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Design and Thermal Analysis for Discontinuous Heat Sink in CPU of Computer

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ABSTRACT

In the present work the experimental and analytical studies were performed in order to optimize geometrical fin parameters for natural convective heat transfer from continuous and discontinuous heat sink installed at North Bridge and at CPU main processor in computer system and discontinuous heat sink proposed for geometrical and cost effective material optimization.

It has been observed that the interrupted fins exhibit a thermal boundary layer interruption which helps increase the heat transfer rate. The study aspires to deal with shortcoming by investigating the effect of fin interruption on the efficiency with which the heat is transferred from the heat sink to the environment. In addition fin interruption leads to noteworthy weight reduction which can lower the manufacturing costs. In contrast adding up interruptions that reduce the heat transfer rate which decrease the total heat transfer rate from the surface area. These two opposing effects clearly indicate that an optimum fin interruption provide the maximum heat transfer rate from naturally cooled heat sink.

To summarize the discontinuous heat sink has better performance and heat dissipation from the heating zone in the computer mother board. It is seen from the above analysis that only central processing unit and north bridge heat sink is generating high temperature and also central processing unit contain fan for forcing air on the heat sink connected through it. But on the North Bridge and South Bridge does not have any fan for force cooling because maximum temperature generate only on CPU socket.

Keywords: Heat sink, Interrupted Fins, Natural Convection, North Bridge etc.

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.

A heat sink is a device that absorbs heat generated on the processor of a computer system and dissipates it into the atmosphere by forced convection process to protect processor from excess amount of temperature. According to the configuration of heat sink, it is classified as follows:

- rectangular channel type heat sink
- circular fin shaped heat sink
- zigzag type heat sink
- stamped shaped heat sink
- annular fin shaped heat sink

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, depending on the application. Natural convective heat transfer from vertical rectangular fins is illustrated in Figure.

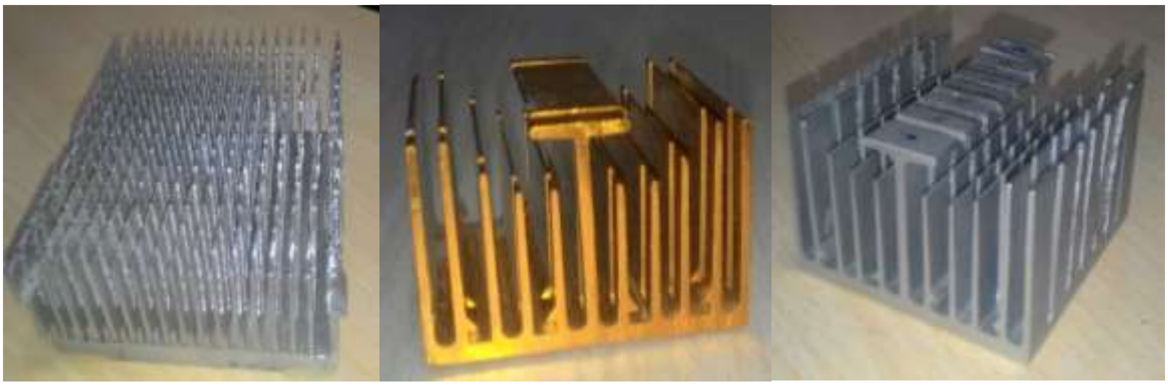


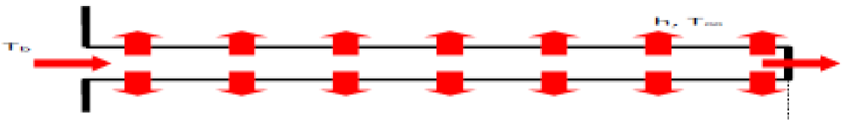
Fig. Different types of fins

Heat transfer from finned surfaces

From the Newton's law of cooling, Q•conv = h A (Ts -T∞), the rate of convective heat transfer from a surface at a temperature Ts can be increased by two methods:

Increasing the convective heat transfer coefficient, h

Increasing the surface area A.



Fin efficiency expressed by:

$$\eta_{fin} = \frac{\dot{Q}_{fin}}{\dot{Q}_{fin,max}} = \frac{\text{actual heat transfer rate from the fin}}{\text{ideal heat transfer rate from the fin (if the entire fin were at base temperature)}}$$

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.

The objectives of the current study include:

1. Predicting the heat transfer rate from the current computer system design.

2. Assessing the heat transfer rate in a non-continuous heat sink at the Northbridge.

3. Evaluating the heat transfer rate for different materials such as copper, along with a new heat sink design.

4. Optimizing the heat sink design based on heat transfer rate.

5. Maximizing the heat transfer rate from both the CPU heat sink and Northbridge heat sink.

6. Designing a cost-effective heat sink with maximum heat transfer efficiency.

Research Methodology

Experimental data was collected through thermocouple readings, as illustrated in the figure, with the system reaching the desired temperature within approximately 30 minutes of operation. In the case of continuous fins, the heat sink's heating initiates the movement of surrounding air due to buoyancy forces, leading to the development of thermal boundary layers at the bottom edges of adjacent fins. These boundary layers eventually merge if the fins are long enough, resulting in a fully developed airflow. On the other hand, discontinuous fins disrupt the growth of thermal boundary layers, maintaining a thermally developing flow region that ultimately leads to a higher natural heat transfer coefficient, as depicted in Figure.

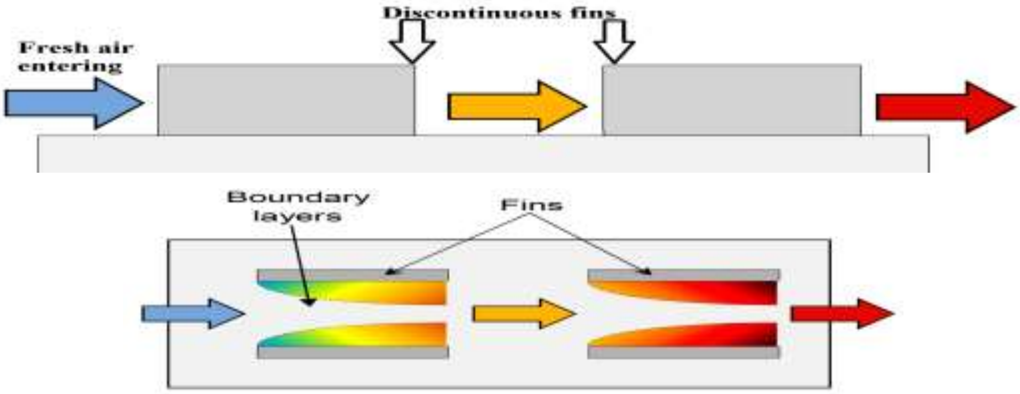


Fig. Heat transfer coefficient

Boundary condition

1. Based on the experimental data, it is evident that the maximum temperature at the lower end of the north bridge heat sink is 100°C or 373.15 K. Therefore, the applied temperature at the bottom end of the heat sink is 100°C or 373.15 K.

2. The entire system is enclosed within a metallic cabinet, and the airflow inside this cabinet is approximately at room temperature. Consequently, the convective coefficient value ranges between 10 to 100. For this particular study, the convective coefficient is assumed to be 25.

3. The maximum time required for the temperature to reach this level is determined to be 1800 seconds based on experimental observations.

4. The Mechanical APDL solver is utilized for the Finite Element Method analysis in this study.

Cad modeling

In the current study, the CAD model is developed using ANSYS Workbench modeling tools to create the geometry of the part or assembly for FEA analysis. Specifically, the CAD geometry of a continuous heat sink is generated directly on the ANSYS workbench due to its relatively simple geometry. Both the Northbridge and CPU heat sinks are designed using the engineering geometry tool within ANSYS workbench.

Result and discussion

Thermal analysis of various heat sinks

1. Thermal analysis for continuous north bridge heat sink of processor:

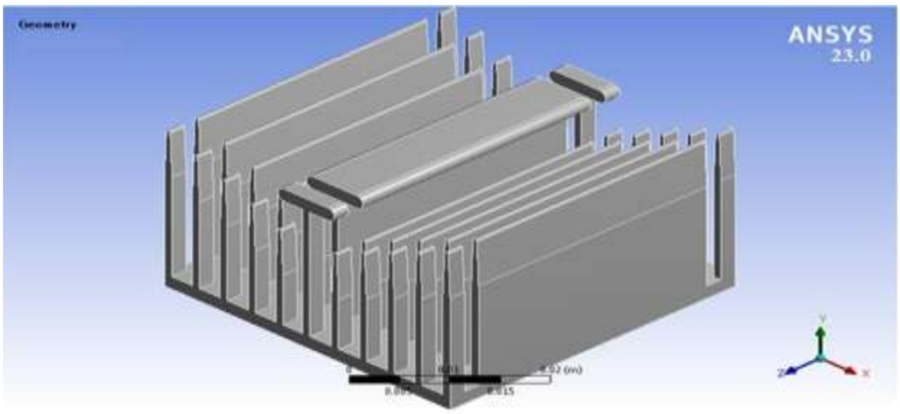


Fig. CAD geometry of north bridge continuous heat sink

Defining material properties: Before proceeding with any analysis, it is crucial to define the material properties. These properties serve as the foundation for further analysis. In the ANSYS environment, there is a vast selection of materials available. However, if the required material is not found in the ANSYS directory, it is possible to create a new material directory to meet specific requirements. In the current project, aluminum has been chosen as the material for the north bridge heat sink.

The result indicates the temperature distribution of north bridge continuous heat sink the maximum temperature is 373.15 K and minimum temperature is 344.15 K

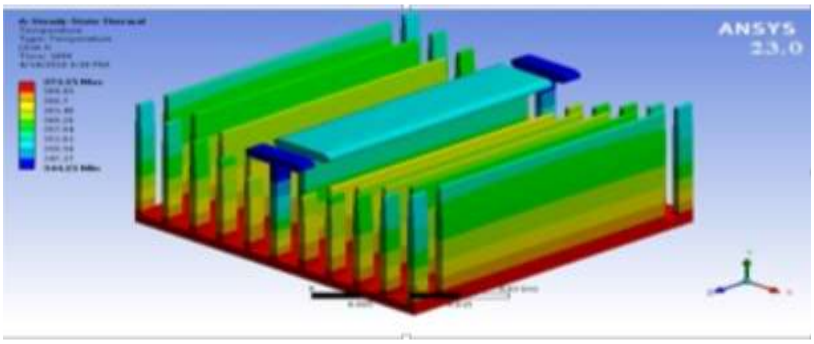


Fig. Temperature distribution of north bridge continuous heat sink

2. Thermal analysis for discontinuous north bridge heat sink:

The ANSYS workbench is used to create the CAD geometry of the discontinuous heat sink. The geometry of the heat sink is not overly complex, which is why the engineering geometry tool available in ANSYS workbench is used to create the heat sink for both the Northbridge and CPU. For the construction of the geometry, the length and width of the North Bridge heat sink are set at 90 mm x 63 mm, with a maximum height of 33 mm. The North Bridge consists of a total of 17 walls, each with different heights, and there is a 2 mm gap between each consecutive wall. To create the interrupted heat sink, a total of 10 divisions are made with a 2 mm gap between them.

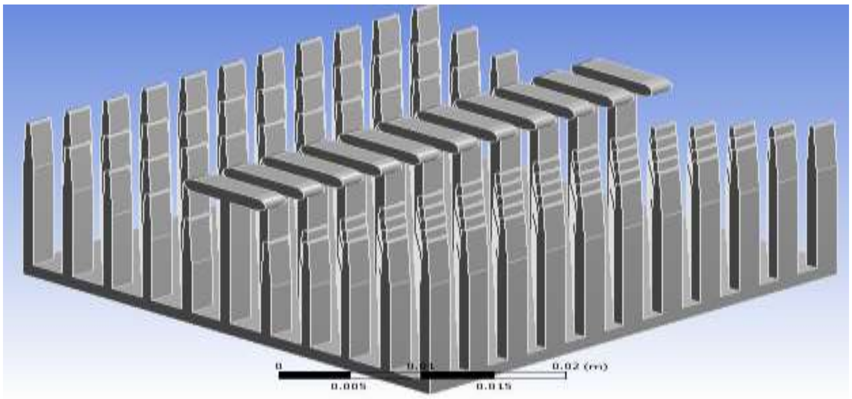


Fig. CAD geometry of the discontinuous heat sink

The result indicates the temperature distribution of north bridge discontinuous heat sink the maximum temperature is 375.55 K and minimum temperature is 341.15

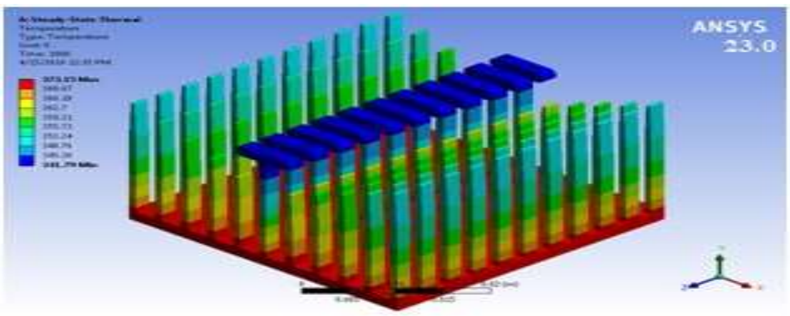


Fig. Temperature distribution of north bridge discontinuous heat sink

3. Thermal analysis for continuous heat sink of central processing unit:

The ANSYS workbench is used to create the CAD geometry of the continuous heat sink. The geometry of the heat sink for the North Bridge and CPU is not complex, so the engineering geometry tool in ANSYS workbench is used for their creation. The dimensions for the CPU heat sink are 90 mm x 63 mm for length and width, with a maximum height of 33 mm. The CPU has a total of 17 walls with varying heights, and there is a 2 mm gap between each consecutive wall. To create the interrupted heat sink, a total of 10 divisions are made with a 2 mm gap. Figure No. 5.13 shows a three-dimensional view of the CPU heat sink.

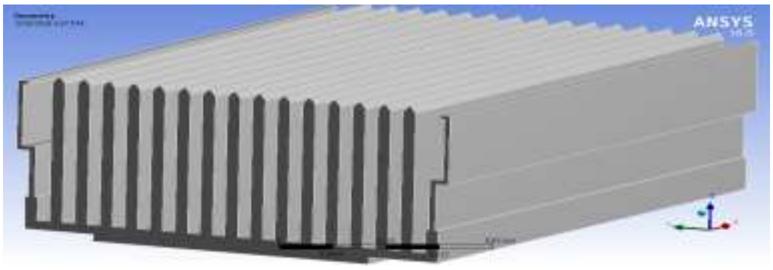


Fig. CAD geometry of Continuous heat sink of central processing unit

The results indicate the temperature distribution of central processing unit continuous heat sink the maximum temperature is 75.924 K and minimum temperature is 70.36 K.

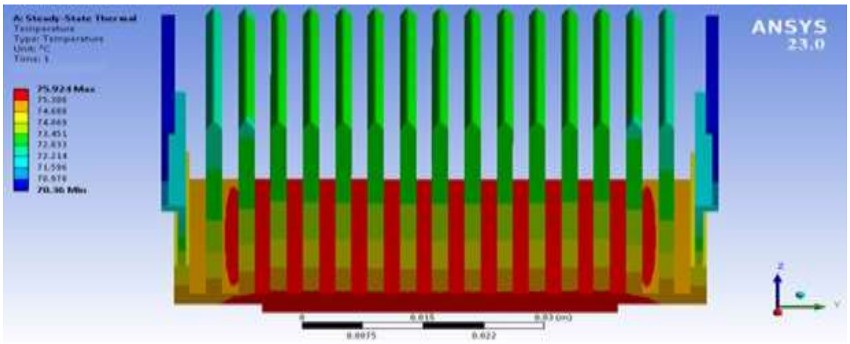


Fig. Temperature distribution of Continuous heat sink of central processing unit

4. Proposed new material as copper for north bridge continuous heat sink:

The Copper material has been utilized for the CAD geometry of the North Bridge continuous heat sink, which was created directly on the ANSYS workbench due to its relatively simple geometry. The engineering geometry tool within ANSYS workbench was instrumental in constructing both the North Bridge and CPU heat sinks. The dimensions of the CPU heat sink include a length and width of 90 mm x 63 mm, a maximum height of 33 mm, a total of 17 walls with varying heights, and a 2 mm gap between each wall. Additionally, the interrupted heat sink was created with a total of 10 divisions, each with a 2 mm gap. Figure No. 5.23 displays a three-dimensional view of the North Bridge heat sink.

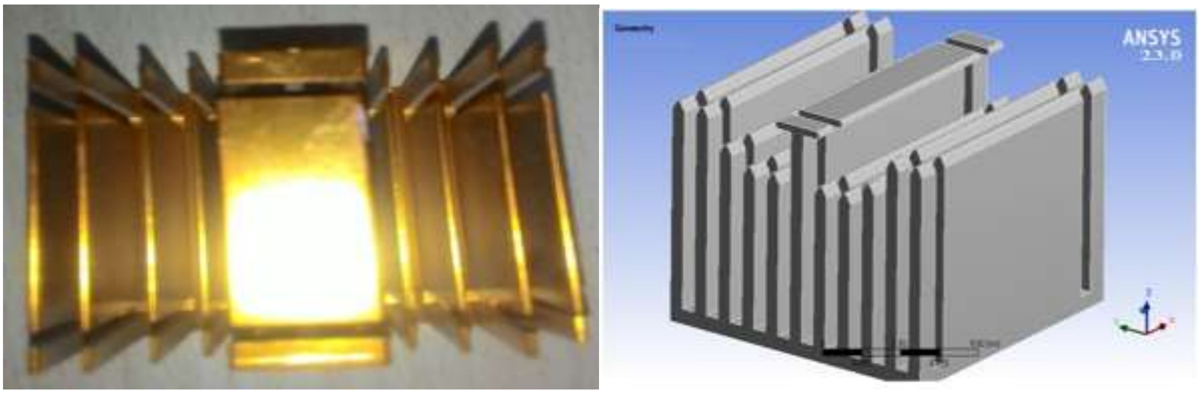


Fig. CAD and Original geometry of Copper as a new material for north bridge continuous heat sink

The above result indicates the temperature distribution of Copper made North Bridge continuous heat sink the maximum temperature is 85.003 K and minimum temperature is 83.267 K.

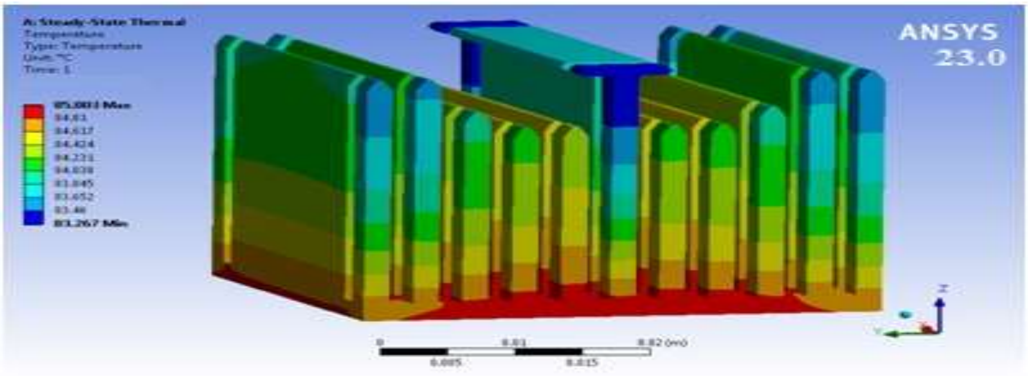


Fig. Temperature distribution of Copper as a new material for north bridge continuous heat sink

5. Thermal analysis of central processing unit circular heat sink:

The ANSYS workbench is used to create the CAD geometry of the circular heat sink for the central processing unit. The geometry of the heat sink is not overly complex, which is why the engineering geometry tool in ANSYS workbench is sufficient for creating the heat sink for both the North Bridge and CPU. The diameter of the central processing unit heat sink is set at 40 mm, with a maximum height of 33 mm. The heat sink for the CPU consists of fins with varying heights, and there is a 0.5 mm gap between each consecutive wall.

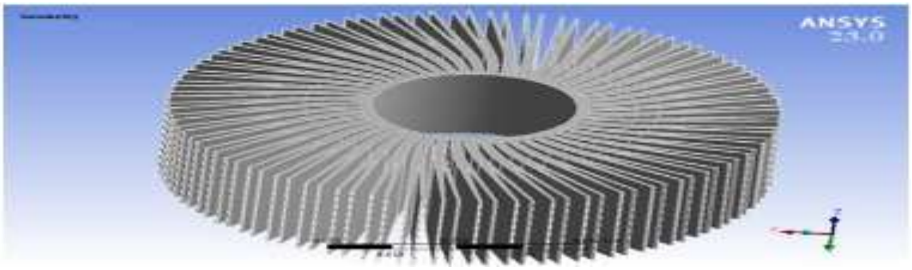


Fig. CAD geometry of circular fin for CPU heat sink

The above result (Figure No. 5.35) indicates the temperature distribution of circular fin for CPU heat sink the maximum temperature is 371.01 K and minimum temperature is 369.2 K.

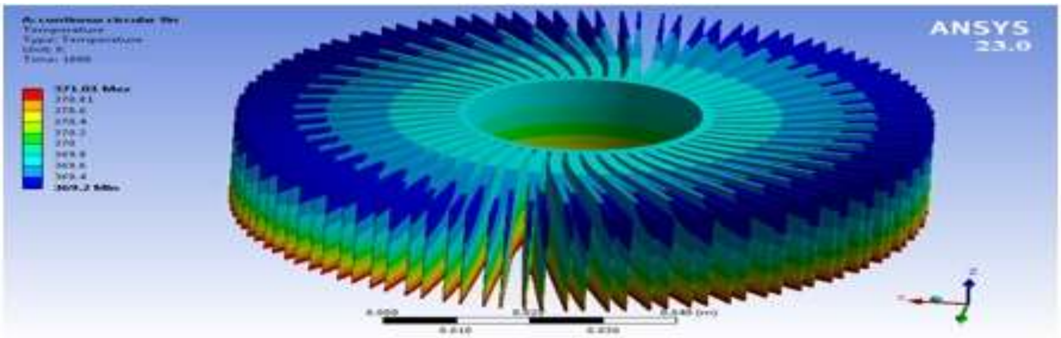


Fig. Temperature distribution of circular fin for CPU heat sink

Validation

In validation, we compare analytical value to experimental value of different heat sink and show the variation our different parameters.

Heat flux cannot be calculated due to uneven geometry of the heat sink

Formula for heat flux

$$q = k \times A\left(\frac{T_{hot} - T_{cold}}{t}\right)$$

Where

K= thermal conductivity of material (237.5 w/mk)

A= cross sectional area (L x W) m2

Thot = maximum temperature at bottom end of heat sink in degree Kelvin

Tcold = atmospheric temperature in degree Kelvin

t = thickness of heat sink in meter

Table: Thermal Analysis of Al North Bridge Continuous Heat Sink

Parameters		Experimental Reading	Analytical Reading
Temperature Distribution (K)	Max.	373.15	373.15
	Min.	339.15	344.15

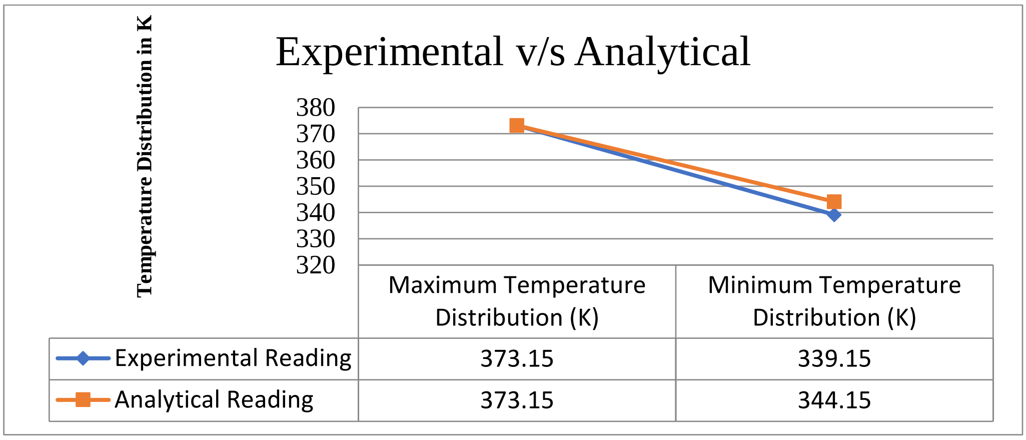


Fig. Comparison between Temperature distribution experimental & Analytical values in North Bridge Continuous heat sink

Table and Figure display the variation in temperature distribution (K) between experimental and analytical readings in the north bridge continuous heat sink. The data illustrates that while the maximum temperature distributions are identical in both cases, there is a variance of 4K in the minimum temperature distribution.

Table: Thermal Analysis of Al North Bridge Discontinuous Heat Sink

Parameters		Experimental Reading	Analytical Reading
Temperature Distribution (K)	Max.	373.15	375.55
	Min.	335.15	341.15

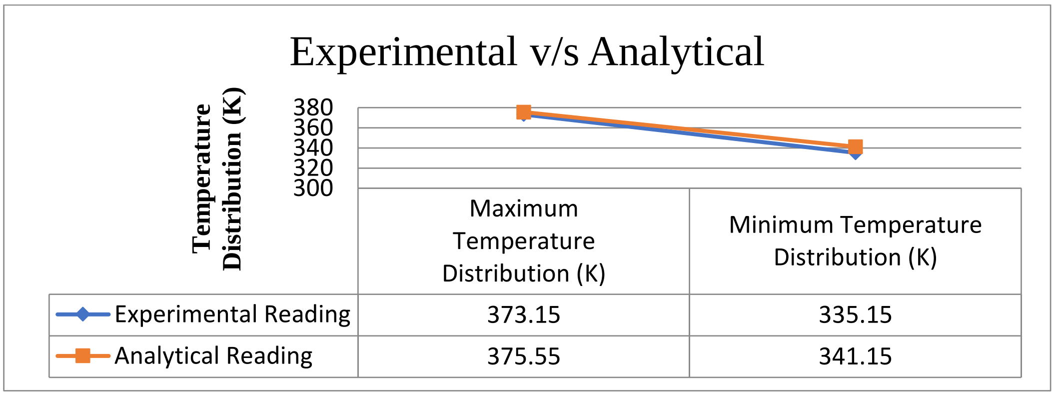


Fig. Comparison between Temperature distribution experimental & Analytical values in North Bridge discontinuous heat sink

Table and Figure present the variation in temperature distribution (K) for both experimental and analytical readings in the north bridge discontinuous heat sink. The graphical representation and tabular data illustrate a difference of 2.4K in the maximum temperature distributions and a difference of 6K in the minimum temperature distribution.

Table: Thermal Analysis of Al Central Processing Unit Continuous Heat Sink

Parameters		Experimental Reading	Analytical Reading
Temperature Distribution (K)	Max.	81	75.924
	Min.	73	70.36

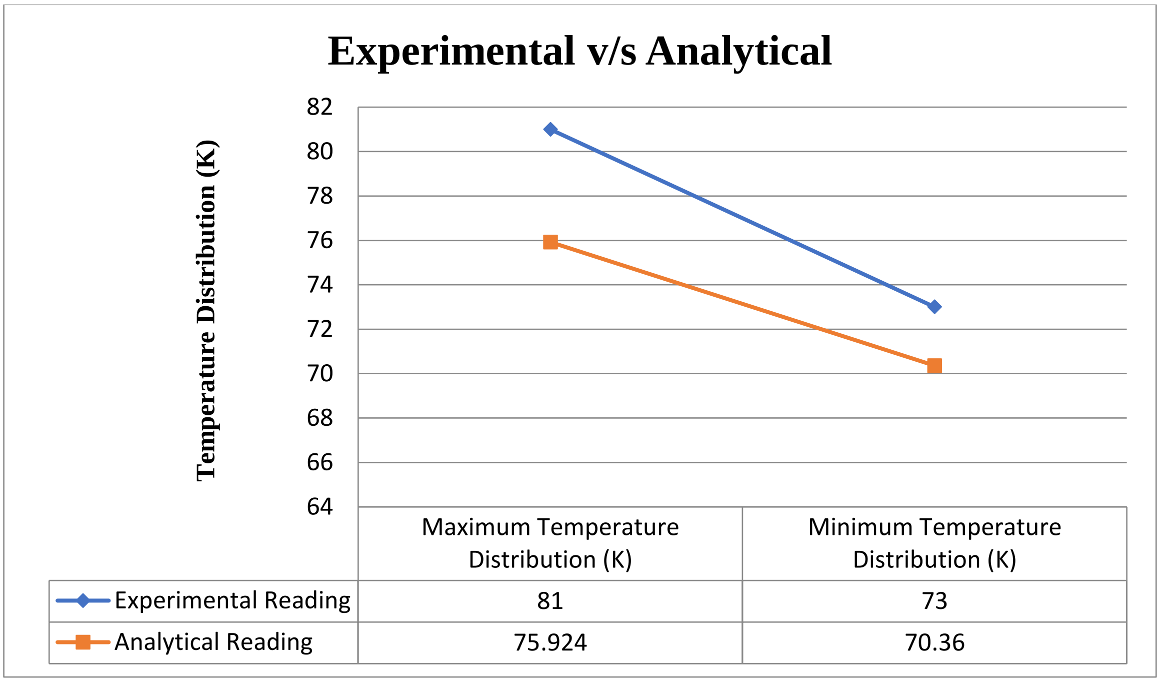


Figure: Comparison between Temperature distribution experimental & Analytical values in Central Processing Unit continuous heat sink

Table and Figure display the variation in temperature distribution (K) between experimental and analytical readings in the continuous heat sink of the Central Processing Unit. The data presented reveals a 5.076K variance in maximum temperature distributions and a 3.36K difference in minimum temperature distribution.

Table: Thermal Analysis of Al Central Processing Unit Discontinuous Heat Sink

Parameters		Experimental Reading	Analytical Reading
Temperature Distribution (K)	Max.	70	73.879
	Min.	54	56.804

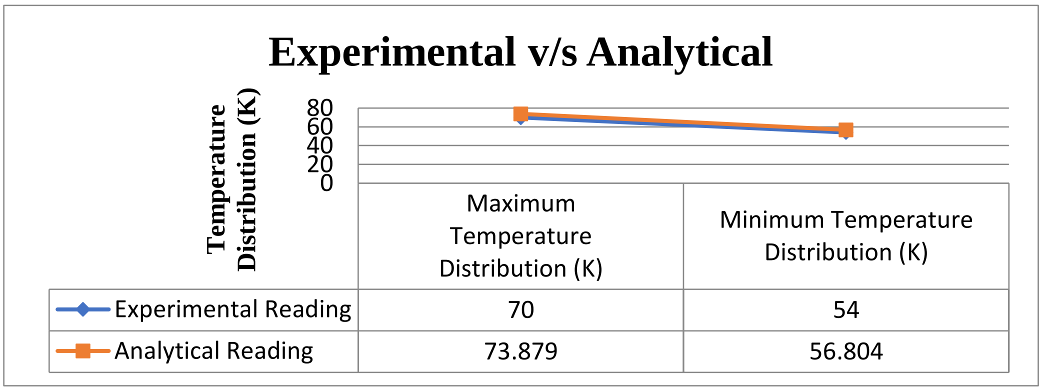


Fig. Comparison between Temperature distribution experimental & Analytical values in Central Processing Unit discontinuous heat sink

Table and Figure display the fluctuation in temperature distribution (K) between the experimental and analytical data for the discontinuous heat sink in the Central Processing Unit. The data reveals a discrepancy of 3.879K in the maximum temperature distributions and 2.804K in the minimum temperature distribution.

Conclusion

Experimental and analytical investigations were conducted to enhance the geometrical fin characteristics for improving natural convective heat transfer from continuous fins integrated into our computer system and the proposed discontinuous fin for efficient material optimization. The subsequent key findings have been summarized in definitive statements.

1. Discontinuous fins are more effective in maximizing total natural convective heat transfer compared to continuous fins.

2. The proposed fin's cost-effectiveness is attributed to its discontinuous geometry in contrast to continuous fins.

3. While all types of fin designs experience maximum temperature development, discontinuous fins exhibit significantly lower temperatures.

4. In this study, both rectangular and circular CPU heat sinks were analyzed for thermal performance. The discontinuous heat sink design, particularly in the rectangular shape, demonstrated superior heat convection from the CPU. 5. The circular CPU heat sink design is deemed safe, with temperature generation not reaching critical levels during thermal analysis, ensuring the safety and stability of the CPU heat sink design.

Future scope

The current project focuses solely on redesigning the north bridge heat sink, but in the future, the south bridge may also be taken into consideration for redesign, along with the CPU heat sink. There are potential future aspects that could be explored for further development.

1. The present work allows for the performance of transient thermal analysis on various types of heat sinks.

2. To gain insight into the airflow around the computer system's motherboard, CFD analysis can also be conducted.

3. In addition to aluminum and copper, there may be alternative materials suitable for heat sinks in computer motherboards.

4. By altering the size of the heat sink, one can evaluate its thermal properties.

5. It is conceivable that heat sinks could be entirely substituted with cooling mediums commonly employed in refrigerators and air-conditioners.

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