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# A Comparative Study of Heat Energy Dissipated from Electronic Devices by CFD Analysis

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***Abstract :*** Heat sinks are the indigenous thermal management hardware used in electronic applications. These heat sinks will boost up the thermal control of electronic components, assemblies, and modules by enhancing their surface area through the use of fins. Present work is concerned with the comparative study of taper pin fin heat sink and cylindrical pin fin heat sink using the commercial CFD software. The heat sink is made from aluminum and air is used as the cooling fluid and a constant heat flux of 100 W/cm$^2$ from bottom and flow velocity of 2m/s. The results showed that for a given boundary conditions, the taper pin fins have less temperature gradient *i.e.*, less thermal resistance than cylindrical pin fins heat sink which results in increase the rate of heat transfer from fins.

***Keywords :*** Heat sinks, Electronic packaging, CFD, Taper pin fins, Cylindrical pin fins.

## 1. INTRODUCTION

Heat sink constitutesgeometricallysimple structure but to find out the accurate fluidflowpath pose enormous difficulty to the attempt to perform thermal analysis. In the industry today, Computational Fluid Dynamics (CFD) codes are widely used as a tool of thermal analysis. CFD solutions of high spatial and temporal resolutions can be obtained on a desktop computer or even a laptop.To meet the next generation, CPU needs the thermal requirement with a low profile heat sink. Therefore, new heat sinks with larger extended surfaces, highly conductive materials and more coolant flow are keys to reduce the hot spots. To meets these constraints, Computational Fluid Dynamics (CFD) is good approach to explore various design alternatives quickly with reasonable accuracy. Usually extended surfaces are used to increase the heat dissipation from electronic components to the ambient air and have been the topic of many studies in recent years. Initial stage studies for pin–fin arrays were performed by Sparrow et al. [1] performed experiments to determine per fin heat transfer coefficients for a pin fin array situated in an oncoming longitudinal flow that turns to a cross-flow. They varied the geometric parameters of round fins including the fin height to diameter ratio (H/D) and the inter-fin pitch to diameter ratio (P/D). The pressure drop across the array was also measured and presented in dimensionless form relative to a specially defined velocity head, which gave a universal pressure drop result for all operating conditions. Subsequent to this study, they also compared the performance of different pin fin geometries [2].One of the most common types of extended surfaces is the pin fin heat sink. The main advantage of this type of heat sinks is independent of the direction of the incoming flow and it is suitable for the situations where the flow paths are hard to predict.

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The various types of heat sinks have been developed and widely used in the industry due to the benefits of easy fabrication and high thermal performance. Two common types are plate-fin heat sinks and pin-fin heat sinks. Plate-fin heat sinks have the advantages of simple design and easy fabrication, while pin-fin heat sinks have an advantage of hindering the development of the thermal boundary layer in a unidirectional flow at the expense of an increased pressure drop. Vedullamanojkumar et al. [3] presented for determining optimum heat sink conditions by the consideration of both heat transfer characteristics and fluid dynamics.

Bahadur and Bar-Cohen [4] proposed closed form analytical solutions for temperature distribution and heat transfer rate from a cylindrical pin fin with orthotropic thermal conductivity, which is usually encountered in the use of thermally enhanced polymer composites. Exact solutions were derived and compared with those from a finite element analysis. The in depth analysis of developed orthotropic axisymmetric pin fin temperature and heat transfer rate equations was carried out to better understand the heat flow rate in such fins.The optimal geometry of an array of fins that minimizes the thermal resistance between the substrate and the flow forced through the fins was reported by Bejan and Morega [5] Both round pin fin arrays and staggered plate fin arrays were optimized in two steps, first the optimal fin thickness was selected and then the optimal size of fluid channel was determined they also compared the minimum thermal resistance of staggered plate arrays and parallel plate fins.Several research works have been concentrated on design parameters [6] and the selection of heat sink module [7] in order to offer a high-performance heat removal characteristic. Shih and Liu [8] have presented an approach to design the plate-fin heat sinks by minimizing the entropy generation rate in order to reach the most efficient heat transfer. Other researchers have used Computational Fluid Dynamic simulation to find the optimal physical design for an electronic system. Ozturk and Tari (2008) have investigated the flow and temperature fields inside the chassis and also the three different commercial heat sink designs have been analysed by using CFD. The flow obstructions in the chassis and the resulting air circulation that affect the heat sink temperature distribution are studied [9].Initial stage studies for pin–fin arrays were performed by Sparrow et al. [10] and Van Fossen[11]. They experimentally studied staggered and in-line pin–fin arrays installed in an internal cooling channel. Analytical models are developed for determining heat transfer from in-line and staggered pin-fin heat sinks used in electronic packaging applications. The heat transfer coefficient for the heat sink and the average temperature of the fluid inside the heat sink are obtained from an energy balance over a control volume [12]. Pin-fin heat sinks possess complicated fluid flow and heat transfer characteristics due to flow separation. Even though various types of empirical correlations based on experimental data have been presented for pin-fin heat sinks, there exists no closed-form analytical model for accurately estimating the friction factor and the heat transfer coefficient. Most of the studies on pin-fin heat sinks have dealt with circular-shaped [13,14] or unshrouded pin-fin heat sinks [15,16]. Ryuetal [17] and Dogruozetal [18–19] studied fluid flow and thermal characteristics of shrouded inline square pin-fin heat sinks experimentally.

## 2. METHODOLOGY

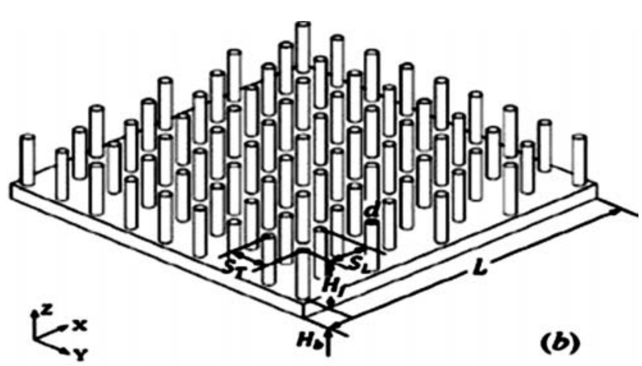


**Fig. 1. Schematic diagram of cylindrical pin fins heat sink.**

In pin-fin heat sinks, arrays of pin-fins are arranged in in-line or staggered manner as shown in Figs. 1. The pins are attached to a common base and the geometry of the array is determined by the pin dimensions, number of pins and pin arrangement. In this work, a total of 35 fins of height of 36mm for taper and plate pin fins heat sink is considered. Fig. 1 shows a sketch of this heat sink.

### 2.1. Mesh Generation and Boundary Conditions

The mesh generated in the model is formed by approximately half a million hexahedral elements distributed uniformly, except in the section near the fin walls where a cell ratio of 1.025 is set. This mesh is adapted to the fin shape. A mesh sensibility analysis was done in order to arrive at the appropriate number of elements for achieving satisfactory results.

The boundary conditions for the models are adjusted according to the interaction of the fluid with the surroundings. Velocity is considered at the fluid inlet section of the model *i.e.*, 2m/s. A constant heat flux $100W/m^2$ imposed on the bottom wall of the solid domain. Zero static pressure is assumed at the fluid outlet section. Symmetry conditions for both domains are considered at the symmetry walls. The walls between the domains are set as interface conditions. The upper wall of the channel and fins are set as adiabatic conditions.

## 3. DESIGN OPTIMIZATION

Many parameters could be used to improve design of heat sinks. In this study we focus on the temperature distribution, Velocity and pressure distribution of both taper and plate pin heat sinks. The Nusselt number is the ratio of convective to conductive heat transfer throw a surface. The heat transfer coefficient and the Nusselt number are related with the following relation

$$h = Nu\, K_{air} / L$$

Where

L Characteristic length, *m*

$k_{fluid}$ Thermal conductivity of the fluid,

$h$Convective heat transfer coefficient.

## 4. RESULTS

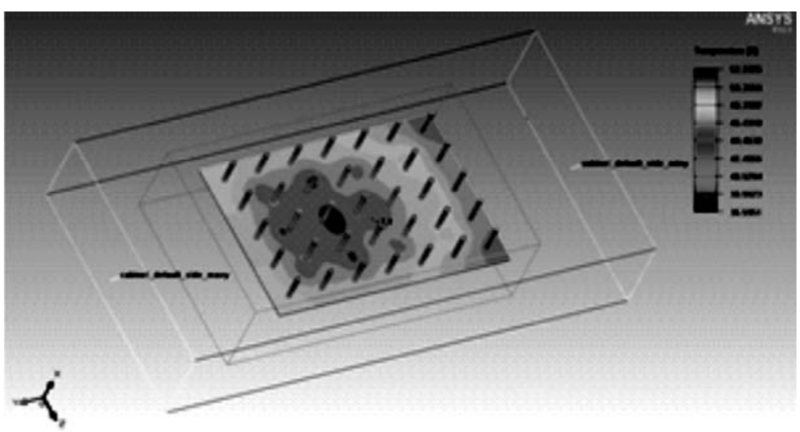


**Fig. 2. Temperature distribution of cylindrical pin fin heat sink.**

From figure (2) we have observed that the temperature distribution along the length of the cylindrical pin fins heat sink. The maximum temperature is occurred at centre of heat sink and the minimum temperature is at edge of pin fin heat sink, This shows a temperature difference of 15.8 °C

The pressure distribution of the pin fins heat sink have maximum at inlet and minimum at outlet and the distribution of pressure we can see by giving boundary conditions and by clicking run solution.

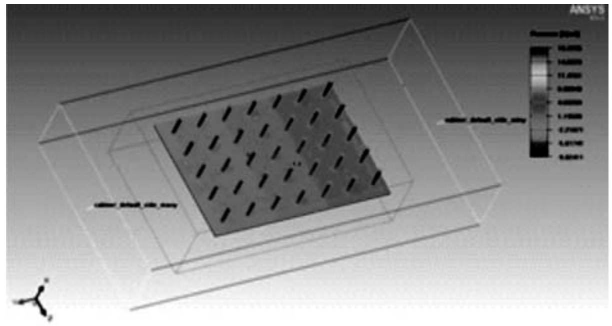

**Fig. 3. Pressure distribution of cylindrical pin fin heat sink.**

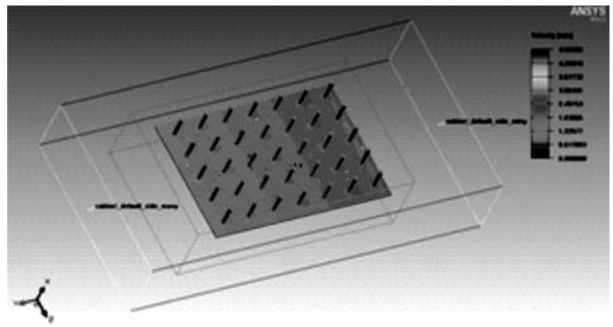

**Fig. 4. Velocity distribution of plate pin fin heat sink.**

The typical figure of pin fins heat sink shows us velocity distribution from inlet section to outlet section, Here the flow is taking place from one side to other side with more uniform distribution and this velocity is maximum at entry position and minimum at exit position which is shown by red and blue colors respectively.

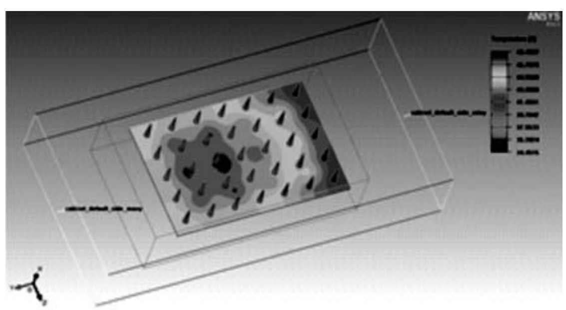

**Fig. 5. Temperature distribution of taper pin fin heat sink.**

From figure (5) we have observed that the temperature distribution along the length of the taper pin fins heat sink. The maximum temperature is occurred at center of heat sink and the minimum temperature is at edge of plate pin fin heat sink. This shows a temperature difference of 10.1°C which is lesser than cylindrical pin fins heat sink.

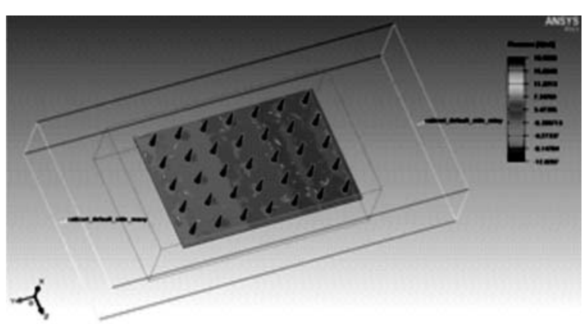

**Fig. 6. Pressure distribution of taper pin fin heat sink.**

The pressure distribution of taper pin fins heat sink is shown in above figure which is maximum and minimum positions at inlet and outlet respectively. In electronics we are trying to reduce the pressure drop so that uniformity might be takes place.

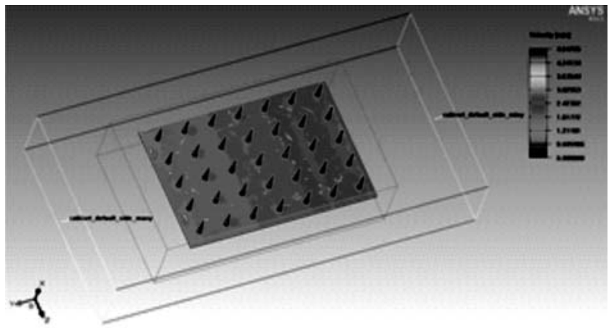

**Fig. 7. Velocity distribution of taper pin fin heat sink.**

From the figure (7) we observed that the velocity distribution and we can see how the flow of velocity will be taken place. To get the more amount of heat transfer per unit area we should concentrate about velocity configuration and fluid flow that has been shown in above figure.

**Table 1. Comparison of different distributions between taper pin fin heat sink and cylindrical pin fin heat sink**

| *S.No* | *Parameters* | | *Cylindrical pin fin* | *Tapered pin fin* |
|---|---|---|---|---|
| 1. | Temperature in °C | Max | 52.3 | 48.5 |
| | | Min | 36.5 | 38.4 |
| 2. | Velocity in m/s | Max | 4.3 | 4.8 |
| | | Min | 0 | 0 |
| 3. | Pressure in $N/m^2$ | Max | 18.22 | 18.9 |
| | Min | –9.02 | –12.0 | |

The tabular comparison showed that the different distributions of various types of pin fin geometries, this analysisinvestigated that the taper pin fins heat sink gives the better solution for electronics packaging compared with cylindrical pin fins because of the less temperature gradient and optimum velocity distributions are achieved in the case of taper pin fins heat sink.

## 5. CONCLUSION

In this study, the heat transfer performance of various fin geometries is compared. This study was carried out by using Ansys Ice pack 16.0 software for analyze the geometries of taper and cylindrical pin fins heat sink. Realistic, manufacturable geometries are considered for maximizing the rate of heat transfer by increasing the temperature gradient and with low pressure drop. The flow and heat transfer through two different heat sink configurations was numerically simulated using the standard k-E turbulence model. By utilizing the theoretical and numerical model, the study concluded that the taper pin fins heat sink configuration offers better performance than cylindrical pin fins heat sink i.e., by less thermal resistance and high heat transfer coefficient.

## 6. ACKNOWLEDGMENT

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