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A Review of Thermal Performance of Heat Sink for Different Fins Configuration

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ABSTRACT

The primary objective of this paper is to examine the advancements in technology that have been made to enhance the heat flow rate using heat sinks. There is intense competition in this field, with researchers employing different configurations in their models to achieve optimal results. This study demonstrates that the heat transferred by the fins is primarily influenced by factors such as the type and shape of the fins, their length, angle, and surface area. Various geometries, including rectangular, trapezium, triangular, and round expansions, have been investigated. Fins are devices that are attached to heat sinks to increase the surface area for maximum heat transfer to the surrounding environment. Different types of fin geometries, utilizing copper and aluminum as heat sink materials, have been simulated under both natural convection and forced convection conditions. Further feasibility studies and optimization are necessary to explore the potential of various fin types in heat sinks.

Keywords: Heat sink, fins, geometry, Ansys fluent, heat flux.

Introduction

The enhancement of heat transfer through the heat sinks located in the flow channel can be achieved by implementing modifications on passive surfaces, such as extended surfaces with geometric alterations. These methods find broad applications in various fields including cooling turbine aerofoils, electronic cooling systems, biomedical instruments, and heat exchangers. Pin fin technology is extensively utilized in numerous applications like computer motherboard heat sinks for microprocessors. The design of efficient cooling systems is crucial for the reliable performance of high power density devices. Several failure mechanisms in electronic devices, such as intermetallic formation, metal migration, and void formation, are linked to thermal effects. In fact, the rate of such failures nearly doubles with every 10°C rise above the operational temperature (~80°C) of high power electronics. Apart from the damage that excess heat can cause, it enhances the generation of free electrons within semiconductors, leading to an increase in signal noise. Hence, thermal management of devices is of paramount importance, as evidenced by the market trends. Thermal management products witnessed a growth from approximately $7.5 billion in 2010 to $8 billion in 2011, and are projected to reach $10.9 billion by 2016, with a compound annual growth rate of 6.4%. Cooling hardware, such as fans and heat sinks, accounts for about 84% of the total market. Other key cooling product segments, like software, interface materials, and substrates, each represent between 4% and 6% of the market, respectively. The North American market is expected to maintain its leading position throughout this period, with a market share of around 37%, followed by the Asia-Pacific region with approximately 23% to 24%. This power dissipation results in heat generation, which is a common by-product in many engineering applications.

The cooling systems for high power density electronic devices vary depending on the application and required cooling capacity. Heat generated by electronic components must pass through a complex network of thermal resistances to dissipate into the environment. Passive cooling methods are often preferred for electronic and power electronic devices due to their cost-effectiveness, quiet operation, and hassle-free solutions. Examples of passive cooling methods include heat pipes, natural convection air cooling, and thermal storage using phase change materials (PCM). Heat pipes efficiently transfer heat from high power density converter components to a heat sink through the phase change of a working fluid. Air-cooling is also considered a crucial technique in the thermal management of electronic packages because of its availability, safety, lack of air pollution, and absence of vibrations, noise, and humidity in the system. The benefits of natural convection have led to significant research on the development of enhanced finned heat sinks and enclosures. The use of fins is one of the most cost-effective and common methods to dissipate excess heat and has been successfully applied in various engineering applications.

Rectangular balances are the most widely used type due to their low production costs and high thermal efficiency. Various shapes of balances, such as rectangular, circular, pin blade rectangular, pin balance triangular, and others, can be seen in Figures.

Literature Review

Singh, B. Ubhi., et.al. [1], The heat transfer through blade expansion in plate balances was both composed and analyzed by the researchers. Various geometries such as rectangular, trapezium, triangular, and round expansions were studied. The findings indicated that plate blades with expansions resulted in 5% to 13% more heat transfer compared to plates without expansions. Among the different types of expansions, the rectangular augmentation plate balance proved to be the most effective.

S. R Pawar and R. B. Varasu [2], The triangular scored blade exhibit facilitates the exchange of warmth through common convection. The researchers explored various indent geometries, such as a blade without any indent, a blade with a 20% indent and territory remuneration, and a blade with a 40% indent and range pay. They considered parameters like height, length, score measurement, balance separating, and balance thickness. The findings revealed that the warmth exchange coefficient is lower in the indented blade compared to the blade without any indent. However, there was a 7% increase in warmth exchange for the 20% scored blade and a 10% increase for the 40% indent balance. Furthermore, the warmth exchange further increases with an increase in the indent size along with territory remuneration.

U. S. Gawai, Mathew V. K. et.al. [3], An exploratory investigation was conducted on heat exchange using a pin fin. The study focused on the heat exchange results of a single blade made of aluminum and metal. The findings indicated that the heat exchange coefficient and efficiency were higher for the aluminum fin compared to the metal fin.

D. D. Palande and Walunj et. al [4], An exploratory examination was conducted on grade thin plate blades heat sink under common convection. The blades were analyzed for perspective proportion and distinctive radiator data wattage. The results indicated that regular convection heat exchange increases with heat input. The convective heat exchange also increases with perspective proportion.

Hagote and Dahake et. al [5], The utilization of V-balance cluster has led to an enhancement in the conventional convection heat exchange coefficient. The V-balance was thoroughly analyzed using ANSYS CFX and experimental methods. Plate blades were employed, with the balances arranged at a 60o angle. The achieved maximum convective heat exchange reached 600.

V. Karthikegn, Babu et.al. [6], The researchers delineated and analyzed the standard convection heat transfer coefficient between rectangular blades in a cluster with various expansions and augmentations. The heat transfer rates through blade clusters with rectangular, circular, trapezoidal, and triangular expansions, as well as 18mm, 20mm, 22mm, and 24mm perforations, were found to be 27.32, 25.63, 25.62, 24.68, 23.82, 23.52, 22.97, and 22.63, respectively. It was observed that the blade cluster with rectangular expansions exhibited the lowest temperature at the end of the cluster compared to the cluster with rectangular augmentations, no augmentations, and apertures.

M. Reddy and G. Shivashankaran et al. [7], A numerical simulation was conducted to investigate the enhancement of constrained convection heat exchange through the use of a permeable pin balance in a rectangular channel. The researchers explored the effects of different gulf speeds, namely 0.5m/s, 1m/s, 1.5m/s, and 2m/s, on round, long circular, and short curved pin blade heat sinks using ANSYS CFD software. The results clearly indicated that the heat transfer efficiencies in the permeable pin balance configuration were approximately 50% higher compared to the solid pin balance configuration.

M. Ali, Tabassum et.al. [8], An investigation was conducted on rectangular balance models with different aperture sizes and quantities, focusing on warmth and water-driven performance. The study involved analyzing a base area of 1088 mm2, varying the number of punctures from 0 to 2, and adjusting the aperture width from 0mm to 3mm. Results indicated that heat transfer and pressure drop increased as Reynolds number rose for all models. Through experimentation, it was observed that efficiency and effectiveness improved with larger or more apertures, while thermal resistance and pressure drop decreased.

K. Kumar, Vinay et.al. [9], An in-depth analysis was conducted on tree-shaped blades in this study. The researchers examined tree-shaped blades with openings as well as tree-shaped blades without spaces. Furthermore, they investigated how different materials, such as aluminum composite, structural steel, and copper alloy, affected the results for the same geometries. The findings revealed that tree-shaped blades with openings outperformed those without openings. Specifically, the copper blades with openings demonstrated the best heat transfer capabilities among all the blades tested. The aluminum blades with openings were also highly effective in heat transfer without distortion compared to the other blades studied.

V. Kumar and Bartaria et al.[10], An exploratory and CFD analysis was conducted on a circular pin fin heat sink using ANSYS Fluent v.12.1. The study involved altering the dimensions of the curved pin blade by adjusting the cross-sectional area. The results indicated that, for all speeds, a 2mm smaller diameter circular pin fin heat sink exhibited better thermal resistance and reduced pressure drop.

K. Dhanawade and Sunnapwar et.al. [11], The square and round punctured blade cluster underwent a thorough examination using constrained convection. The aperture size for the examination was modified, with square apertures measuring 10mm, 8mm, and 6mm, and round apertures measuring 10mm, 8mm, and 6mm in diameter. The results obtained indicated that the Nusselt numbers increased as the Reynolds number increased. Additionally, the heat contact increased with an increase in puncturing, and the use of punctured blades enhanced heat transfer. Furthermore, there was a reduction in pressure and material consumption, resulting in decreased expenditure on blade material.

P. Chaitanya and G. Rao et al.[12], The transient warm analysis of drop molded pin blade cluster was conducted using CFD. A comparative study was also carried out between round shape pin blade and drop molded pin blade. The findings indicated that heat transfer increased due to the larger contact surface area between the fluid and the blade. Moreover, there was an increase in pressure drop for drop molded pin blades compared to round pin blades.

H. Dange and Patil et al. [13], The trial and CFD investigation were conducted to analyze heat exchange on a circular blade through forced convection. The investigation involved varying the speed, and the results indicated that the heat exchange coefficient increases as the liquid speed rises.

Junaidi, Ansari et.al. [14], An in-depth analysis was conducted on the spread pin blade heat sink. CFD analysis was carried out using ANSYS Fluent 12.1, considering different angles (4 degrees, 5 degrees, 6 degrees, and 7 degrees) of the pin blade in relation to the base plate. It was observed that heat transfer during natural convection is enhanced in the spread pin fin configuration. Additionally, the spread pin fin design promotes better air turbulence.

Dhumne and Farkade et al.[15], An examination of tube-shaped perforated blades was conducted to analyze heat exchange, revealing that the Nusselt number increases as the clearance ratio and inter-blade spacing decrease. Additionally, the friction factor increases with a reduction in inter-blade spacing. Various sizes of perforated blades were used for this study.

Mehran Ahandi et.al [16] The researchers conducted a numerical investigation and cautiously persistent study on normal convection heat transfer from vertically mounted inline interfered with blades. They carried out a 2D numerical simulation to explore the effects of blade intrusion using established software. A custom test bed was developed to validate the theoretical findings. A comprehensive experimental and numerical parametric analysis was conducted to assess the impacts of blade spacing and obstruction. The results indicate that the interferences enhanced the heat transfer rate by resetting the thermal and hydrodynamic boundary layer. Twelve heat sink tests were machined and tested to validate the current numerical study. It was demonstrated that the heat flux from the heat sink increased when interferences were introduced. A new compact correlation was developed to calculate the optimal blade interference for a targeted rectangular heat sink.

A Ledezma et.al [17] considered the mathematical headway of a party of staggered vertical plates that are presented in changed volume they performed improvement for scattering, no of plates, plate estimation and sway between sections. The degree used is Pr=0.72 and $103 \leq Ra \leq 106$ where Ra is Rayleigh number considering the upward estimation of get together. They induced that it is possible to improve mathematically within lessening to design of a restricted size volume the overall warm obstruction.

Shivdas S kharche et.al [18] studied, both with and without scores in the middle, the possibility of normal convection heat exchange from vertical rectangular blade clusters. They looked at several geometric shapes' indents. Following the test investigation, they made the assumption that the indented balances' warmth move rate was higher than that of the unnotched blades.

Wadhah Hussein et.al [19] investigation to look into heat transfer through normal convection in rectangular blade plates with circular holes acting as heat sinks. The initial blade in the example of the apertures had 24 round punctures, and the holes were increased to 8 for each balance, reaching 56 in the fifth balance. They spread the holes throughout four segments and six to fourteen lines. They observed that, with a lesser force of 6 W, the temperature along the non-punctured blades ranged from 30 to 23.70. As the measurement of holes increased, they saw that the temperature loss between the tip and the balance base increased. For non-punctured balances, the temperature dropped from 250 to 49 0C at the highest force of 220 W.

M J sable et.al [20] The focus of their study was on how tall vertical balances limit the improvement of heat exchange due to boundary layer development. They investigated the process of heat exchange enhancement for natural convection near a vertical heated plate with multiple V-shaped partition plates in the surrounding air. They found that the V-shaped partition plates not only acted as extended surfaces but also as flow tabulators. To enhance heat transfer, they attached angular partition plates with upstream-facing edges to the base plates. They observed that when the height of the plate exceeded certain critical values, the heat transfer in the downstream region of the partition plate was enhanced due to the inflow of lower temperature fluid into the separation area. They also found that among the three different blade cluster configurations on the vertical heated plate, the V-shaped balance array design performed better than the rectangular vertical balance array and the V balance array with base spacing design.

Mohamed Najib Bouaziz et al [21] The purpose of this study was to assess the effects of non-rearranged circumstances on the effectiveness of longitudinal balances. To achieve this, a more practical model was developed, taking into consideration the variable profile and temperature-dependent thermo-physical properties in a transient two-dimensional balance with non-uniform heat generation. A distinct exponential limited contrast strategy, which is conditionally stable, was employed to discretize the mathematical equations used in the study. The numerical approach involved solving the nodal temperature distribution based on the type of node, in order to achieve a steady-state heat exchange. Subsequently, numerical simulation was used to demonstrate the sensitivity of several parameters on the effectiveness of the balance. The numerical results were compared to traditional solutions for direct analysis. Extensive numerical investigations were conducted, revealing that temperature-dependent heat transfer coefficient and heat generation lead to a significant reduction in balance effectiveness. The combined effects of parameters in this non-linear problem were not negligible.

Sasikumar and Balaji et al. [22] A one-dimensional balance mathematical statement was solved using a second-order finite difference scheme to analyze a characteristic convection heat exchange and entropy generation from a range of vertical blades positioned on a flat channel, with a turbulent liquid flow inside. The investigation took into account the variation of base temperature along the pipe.

Kundu and Das et al. [23] The temperature profiles of longitudinal balance, spine, and annular blade were analyzed diagnostically using a unified approach with the assistance of the Fresenius growing arrangement. Assumptions regarding the length of bend glorification and protected balance tip condition were relaxed, and a straight range of the convective heat transfer coefficient along the blade surface was taken into account. The thermal performance of all three types of blades was evaluated across a wide range of thermo-geometric parameters. It was observed that the variable heat transfer coefficient had a significant impact on the blade efficiency. In conclusion, a generalized approach was proposed for the optimal design of straight reduction blades. A graphical representation of optimal blade parameters as a function of heat duty was also provided.

Haldar et al. [24] The contribution of balances alone to the overall heat exchange was minimal, but they had a significant impact on the heat exchange from the exposed area of the chamber. Out of the various parameters of the blades, thickness had the most significant influence on heat exchange. In the case of thin balances, there was a specific blade length that maximized the rate of heat exchange. The optimal number and dimensionless length of the balances were determined to be 6 and 0.2 respectively, when the balance thickness was 0.01.

Dibakar Rakshit and Balaji et al. [25] The investigation involved examining the conjugate convection occurring in a finned channel, where vertical rectangular balances were installed on the exterior of the channel. The mathematical model used to analyze the flow was a two-dimensional, steady, incompressible, and laminar flow with consistent properties for the fluid outside the channel. On the other hand, the flow inside the channel was assumed to be turbulent, with limited convection as the heat transfer mechanism.

Haw-Long Lee et al [26] The study addressed the challenge of determining the hidden heat flow on a pin fin base using the conjugate gradient method. Prior information on the nature of the hidden quantity was not necessary for the evaluation process. The accuracy of the reverse analysis was verified by comparing actual and predicted temperature values at various points on the pin fin. The numerical findings indicated that accurate heat flow estimates were obtained for all experiments. Additionally, this approach was utilized to calculate the heat flow acting on an internal surface where direct measurements were not feasible.

Inmaculada Arauzo et al [27] The development of a fundamental scientific methodology for the presumed arrangement of the semi one-dimensional heat conduction equation (a generalized Bessel function) governing the temperature variation in annular blades of hyperbolic profile was a significant achievement. This particular shape was crucial due to its heat transfer performance being comparable to that of the annular blade of elevated parabolic profile, known as the ideal annular blade capable of maximizing heat transfer for a given volume of material. The key feature of the analytical approach developed in this study was that for practical combinations of the extended BIOT number and the normalized radii ratio, the truncated power series solutions involving a moderate number of terms yielded excellent results of high quality. The analytical findings were conveniently presented in terms of the two primary quantities of interest in thermal design applications, namely the heat transfer rates and the tip temperature.

Conclusion

After conducting an extensive analysis of the aforementioned papers, it becomes evident that all efforts aim to improve the heat transfer rate through the utilization of heat sinks by increasing the surface area. Numerous studies have been conducted to explore the design, configuration, and material of fins, as well as their performance under various conditions.

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