mass.

Shitole and Arkirimath [42], presented an experimental work to calculate the heat transfer rate of a heat sink by using a vertical perforated plate under natural convection. Aluminum fins with dimensions of (200 × 200 × 20) mm and with different shapes (circular, square and triangular) and perforation size were used and compared with the non-perforated fin. The area of perforation was varied from (33.2 to 176.8 mm2) and the heat input was varied from (60 to120 W) to investigate their influence on the heat transfer coefficient. The results showed that the heat transfer increases by increasing the heat input supply as well as perforation area. Moreover, the circular perforation had a higher heat transfer coefficient than the triangular perforation.

Prasad et al. [43], carried out an experimental study to investigate the effect of a number of perforation on the heat transfer rate for a cylindrical heat sink under natural convection (the same work done by [44, 45]). The voltage supplied to the heat sink was ranged from 100 to 220 V. The perforation diameter was constant but their number ranged from 24 to 60. The experimental results were compared with results obtained from computational analysis using the ANSYS program. The results showed that the heat dissipation increases by 20% to 70% as the perforation number increases from 24 to 60.

Venkitaraj and Sanooj [46], investigated numerically the heat transfer enhancement by using fins with different perforation shapes under natural convection. Circular, square, elliptical and triangular perforations with a variety of diameters are designed. The heat input supplied to the heat sink ranged from 15 to 30 watt. The results obtained were compared with that obtained when using solid fin under the same conditions. It was found that the perforation fin dissipates more heat than solid fin [47] and the maximum heat transfer coefficient (9 W/m2.K) was achieved by using perforation area equivalent to 12 mm diameter. In addition, circular and elliptical perforation shapes nearly have the same characteristics [48]. Triangular perforation had the lowest heat transfer coefficient among the other shapes.

Feng et al. [49], investigated experimentally and numerically the heat transfer enhancement by using cross fins heat sink under natural convection. The thermal efficiency of the cross fin heat sink was compared with the corresponding plate fin heat sink in a horizontal orientation. The plate fin heat sink dimensions were 200mm length, 21mm height, and 2mm thickness. The cross fin heat sink has the same dimensions, but the length of the short fin was 50 mm as shown in Fig.7. The heat supplied ranged from 20 to 60 watt. The results showed that cross fin heat sink enhanced the heat transfer coefficient by 15% with the same volume and materials used in reference plate fin and without more cost.

3. CONCLUSION

The extensive research has been conducted in improving design of heat sink using both experimental and numerical methods. The study conducted by various researches has shown that perforated fins have better heat dissipation capacity as compared to solid finds. The research findings has also shown the effect of perforated diameter on heat transfer characteristics. The circular perforation has higher heat dissipation as compared to triangular perforation. Out of various designs of heat sink tested, the slotted kidney fin with staggered arrangement has highest heat transfer coefficient.

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