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# Heat Transfer Enhancement of Plate Fin Heat Sinks – A Review

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## ABSTRACT

Heat sinks have been commonly used for cool electrical, electronic and automotive parts in many industrial applications. They are effective in extracting heat at high temperatures from surfaces. The reliability of such systems depends on the temperature of their operation. Heat sinks are important components of most of these devices' thermal management systems, such as: diodes, thyristor, high power semiconductor devices such as integrated inverter circuits, audio amplifiers, microprocessors or microcontrollers. This paper highlights the use of heat sinks in electronic cooling applications, and discusses relevant literature to enhance the heat transfer efficiency of plate fin heat sinks by modifying the surface, interrupting the boundary layer and shifting the path.

***KEYWORDS:*** *Heat transfer, Heat Sinks, Plate fin heat sink, CFD, Convection, Thermal resistance, Base Temperature*

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## I. INTRODUCTION

Electronic devices are often used in our everyday lives because of the rapid growth of electronic technology. However, electronic devices must be decreased in size and weight and heat flow per unit area significantly increased. In the event that the electronic component's working temperature reaches the desired temperature level. In order to ensure a stable operation of electric devices, the development of the heat transfer rate and the maintenance of the die at the optimal operating temperature played an important role [1, 2].

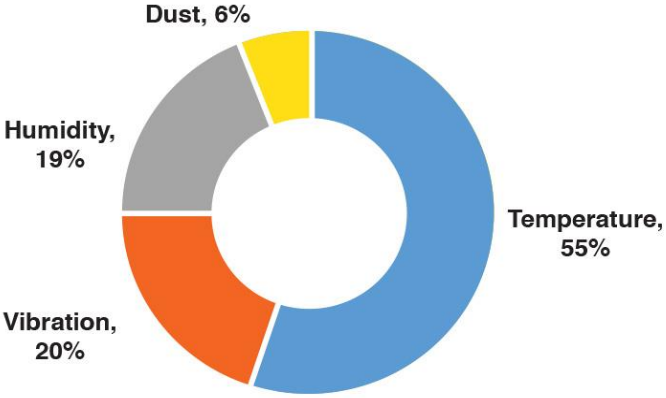

**Figure 1: Major causes of Failure in electronic Components.**

While a large number of new cooling technologies have been introduced and implemented, including heat pipes cooling, cold water and even liquid nitrogen, air cooling by a heat sink is, as a result of their low cost, availability and durability, a popular solution for the management of electronic packaging.

Heat sinks are typically mounted on the tops of the electronic packages in electronic thermal management to increase heat escape, and to monitor the temperature of the junction of the packages. The ultimate aim of the design of the heat sink is to dramatically improve convective heat transfer by reducing increases of the stream-specific pressure drop penalties. PFHSs are the most commonly used for its simple structure and output.

Nowadays, because of the conventional cooling techniques limitations, new designs are investigated to increase and control heat flux to keep the working temperatures in an acceptable range. Heat sinks are one of the efficient ways for cooling electronic integrated components and controlling them to work under the allowable operational temperature [3, 4]. Due to the advantages of easy manufacturing and good thermal efficiency, a range of heat sinks has been developed and widely used in the industry. Two types of heat sinks and pin-fin heat sinks are common. The advantages of simple design and easy manufacturing are plain-fin heat sinks, while pin-fin heat sinks have an advantage that impede the thermal boundary layer creation at the cost of an increase in pressure. Since the two heat sinks have their own benefits, they are widely used for electronic equipment as cooling solutions [4, 6].

### 1.1. Heat Sink

A heat sink is a passive heat exchanger that transfers the produced heat from an electronic or mechanical equipment to a medium for the fluid, usually air or the liquid coolant, where it is dissipated from the equipment so that the temperature at optimum levels is controlled. Heat sinks are used on computers for cooling CPUs, GPUs and some chipsets and RAM modules. Thermal sinks are used for high-performance semiconductor equipment such as power transistors and optoelectronics such as lasers and LEDs where the component's ability to dissipate the heat is inadequate to minimize its temperature [5].

**Figure 2: A fan-cooled heat sink on the processor of a personal computer.**

A heat sink is designed to increase its surface area in connexion with the ambient cooling atmosphere, for example the air. Factor that influence the efficiency of a heat sink are air velocity, choice of material, configuration and surface treatment. The temperature die of the integrated circuit also has an effect on heat sink connexion mechanism and on the thermal interfaces [7, 8].

Thermal adhesive or thermal grate increases the efficiency of the heat sink by covering air spaces between the heat pump and the heat sink. An Aluminium or copper heat sink is normally made of.

### 1.2. Heat Transfer Principle of a Heat Sink

A heat sink converts thermal energy from a heat sink into a lower fluid medium. The medium of the fluid is often air, but it can also be water, coolants or oil. The heat sink is also called a cold platform when the fluid medium is hot. In thermodynamics, a heat sink is a thermal tank that can consume arbitrary heat without increasing the temperature significantly [9].

For the transfer of heat by convection, radiation and conduction, practical electronic devices must have a temperature higher than the atmosphere [10]. The electronics power supplies are not 100 % effective, so extra heat is generated and can be detrimental to the device's operation. A heat sink is also included in the heat dispersion design.

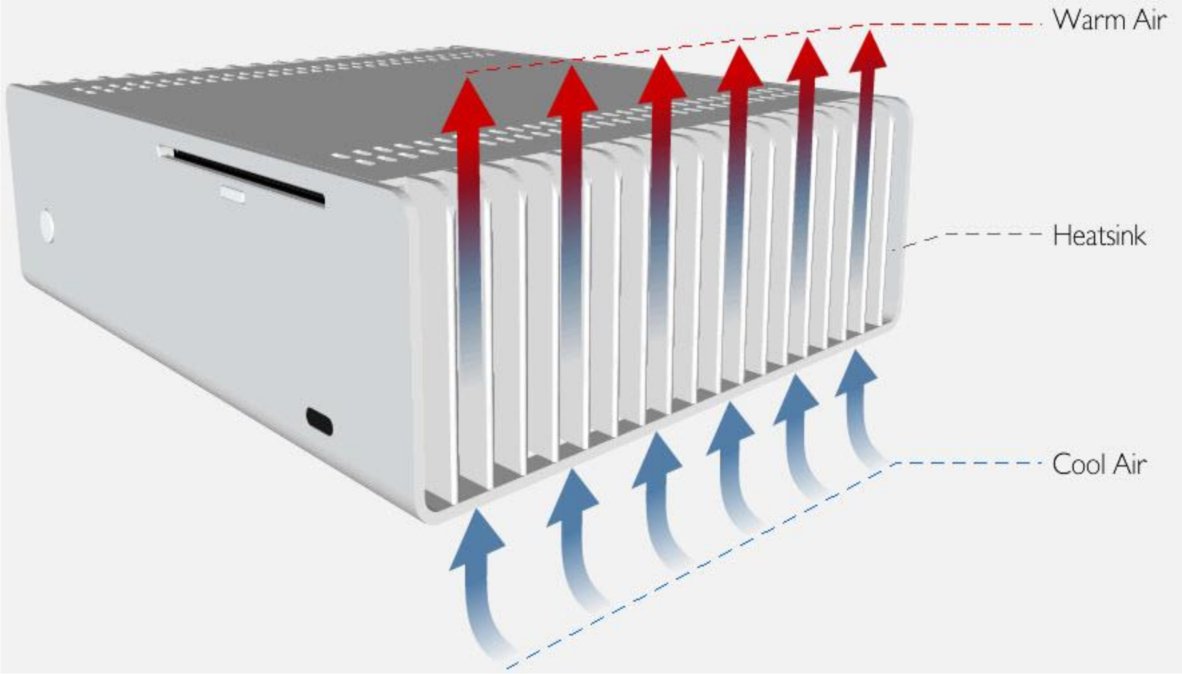

**Figure 3: A Heat Sink Principle.**

Consider Fourier's heat driving law to grasp the concept of a heat sink. The heat conduction legislation of Fourier, simplified into a unilateral form in x-direction, shows that heat is transferred from higher temperature regions to lower temperature regions when the temperature gradient is present in the body. The heat transfer rate, which is $q_x$, is proportional to the temperature gradient product and the cross-sectional range through which heat is transmitted [12].

$$q_x = -KA\,\frac{dT}{dx}$$

Now imagine a heat sink in a pipeline where air passes through the pipeline. The heat sink base is believed to be higher than the air.

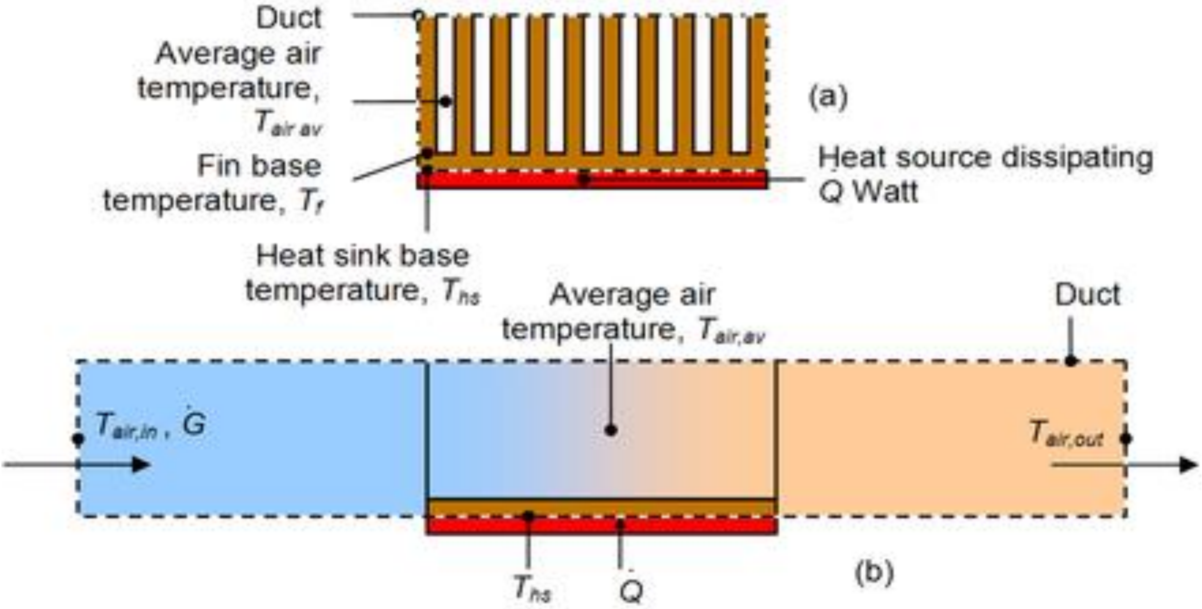

**Figure 4: Heat Sink in a duct [13].**

The following equations are illustrated in the following: applying energy conservation for stabilization conditions and Newton's cooling law to temp. Nodes in the diagram [13, 14]:

$$\dot{Q} = \dot{m}\,c_{p,in}\,(T_{air,out} - T_{air,in})$$

$$\dot{Q} = \frac{T_{hs} - T_{air,avg.}}{R_{hs}}$$

$$\text{where, } T_{air,avg.} = \frac{T_{air,in} + T_{air,out}}{2}$$

**These above equations show that:-**

A. When air flows through the heat sink, the ambient air temperature is increased. This raises the base temperature of the heat sink. The heat sink would also increase the thermal resistance. The net effect is a higher temperature of the base sink.
B. Later this article indicates an increase in thermal resistance to heat sinks, with a decrease in the flow rate.
C. The air inlet is closely related to the temperature of the base of the thermal sink. For example, if a product has air recirculation, the inlet air temperature is not the temperature of the ambient air. Consequently, the inlet air temperature of the heat sink is higher and the heat sink base temperature is higher as well.
D. If there is no air flow around the heat sink, energy cannot be transferred.

### 1.3. Types of a Heat Sink

The cooling solution for the problem of heat dissipation has been planned for various kinds of heat sinks. The heat sinks are categorized according to different parameters [15].

**Active Heat Sink:** The active heat sink is used by the fan (HSF). A fan can be mounted just above the heat sink in most computer processors. The cooling mechanism uses electricity. In the liquid cooling system, active heat sinks are used.

**Passive Heat Sink:** If there is no fan, the heat sink is passive. There is no mechanical aspect available to them that makes them reliable. The heat sinks are constructed of radiators made of aluminium finish. They release heat through the convection principle. The right and continuous airflow between the fins ensures that the system is completely stable.

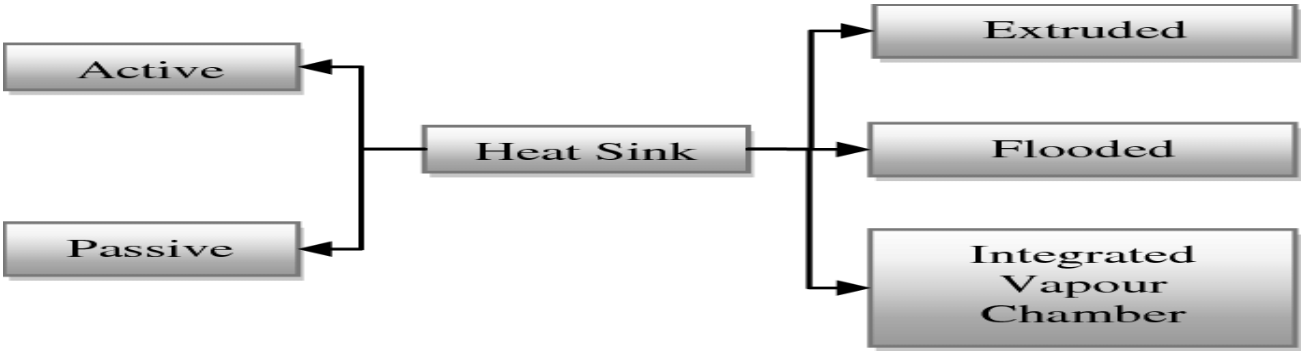

Figure 5: Heat Sink Classification [17].

**Extruded heat sinks** are normally created by Aluminium extrusion or other material. It's a single heat trap. Rarely rectangular are the fins.

When the requirement is higher power dissipation, heat sinks are filled. The ratio of the finish to finish size can be as poor as 1:3[9] in **flooded heat sinks.** In this case, the fins are near.

The heat pipe, on the other hand, is used in the **integrated steam chamber** drain. The problem of heat diffusion resistance is well solved with the use of heat pipes

### 1.4. Heat Sink Performance

The performance of heat sinks are a consequence of many parameters, including [15, 17]:

- Geometry
- Material
- Surface treatment
- Air velocity
- Interface with device

### 1.5. Applications of the heat sinks

Some applications can be listed [20] :

- Steam power station economizers
- Transformer power and engines
- Hot water and steam conditioning system convectors
- Aircraft cooled turbine tubes, I.C. Air Compressors and Generators
- Refrigerator and conditioner coils and condensers
- The machinery in electronics

### 1.6. Extended Surfaces (Fins)

Extended surfaces are also called fins. Whenever the surfaces available are not sufficient to transmit the appropriate amount of heat, fins are used. Different types of fins are generated and the design depends on the type of operation.

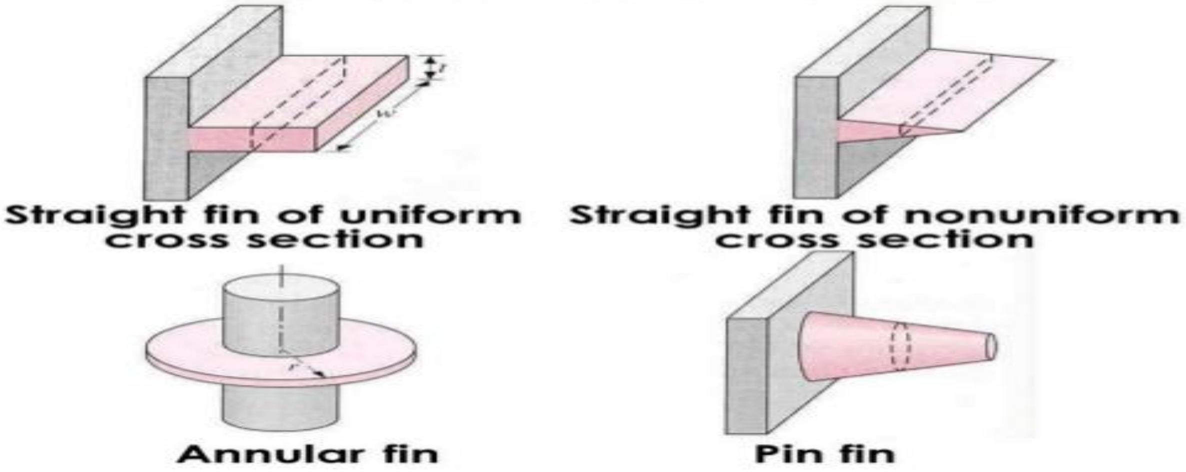

Figure 6: Types of fins

## II. LITERATURE REVIEW

In recent years, the efficiency of thermal sinks has based on various research ventures and has been analytically, numerically and experimentally studied. In order to reduce the corresponding thermal resistance in order to improve heat transfer from electronic products, most experiments were carried out with heat sinks.

This chapter provides a brief review of the related literature to demonstrate the scope of the study that is already published in open literature on the heat sink.

**Maveety and Jung (2001)** analyzed contrasting theoretical and experimental findings for a pin-fin heat sink cooling output with an impinging air flow. In addition, optimization experiments were also undertaken to measure the cooling efficiency results by modifying the fining geometry. The empirical findings revealed the dynamic pressure gradients within the fine range and better mixing / heat transfer with a higher pressure gradient. It also revealed that a complicated fluid motion caused vorticity, circulation and flux reversals in high pressure gradients **[1]**.

The effect of aerodynamic cooling fins on spaced hot sinks was numerically analyzed by **Leon et al. (2004).** The findings showed that for rectangular inline refreshing fins the aero-defining performance of rounded staggered cooling fins could be 2.80 higher with equivalent refresher intensity. For heat sinks with staggered configuration, the use of circular cooling fins is then recommended to reduce the resistance to flow. Moreover, only when the Reynolds are greater than 800, can the beneficial effect of rounded cooling fins manifest **[2]**.

The analysing-numerical technique to model natural convective heat sink cooling with electronic cooling software was carried out by **Narasimhan and Majdalani (2006).** The findings showed that the compact solution findings in considerable savings in mesh size and calculation time with a slight acceptable error **[3]**.

**Yue-Tzu Yang et al. (2009)** performs platform-circular pin-fin heat sink numerical measurements and offers practical insight into flow and transition functions. The governing equations are overcome using an orthogonally uniform phased grid control-volume-based finite-difference approach with a power-law system. The SIMPLEC algorithm addresses the relation of the speed and pressing conditions of the momentum equations. A plate fine heat sink and multiple circular pins between the plate fin fins is made of a plate fine heat sink. The findings demonstrate that there is greater efficiency than the heat sink of the plate-circular pin-fin **[4]**.

The pressures exerted by heat flow (uniform and non-uniform) and between the heat sink and the ventilator were explored by **Marco et al. (2010).** Displayed and analyzed were the speed distribution in the channels and the average thermal resistance. The results demonstrate that when heat source is spread over the entire surface of the heat sink, the system is more effective and, in this situation, the reduction in spacer volume decreases the thermal resistance **[5]**.

**Vivek Kumar et al. (2013)** gives practical insight into the empirical properties of flow and heat transfer. The regulatory equations are solved with the use of an orthogonal, non-uniform, phased grid regulation volume-based finite differentiation strategy. Through computational fluid dynamics the velocity and the pressure constraints of the momentum equations are solved. A heat sink plate finished with several circular pins between the plate fins consists of the Heat Sink Elliptical Pin Fin. The findings demonstrate the unusual efficacy of Elliptical Pin Fin Heat Sink as opposed to the flat heat sink **[6]**.

**Kim et al. (2014)** conducted an experimental analysis and suggested to use a formula based on the average volume of both configurations to estimate the pressure drop and thermal resistance. They found that, if the dimensionless duration of thermal discharges is long and the pumping capability is limited, optimised thermal discharges have lower thermal strengths than optimised plates fin heat sink. However, where the dimensionsless pumping capacity is strong and the dimensionalless duration of the heating sinks is short, the optimised plate-fin heat sinks have less thermal resistance **[7]**.

**Li et al. (2015)** studied the flow field distribution and temperature fields of heat sinks subject to impinged flow, with small flat fins. In this paper, the pressure decrease was studied for three sets of fine forms namely rectangular, ring head and elliptic. They find that the end forms control the secondary flow and flux separation prominently **[8]**.

The cooling efficiency of micro-structured flat-plate heat sinks was comparison to that of cross-cut thermo-electric heat sinks by **Rezania and Rosendahl in 2015[9].**

In order to complete the thermal performance optimization and bottom wall temperature homogenization of the double coating heat sink using a simplified conjugate gradient process, **Leng et al . (2015)** developed a three-dimensional solid fluid model **[10].**

In the course of experiments and numerical simulations [11], **Naphon et al. (2016)** examined the efficiency of microchannel heat sink with impinging nano-fluid flow.

Because of the optimum design problems with uniform heights of fine and widths in the impeding heat sink module, **Huang and Chen (2017)** carried out numeric simulations [12].

**Kavita et al. (2019)** have experimentally researched the use of forced convection square and circular perforated plate fin arrays. The scale of the drilling ranged from six mm, eight mm and ten mm. The Reynolds ranged from 2.1 × $10^4$ to 8.7 × $10^4$. He found that a small Reynolds number allows more thermal transfer with the square perforated fin, and a high Reynolds number provides better circular perforated fin array efficiency **[13]**.

Primary research is continuing to optimise the flat fin or other heat sink geometry measurements. This optimization should ensure that the temperature is low and evenly distributed and that the pressure decreases. Some researchers have developed heat sink model optimization; these models are a means of ensuring that the future PFHS is optimised.

Finally, the growing interests within the PFHS, as can be seen from the number of available studies, lead us to conclude that this study would provide us in this decade with an optimised solution for electronic device cooling.

## III. CONCLUSION

In spite of the aforementioned advances, varying degrees of success have been reported in previous works. It has been found that from above literature review highlights that, several studies were done for analysing the effects of the configurations of the pin-fins design in plate fin heat sink(PFHS) the effect of velocity over various shapes of pin fins like circular, elliptical mounted with plate fin on a flat plate is recorded [4,6]. To demonstrate the feasibility of more enhancement in the cooling efficiency of the plate-fin heat sinks with different profiles like Circular Plate Fin Heat Sink (PFHS), Elliptical plate Fin Heat Sink (EPFHS), more effective designs are needed to be investigated.

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