Engineering and Technology Journal
Journal homepage: engtechjournal.org

An Elaborate Review for Micro-Fin Heat Sink

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Submitted: 28/05/2019 Accepted: 06/07/2019 Published: 25/1/2020

K E Y W O R D S

Heat sink, micro pin fins, Heat dissipation, Review, Heat transfer

A B S T R A C T

Heat sinks are low cost, the process of manufacturing reliability, and design simplicity which leads to taking into consideration various cutting-edge applications for heat transfer. Like stationary, fuel cells, automotive electronic devices also PV panels cooling and other various applications to improve the heat sinks thermal performance. The aim is to focus on some countless fundamental issues in domains such as; mechanics of fluids and heat transfer, sophisticated prediction for temperature distribution, high heat flux removal, and thermal resistance reduction. The outcome of this survey concluded that the best configuration of heat sinks has a thermal resistance about (0.140 K/W to 0.250 K/W) along with a drop of pressure less than (90.0 KPa) with a temperature gradient about 2 °C/mm. Heat sinks with square pin fins lead to enhance the effectiveness of heat dissipation than heat sinks with microcolumn pin fins. While other researches recommend the use of high conductive coating contains nano-particles. The present survey focuses on the researches about future heat sink with micro fin and the development to resolve the fundamental issues. The main benefits and boundaries of micro fins heat sink briefed.

How to cite this article: I. A. Hasan, S. R. Fafraj and I. A. Mohmma "An Elaborate Review for Micro-Fin Heat Sink," Engineering and Technology Journal, Vol. 38, Part A, No. 1, pp. 105-112, 2020.
DOI: https://doi.org/10.30684/etj.v38i1A.331

1. Introduction

The results of accelerated growth in technology, industrial development continue to enhance system power and size reduction, which leave us with unavoidable challenges for thermal management of various apparatuses to preserve the desired functioning temperature. Heat sinks used in a broad type of applications to dissipate the undesired heat to ambient as well efficient heat dissipation needed, the best examples for heat sinks like in heat engines, refrigeration, lasers, cooling electronic devices, and lately PV panels. Heat sink performance (including free convection, liquid-cooled, forced convection, and whatever combination) is a function of geometry, material, total surface coefficient of heat transfer, the effect of evaporative cooling [1], and another used nanofluid as cooling medium [2]. Commonly, thermal performance in forced convection increased by enhancing the heat sink thermal conductivity. Expanding the surface area (adding extended surfaces, like foam metal or fins), materials and by improving the total area heat transfer coefficient (generally by boost fluid velocity, like additional pumps and fans). The particular value of miniaturization has appreciated for many years in many areas, such as microelectronics and more lately in micro electro mechanical systems (MEMS). Systems, along with less space, faster performance, energy, and material can be achieved. In addition, in the nanometer field, there are new novel outcomes because of the enhanced surface to volume proportion and quantum phenomena [3]. In this article, we study up-to-date advancements in thermoelectric transport and micro scale thermal with a focus on the effect on the thermal management of solar panels and an integrated circuit (IC). This paper includes the findings that deal with different features of cooling methods, involve papers about pin fin heat sinks experiential work on investigating cooling performance and numerical modeling, high-level cooling methods, and stability.

2. Heat Sinks Fabrication

Two primary varieties of finned heat sinks, which are; plate-fin and pin fins heat sinks, which fabricated and produced by many large and small corporations. The base tube materials used to manufacture heat sinks should possess high-level thermal conductivity such as aluminum, aluminum/brass, copper, copper/nickel, brass, and copper/nickel can be utilized to produce the heat sinks with fins (FHSs). Based on the expense and the materials fabrication simplicity. Latterly, the finned heat sink technology design becomes the standard method for electronics cooling and pin fin technology to improve heat sink performance. This is due to the pin fin heat sink appropriates for various purposes including processes using liquid or gas. Because of the heat transfer quality for pin fin heat sinks in electronics, cooling is best [4-5]. Moreover, to overwhelm the difficulties associated with heat transfer enhancement such as low average heat transfer efficiency, high thermal resistance, as well as high-pressure drops loss. Pin fins heat sink as an extended surface used with electronic applications. Fins morphology holds a vital function in the making and heat transfer features. Rectangular, conical, cylindrical, and semi-conical are the typical geometry uniform for pin fins [6]. Hence, it appears that it is the appropriate time to use the technology with conventional heat sinks in industrial purposes also. Generally, the layouts of pin fin formed from a system of solid pins attached on top of the heat sink surface. The pins arrangement can be either in-line or staggered, usually formed pins arrays and the working fluid flows vertically or parallels to the pin axes. The process of making micro fins can be done by either dry etching or standard wet processes [7]. By utilizing a micro electro discharge wire machining" (EDWM) method to manufacture the model [8], manufactured arrays of micro fin with height fin dimension of 100mm and 200 mm into bulk silicon wafer utilizing Micro electro mechanical systems(MEMS) method. The approach split into two significant steps: first, the metal sedimentation process for the electrical heater, then in-depth fin geometry etching process, then the last step accomplished by Deep Reactive Ion Etching as shown in Figure 1. (DRIE, from (f) to (h))[9]. Introduced a novel DRIE method to achieve different microstructures and nanostructures. Nano-wires and Fins arranged in bulk silicon on more than one level. Dry etching methods, as well recognized as Reactive Ion Etching (RIE), these methods use both chemicals and physical influences to separate material of the wafer surface [10]. Wet etching is quicker compared to a dry etching; however, it has some limitations. The efficient employment of superior micro fabrication technologies, coupled with knowledge of the essential fluid flow phenomena and heat transfer phenomena, will be sufficient to meet the difficulties of heat loads dissipation above 5MW/m2 to 10.0 MW/m2 or 0.50 kW/cm2 to 1.0 kW/cm2) [11].

3. Heat Sinks in Industrial Applications

Power dissipation occurs in most engineering applications, and represented as heat which results in performance reduction for these engineering systems by the unwanted heat, due to the designed temperature limits for these applications to operate in proper conditions. Otherwise, overheating could lead to device failure when passing these temperature limits. Nowadays, the electronic devices sizes are getting smaller; meanwhile, the losses of thermal power for those devices are increasing [12]. The forced convection industrial applications for heat sink different from electronic component cooling to fuel element cooling in nuclear reactors [13-14]. Each heat sink type is designed based on the desired kind of implementation. For instance, when the drop in pressure is not a critical element, Schwartz kind structure or fin foam can be highly suggested. Nonetheless, if the drop in pressure is a critical element, where more than 20Pa, it perhaps more suitable to use parallel plate fins, as for applications have a drop in pressure less than 20Pa, honeycomb-shaped heat sinks are used. Furthermore, if pumping capacity is defined, fin -foam, Schwartz and honeycomb type structure could improve the thermal performance [15]. Fins with a proportion of height to a diameter within 0.5and4these fins named short fins, and utilized on the rear edges of the aerospace industry, cooling of electronics devices, and gas turbine. When this ratio exceeds, these heat sinks utilized in the applications for heat exchanger [13]. Pin fins and Plate-fins are utilized for CPU cooling of computers (PCs), electronic component devices cooling [16], advanced gas turbine blades cooling, compact heat exchanger and integrated circuit chips (ICs) [17].

4. Review Presentation

With the accelerated adoption of electronic devices and PV panels, the issue of thermal management becomes crucial subjects. A high number of researches focusing on nano cooling and micro cooling technologies, because of their significance in electronics: nano scale and micro scale size electronic devices could produce heat fluxes overrun thousands W/ cm^2 [18]. Thus, great endeavors have done to grasp heat flow systems in these devices. The heat sinks are employed to reduce the thermal resistance and dissipate the produced heat. The leading goal to come out with the heat sinks design is to decrease the thermal resistance. In general, the performance of heat sinks relies upon so many factors such as; the geometry dimensions of cooling channels, used fins, thermal resistance, and heat source capacity, airflow bypass, and location [19]. The performance of a heat sink was determined both traditionally as well as experimentally. The outcomes were obtainable in the format of the design graph in the heat sink index [3]. Micro pin fins heat sinks (PFHS), distinguished by low- level thermal resistance, regular temperature pattern with the flow direction and small structure, are valuable and useful for electronic devices thermal management. To boost the performance of cooling of pin fins heat sinks with micro square cross section, an optimizing geometry method-adjusting pin fin located angle and porosity introduced. The heat transfer and flow features were investigated numerically, and pin fins heat sinks with micro square cross section geometry was optimized [20]. In order to show the features and benefits of the micro scale square pin fins heat sinks, a comparison made between the square and the column pin fins. The results indicated that both the located angle and pin fin porosity are crucial for thermal performance and the cooling ability for the square pin fins heat sinks of micro size. The optimal thermal rendering achieved with situated angled with situated angle, and porosity were 30.0° and 0.750 respectively. Moreover, optimized square pin fins micro heat sinks showed higher thermal performance in comparison to column pin fins heat sinks of the micro size that signifies there is a great potential to use micro square pin fins of micro size heat sinks with electronic devices of high energy density for thermal management. [21] Variable fin density of micro pin fin heat sinks were numerically analyzed to show the ability to disperse the high heat flux predicted for the "2016s IC chips" with minimum pressure dropping and homogeneous temperatures of the junction. The outcomes revealed that the shape of fin performs an essential part in pressure decline instead of the dispersing of heat, which was primarily influenced by the ratio of heat transfer section to fluid magnitude. Flat shaped fins gave the highest performance. The fin length of 100 µm made the system further desired (a reasonable pressure drop with good heat dissipation) and based on Figure 2. Considering constant junction temperature and constant heat flux is accomplished. Cooling of a single hot spot high heat flux for electronic chips and evaluated the hydrothermal performances of various shapes for micro pin fin. Hydrofoil shape, circular shape, symmetric convex shape, and modified hydrofoil shapes were cross section styles utilized for micro pins fins. Every cooling arrangement had similar staggered systems for pin fins of micro size. A simulation of an IC with a footprint of 2.45 mm by 2.45 mm with 0.5 mm by 0.5 mm central hot spot. A constant heat flux of 2000.0 W per cm2 was used in a boiling point, while the other area of the chip imperiled to the uniform heat load of 1000 W cm2. Hydrofoil and the circular shapes cross sections area of the pin fins of micro size unchanged to have a decent comparison. Hydrofoil shape and convex shape patterns revealed a significant decline in the needed Pumping power, and the peak needed pressure. During the last case, micro pin fins height extended to be 400.0 µm to dissipate 100.0% of the entire heat load by convection, while keeping the maximum temperatures within an adequate scope. [22]. This paper investigates micro heat sinks pressure drop and thermal resistance at different factors like; pitch transverse directions, distance in the axial, hydraulic diameters of the pin fins, the aspect ratio of the pin fins, and the flow rates for the device liquid. The figure of merit (FOM) includes both the pressure drop in the article. The thermal resistance over the heat sink was introduced and evaluated the performance on the base of this figure. The heat sinks exposed to a uniform distribution of heat influx at the rear side of the heat sink and distinctive study established on consistent Reynolds number (Re) of liquid flow by the channel entrance. Water was the fluid utilized in this study. In addition, Reynolds number limit from 50 to 500 was applied in this study. Covent or Ware™ computational software is used to simulate the study cases. The distinctive investigation was done by dividing the study into four cases. In case number one, the distance of axial pitch is ranged from 350 µm to 650 µm via maintaining a constant pin fin aspect ratio structure at 0.5. In case number two, the distance of transverse pitch is ranged from 150.0 µm to 300.0 µm and maintained aspect ratio similar to case number one. In case number three investigates, the impact of changing the aspect ratio from 0.330 to 1.0 of the pin fins structures by maintaining both pitches fixed. In the fourth case, investigates the difference in the heat sink performance with the change in the in fins hydraulic diameter. The outcomes of this study show the significance of considering the thermal resistance as well as pressure drop in assessing micro pin fins heat sinks total performance. Circular pin fins heat sink display higher performance for less than 300 Reynolds number compared to square pin fins heat sink and vice versa when above 300 Reynolds number. The figure of merit differs much with the modify in the parameters such as; transverse pitch distances, axial pitch distances, pin fins hydraulic diameters, and aspect ratio [14,8] described that heat transfer relationship for macro fin arrays is insufficient for the correct assessment of micro scale systems heat transfer rate. Furthermore, they added that at micro scale systems, the orientation effect is negligible.

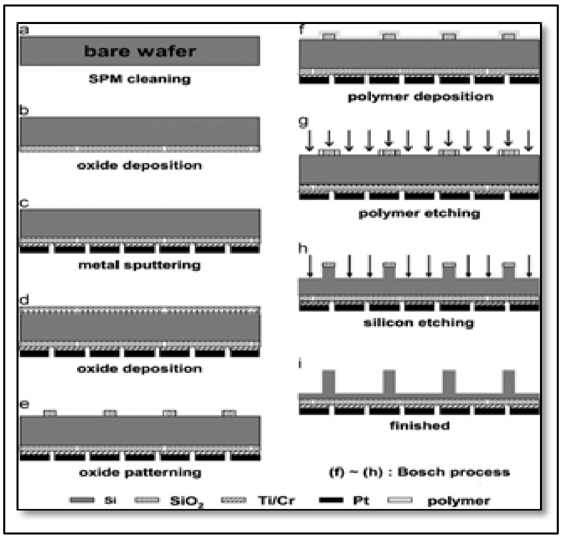

Figure 1: Micro fins array fabrication steps [8]

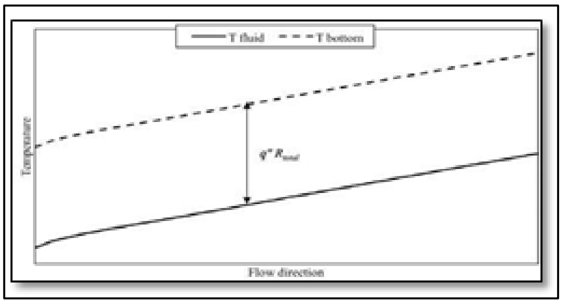

Figure 2: description for temperature differences in inner flow system under fixed flux of heat and thermal resistances [19]

5. Heat Transfer and Pressure Drop Characteristics

During the past century, numerous researchers have investigated many drops of pressure and heat transfer features for flow over tubes bank for macro scale and a substantial quantity of information and relationships for friction factors magnitude and coefficients of heat transfer are already in the articles. Accurate relationships for many flow regimes such as; (turbulent or laminar, transitional), pin-fin arrangements (in-line or staggered) as well pin geometry including a transverse/longitudinal, ratio of pitches to diameters and ratio of pin heights to pin diameters (L/D)had been improved [7]. Studied the thermal effect for heat sinks made of copper with 0.25mm to 1.0 mm of fins highs. The outcome revealed that the amount of convective heat transferring coefficients improved when lowered the fin height, as shown in Figure 3 or by extended fin spacing Figure 4. With the many tested designs, the highest amount of 8W/m2 K convective heat transfer coefficient got when the spacing of 1.0 mm and fin height of 0.25mm.

In the research, an array facing upward considered, evenly heated with an electrical mat along with input power between 0.20 W to 1.60 W. The outcomes of heat transfer coefficients by convection revealed that the values improved by either reducing the fin height or expanding the fin spacing. The fins thickness effect was ignored on thermal exchange. The examinations specified in this section indicate huge possibilities with water-cooling at a single phase. The effective use of cutting edge micro fabrication technologies, coupled with a knowledge of the primary fluid flow phenomena and heat transfer, will be up to meet the difficulties of dispersing heat loads more than 5.0 MW/m2 to 10.0 MW/m2 (0.50 kW/cm2 to 1.0 kW/cm2) [16]. Analyzed heat transfer conditions for flow channels created by rectangular heat sink fins using numerical, analytical and computational techniques of different complexity. At first, outcomes presented for ideal fins, which are 100% effective utilizing Nusselt number expression to represent entry to exit heat transfer conditions. Then, uniform fin effectiveness based on Nusselt number is used. Further information presented by letting both fins efficiency and Nusselt number to differ at the flow channel and using numerical integration to calculate air temperatures. Eventually, the influences of flow turbulence by the entry of the heat sink and cooling fins axial conduction were created in a computational fluid dynamics (CFD) study by finite element treatment of the fin [17]. Examined drop of pressure and heat transfer features for arrays of micro pin fins inside narrow rectangular groove with flow air at varying rates starting from laminar flow to turbulent flow was studied. Pin fins of Micro size made of copper using micro fabrication techniques with dimensions of 150 µlm - 400 µlm long and 75 µlm - 700 µlm in diameter. Performance proportions that comparing heat transfer and drop of pressure properties are assessed to study the micro pin fin surface performance when pressure drops along with heat transfer are significant. In conclusion, the results show that heat transfer enhancement due to fluid dynamic impacts produced at micro pin fins has a more robust part than the increase of micro fins area. The maximum heat transfer improvement obtained was 79% higher than plain surface because of micro pin fin dimensions; diameter of 400 µlm and a height of 250 µlm. These outcomes supporting the assumption that micro pin fins surfaces may be utilized for enhancing the fan cooling performances that supports heat sinks with electronics devices thermal control [19]. The drop of pressure and heat transfer coefficient amounts are summarized for pin fins heat sink with a height of 1 mm and cross section of 1 mm X 1 mm. The pin fins were made on a square base plate size 50 mm, in line arrangements and pitch of 2.0 mm. The data were collected during boiling of deionizer water at barometric pressures. The mass influx was from 40.0 kg/m2 to 200.0 kg/m2, and the heat flux was from 30kW/m2 to 470 kW/m2. The examination area made hot from underneath by an electrical heater that is usually used for uniform heat flux boundary condition. [23], this article examines the drop of pressure and heat transfer over micro pin fins. Explicit expressions determined for the whole thermal resistance experimentally and discussed verified. Thermo hydraulic and geometrical parameters influencing the overall thermal resistance considered. It was noticed that minimal thermal resistance is obtainable by utilizing pin fins heat sink. In several cases, the rise in flow temperature affects the convection thermal resistances that is much smaller than overall thermal resistances carried out numerical research about radiation heat transfer and natural convection from micro fin heat sink array [24-25]. The outcome revealed that the radiation exchange is responsible for 22.0% of the overall heat dispersing, so radiation exchange should be a part of the investigation with natural convection mode micro fins heat sinks. The simplicity of micro fins makes it a practical solution to enhance system cooling even if the performance of micro fins is less compared to carbon nano tubes CNTs heat sink with micro pin fin [20], distinguished by compact structure, low-level thermal resistance, and uniform distribution of temperature with the flow path, it is efficient and important for electronic devices thermal management. To improve micro pin fins with square cross section heat sink cooling performance, geometry optimization method by changing pin fins located angle and pin fin porosity is suggested in this article. To show the features and benefits for the micro square PFHS, the differentiation between the column pin fins and the square pin fins were performed. The numerical outcomes show the importance of both located angle and the porosity of pin fins for thermal performance and the cooling function for micro square PFHS; the optimal angle position and porosity for thermal performance are 30o and 0.75 respectively. Moreover, optimized micro square pin fins heat sinks offer greater thermal performance compared to micro column pin fins heat sinks that concluded that micro square pin fins heat sinks have a great potential to be used with electronic devices for thermal management George [28]. Studied cylindrical micro fins heat sinks, thermal manner, and posterior heat transfer enhancement. Thermal models that have been considered changeable thermal characteristics following power, linear, and exponential laws. The numerical clarifications were used to conduct boundary examinations and to make thermal performance enhancement for the sharp fins in contrast to the existing smooth fins. The simulations' results confirmed that the thermal efficiency for the micro fins was influenced by the geometric ratios, nonlinear thermal conductivity, thermal geometric parameter, and roughness of the surface of micro fins. Furthermore, the thermal performances of the fins improved by geometric ratio and surface roughness. The proportion of fin efficiency described as the ratio among rough fin efficiency to smooth fin efficiency. Also, it found that it may be higher, during the smooth fins and the rough fins are experiencing identical operations states together with the same physical, thermal, material features, and geometrical. Electronic devices and thermal systems thermal management might improve via utilizing rough surface fins or heat sink.

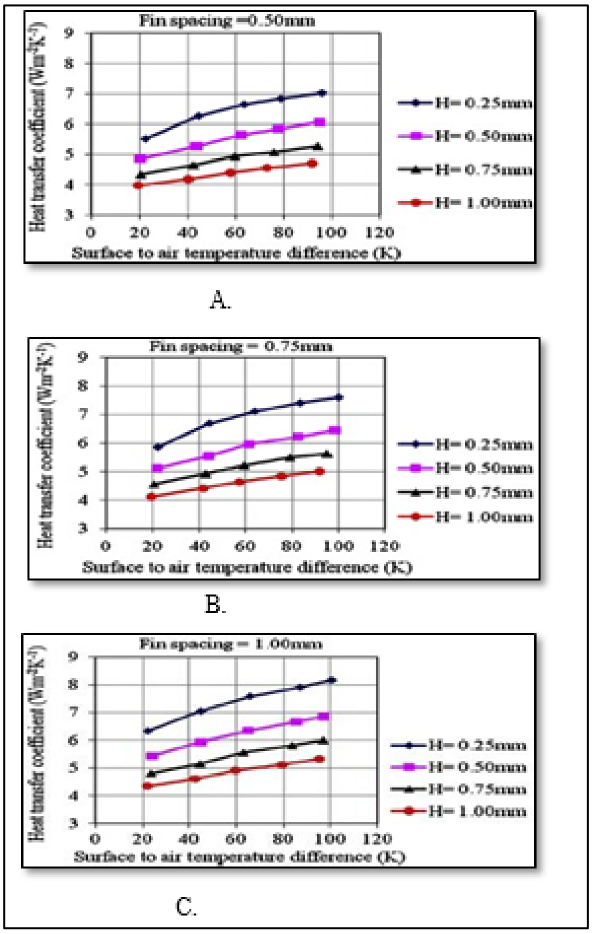

Figure 3: Effect of fin height on the heat transfer coefficient, Fin spacing; (A: 0.50mm, B: 0.75mm, C:1.00mm) [5]

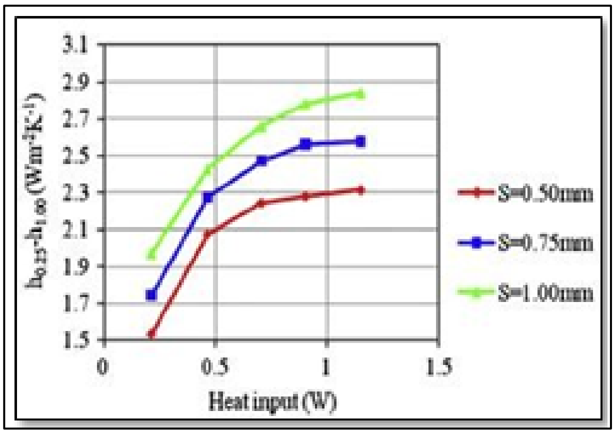

Figure 4: Impact of fins spacing in heat transfer coefficients [5]

6. Conclusions

This article provided a comprehensive view of the researches done about pin fin heat sinks. Also, a summary about the future research to understand heat sinks, and the type of coolant effect that provides better performance, which seems to be liquids have higher cooling properties compared to gases, due to lower thermal resistance. The most used coolant is water due to low cost, available and high heat capacity. An investigation about better performance and low-cost coolants can be done using computational fluid dynamics (CFD) simulation to examine different types of coolants and support the simulation results with experimental outcomes. The arrangement of pin fin or other heat sink geometry dimensions is still in its fundamental research level, which needs to focus on ensuring low-pressure drops, also uniform temperature distribution. Some researchers presented heat sinks optimization; these models have the direction for future optimization models that will ensure the highest performance of future pin fin heat sinks. The properties of the fluid are influenced by changes in temperature; yet, most of the investigations cited did not acknowledge this fact. Researches considering the fluid temperature dependent characteristics will surely provide more detailed and realistic outcomes than constant fluid characteristics studies, by estimating the pin fin heat sinks actual performance. The increasing interest into the pin fin heat sinks, which is obvious at the available number of studies, points to the conclusion that investigation in this area will provide an optimized solution for cooling electronic devices and of PV panel.

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