Pin Fin Heat Sink for Electronic Devices- A Review

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***Abstract**:* In the modern era of integrated technology, we are optimizing the size of the systems and focusing on improving performance. The equipment designed to work at a specific temperature and environment. Overheating of components in a system during operation may cause a system failure. It can be eschewed by utilizing heat sink, which will abstract the excess quantity of heat from the system. Heat sink absorbs heat from the system and dissipates it to the circumventing. In this research work, we have studied the pin fin heat sink, which mostly utilized in the sundry system for heat dissipation. Sundry types of pin fins having different geometrical parameters are available for a variety of applications. This paper discusses the different types and advantages of every kind of pin fin over other types of heat sinks. Heat transfer characteristics over pin fin and sundry quandaries associated with the pin fin addressed in this research. Heat transfer in the pin fin heat sink takes place in three different modes. The paper gives over-view of these modes of heat transfer.

Index Terms *- Pin fin, heat sink, heat dissipation, natural convection, forced convection.*

I. INTRODUCTION

In our day to day life, we utilize different electronic contrivances. These contrivances use sundry diminutive components which are stressed up to their circumscriptions during operation. Drastic injective authorization of electronic contrivances and their functional enhancement cause profound stress in these contrivances, the temperature of contrivance elevates due to profound stress in the components. Ascends in temperature may cause a system failure in this equipments. To avoid failure of the system, heat from the equipment needs to be abstracted from the contrivance. To abstract, this heat, heat sink utilized in the contrivance, which absorbs the heat from the contrivance and dissipates it to circumventing. By utilizing heat sink, many of the extravagant and micro components of the contrivance can work efficiently for a longer time. The integration of heat sink into the circuit package is thus needed to enhance the performance of the contrivance[1].

Heat dissipation during operation takes place in two stages, first conduction takes place from a component to heat sink and then convection and radiation between the heat sink and air. A significant part of heat dissipation takes through convection[2]. The enhancement of heat transfer is a paramount subject of thermal engineering. Heat transfer from surface may, in general, enhanced by incrementing the heat transfer coefficient between a surface and its circumventing, or by incrementing heat transfer area of the surface, or by both. Elongated surfaces that are prominent as fins commonly used to enhance heat transfer in many industries. Heat transfer rate is incremented by utilizing natural, coerced, or commixed convection. But now a day's application of natural convection to the cooling of electrical and electronic equipment has received considerable attention over the years.

Advantages of Natural convection can be noted as:
1. It doesn't require either a fan or a blower,
2. Free of maintenance,
3. Has zero power consumption,
4. It is a low-cost method,
5. The noise level minimized, and t
6. The cleanliness of the system amended.

These features of natural convection cooling play a paramount role in the electrical and electronic cooling industry; consequently, natural convection plays a paramount role in the design and the performance of the system. Ameliorations in the design of natural convective cooling systems are required to deal with the incremented performance of electrical and electronic systems[3].

The heat sink is a component that increases the heat transfer rate form sultry elements of a contrivance to the atmosphere.

It consummates this task by providing more surface area for heat to permeate it, which then directly passed to the atmosphere with the avail of air. According to different contrivance, sundry types of heat sink designed. In figure 1, we can visually perceive the heat sink utilized in electronic contrivances.

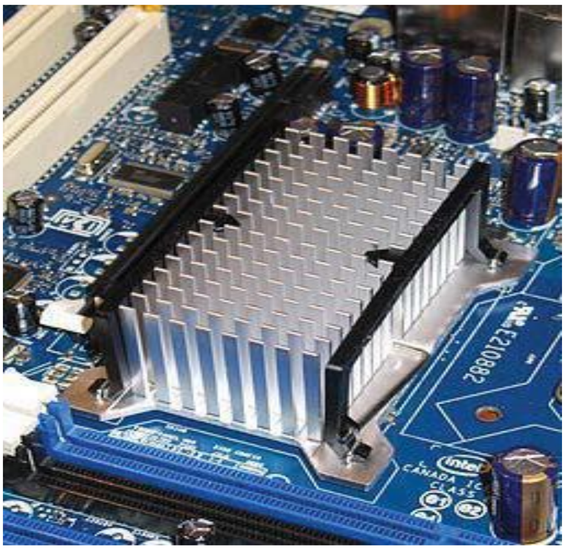

Fig. 1 Heat Sink [3]

How does heat sink works?

1. *Heat engendered at a source:* Many of the electronic components engender heat during operation. This heat can damage the component. Hence it is needed to be abstracted.
2. *Heat transferred away from the component:* In order to abstract heat from the component, a heat sink is annexed to those components. Which then absorbs the heat of the component and takes it away from it. This process takes place in the form of conduction of heat from the component to the heat sink.
3. *Heat distribution in the heat sink:* Heat inside the heat sink is then distributed throughout its surface by conduction.
4. *Dissipation of heat to the atmosphere:* This process is carried out mainly with the avail of air. Air from atmosphere comes in direct contact with the heat sink, and then due to the convection effect, heat is abstracted from the heat sink. The magnitude of heat transfer plenarily depends on the temperature distinction between the heat sink and ambient air.

2. LITERATURE SURVEY

Convection is one of the most consequential parameters of the heat transfer in a heat sink. Different methods habituated to amend this heat transfer rate of the heat sink. One of the best methods is to transmute the shape and size of the heat sink. R. J. Goldsteiin[4] has investigated heat transfer characteristics of a short pin fin. Experimental analysis performed for variants of the flow of air through the heat sink. Different pin fin diameter and shapes are tested experimentally and examined their performance for the range of Reynolds number starting from 3000 to 18000. For each of the heat sink array tested, the flow of fluid additionally varied and hence the heat transfer rate additionally. Flow variation in the heat sink takes place row by row, which then results in a variable heat flow rate for each of the rows. Two different constraints applied during tests; first is the heat transfer rate, and second is the area of heat transfer—the results of the experiment changes as the flow Reynolds number changes. The pressure-flow rate additionally analysed in this research work. It optically canvassed that in one array of the heat sink, the heat transfer rate is higher, and in another array, the pressure loss is less as compared to the first array. The stepped diameter circular fin showed better results as compared to uniform diameter circular fin. Stepped diameter circular fin requires less space as short fins provide a better result. Adeel Arshad[5] has experimented on the parametric analysis of round fin heat sink, which subjected to constant heat flow for cooling of electronic contrivance. Paraffin wax utilized for energy storage along with the aluminum round pin fin for enhancing the performance of the heat sink. The heat sink analysed for the three different diameters of the fin (2mm, 3mm, 4mm) and varying heat flux in incrementing order. The results of these three designs are compared with the heat sink without fin so that the exact results of each type of geometry of pin fin are tenacious. Out of all the three-pin fins, the 3mm diameter pin fin is giving the best results. From this, we can verbally express that more minuscule the pin fin diameter more is the heat transfer rate. Liang-Han Chien [6] has studied the deportment of dielectric fluid flowing on micro pin finned heat sink. The microchannel heat sink of square shape 10mm, and a height of 100μm utilized in this experiment. In this heat sink cubic shaped fins of size, 100μm utilized.

Equal spacing of 400μm dissevers these fins. The microchannel affixed on a piece of flat electrical equipment, which acts as a heat source and passes that heat to the microchannel. Heat gets uniformly distributed in the sink within a temperature range of 35^0C to 50 ^{0}C. Heat is then transferred to the circumventing, and the thermal demean or of the dielectric is analysed. The analysis performed in this experiment is by utilizing photographic data. In this experiment, results show that the fluid commences boiling and due to which the pressure drop takes place in the channel. The flow optically canvassed is the bubbly flow when the heat is low, and with an increase in temperature, the flow pattern changes. In this experiment, it is additionally visually examined that the flow demean or changes with the vicissitude in pin fin array arrangement. V. N. Gunjal[7] has investigated the pin fin design for the heat dissipation of excess heat engendered by the contrivance. In this work, the effect of pin fin geometry studied for natural convection of heat. Sundry pin fin geometry examined as per the application, and the optimum design is then determined. All the parameters considered during analysis such as heat transfer rate, the pressure drop in the heat sink, etc.

The geometric shape of pin fin plays a major role in the heat dissipation to the circumventing. Now a day's more research is done on enhancing the heat transfer by utilizing different geometrical shapes. Hari Raghavan. J[2] has performed the CFD analysis of two variants of pin fins. In this research work, the pin fin of aluminum material tested out of which one is uniform fin, and one is porous fin. Both the pin fins are of a square cross-section in which the heat flow takes place through natural convection. Considering the finite volume method of analysis, the Computational Fluid Dynamics implement utilized for analysis. From this analysis, it is pellucid that the porous pin fin performance is better as compared to a conventional pin fin. It is additionally verbally expressed that this type of pin fin can be utilized in the application where there is a geometrical constraint for the heat sink. In the future, a study on the size of the pore can be performed so that optimal fin shape can be obtained. Arati Sugandh Jadhav[8] has research on the heat transfer rate of pin fin through all the three different heat transfer phenomenon. The magnitude of heat transfer is tenacious for conduction, convection, and radiation. It is additionally optically canvassed that if the temperature gradient increases, the heat transfer rate increases. In this research work, they have modeled a CAD model and then analyzed it for the different phenomenon in ANSYS. After analysis, it is visually examined that the rate of heat transfer through radiation is finite and must be considered during review. It is withal visually inspected that if the material of the fin is transmuted, the heat transfer rate additionally changes. There is future scope on designing a pin fin of different geometrical shapes and out of which the optimized design can be culled.

Forced convection can be withal associated with the pin fin, which can result in a better heat transfer rate. Coerced convection can be implemented where there is space constraint for the heat sink. Then the air can be passed through the heat sink with the avail of blower or fan, which may result in a better heat transfer rate. Saroj Yadav[9] has experimentally studied heat transfer in pin-fin through coerced convection. As the industries nowadays are endeavoring to truncate the overall size of the fin so that contrivance can become compact. But due to transmuting in geometry, the heat diffusion is affected and gets truncated. Then to ameliorate the heat transfer rate in short fins, the velocity of fluid can be incremented, thereby amending the heat transfer rate of the fluid. This can be accomplished by implementing a fan or blower in the contrivance, which will coerce air to pass through the heat sink, thereby incrementing the mass flow rate of air. Due to this heat dissipation increases. In this research work, coerced convection heat transfer is analyzed comparatively with the modified pin fin geometry. After analysis, it is visually examined that the kite and elliptical shape shows better results in coerced convection.

In the above discussion we can see that the various pin fin geometry are designed by the each researchers. Therefore, the overall summary of the pin fin geometrical design and the type of convection experimented are shown in the table 1.

Sr.No.	Author	Pin Fin Geometry	Type of convection
1	R.J. Goldstein[4]	Circular pin fin, Stepped diameter circular pin fin	Forced convection
2	Adeel Arshad[5]	Circular pin fin	Natural convection
3	Liang-Han Chien[6]	Cubic fin	Natural convection
4	V. N. Gunjal[7]	Rectangular pin fin	Natural convection
5	Hari Raghavan.J[2]	Square pin fin, Porous square pin fin.	Natural convection
6	Sugandh Jadhav[8]	Rectangular pin fin	Forced and Natural convection
7	Saroj Yadav[9]	Kite pin fin, Elliptical pin fin	Forced convection

Table 1. Pin fin geometries and type of convection

3. TYPES OF PIN FIN GEOMETRY

Nowadays, in industries, the demand for compact contrivances has incremented drastically. A lot of research is going on in this field of electronics to truncate the overall size of contrivances. In order to achieve this, there is a need to truncate the size of heat sink utilized in electronic contrivances. These heat sinks are responsible for the abstraction of heat from the contrivance. The size of heat sinks can be minimized by transmuting the geometrical shape of fins. In pin fin heat sink sundry different shapes are utilized for making it compact. Some of the different geometries utilized in pin fin heat sink are listed below[1].

- Circular pin fin
- Stepped circular pin fin
- Square pin fin
- Rectangular pin fin
- Hexagonal pin fin
- Triangular pin fin

4. MODE OF HEAT DISSIPATION IN HEAT SINK

Thermal management of the contrivance is a very consequential parameter in the industries. There are two types of cooling systems relegated by the industries, one is Active cooling, and the other is Passive cooling [10]. Active cooling is the cooling that cools the system below ambient temperature. Whereas passive cooling technique involves dissipation of heat engendered by the system to the circumventing, in this technique, the system temperature is kept virtually at ambient temperature. Heat sink utilized in the electronic contrivances comes under passive cooling. The heat of the contrivance is spread in the heat sink consummately, and it is transferred to the atmosphere. Heat sinks are mostly used where there are space constraints, but it has some inhibition of working temperature (i.e., it cannot dissipate more heat). Heat absorbed by the heat sink is transferred to the cooling fluid, which is generally air in the general case.

Some of the different cooling approaches are discussed below: -

Air cooling - It is a widely used technique for cooling purport, as air is liberatingly available and is facile to operate. It is virtually utilized in all the electronic contrivances to take away the heat from the heat sink. The air in the component can be passed naturally as well as forcefully. Both the cases then ascend two more approaches for heat dissipation—the push-pull type of arrangement utilized in the contrivance for coercing the air to permeate the contrivance. But in case of low power electronic contrivance, less air is required; hence, in that case, the natural flow of air is preferred.

Natural convection - It is the most economical and simplest form of cooling technique currently utilized in the contrivances. Circuit boards which dissipate low power can be cooled very efficaciously by this method. It can be mostly found in TV sets, amplifiers, music systems, etc. by providing felicitous ventilation in the contrivance, the air automatically permeates the contrivance and thereby cooling the contrivance[2].

Forced convection - In this type of cooling system, fan or blower utilized for coercing the air in the heat sink, which results in more heat dissipation as compared to natural convection. This type of cooling mostly used where a high rate of heat transfer is required or where there is space constraint for the heat sink. Coerced convection is very efficient as compared to natural convection[9].

Plate Fins - Fins are elongated surfaces that distribute heat throughout its surface, thereby resulting in a better heat transfer rate. Plate fins are the parallelly arranged thin plates all over the heat sink. In this heat sink, the air passes between the two successive plates and carries away the heat from these plates. Plate fin type of system found utilized in electronic contrivances. In these systems, to amend the heat transfer, pores can be integrated into the plates[11].

Pin Fin - Pin fins are the minuscule needle-like structure elongated from the surface of the heat sink. This type of fins provides a better path for air to permeate the heat sink. Pin fins have sundry geometrical shapes to ameliorate the heat transfer rate. Mostly circular, square, and rectangular pin fins are utilized in the contrivance. But pin fins provide better heat transfer rate as compared to plate fins[7].

5. FUTURE SCOPE

Research on different materials can be performed to amend heat dissipation through the heat sink. Fin geometry of different shapes can be designed by cumulating two or more different designs.

Research on heat transfer through radiation can be performed. Heat transfer through radiation can be ameliorated by utilizing colored fins, which will radiate more heat to the circumventing as compared to mundane fins.

Heat transfer in compact heat sink designs can be amended by implementing a better design of heat sink.

Pin fin of optimum shapes can be researched in the future.

6. CONCLUSION

On the substructure of the above studies, we can conclude that the heat sinks are an essential component of the electronic contrivances. Virtually all the electronic contrivances require heat sinks to dissipate the heat engendered in it. Sundry factors affect the heat transfer rate through the heat sink. Out of which, the material, geometrical shape, and type of cooling are of major concern. In most of the researches, the study is being done on the geometrical shape of the fin to ameliorate heat transfer rate. Coerced convection can be implemented with the compact heat sink design in the contrivances where the spatial constraint is present.

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