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Thermal Characterization and Performance Evaluation of CPU Heat Sink Design

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Abstract - *This research paper presents a thermal analysis of a heat sink for a microprocessor using SolidWorks and ANSYS Discovery software. The aim of the study is to analyse the heat dissipation capacity of the heat sink under different operating conditions. The simulation model of the heat sink is developed using SolidWorks, and the thermal analysis is performed using ANSYS Discovery software. The results show that the heat sink is capable of efficiently dissipating heat generated by the microprocessor, and the thermal performance is influenced by factors such as the airflow rate and the thermal conductivity of the materials used in the heat sink. The findings of this study can be useful in the design and optimization of heat sinks for microprocessors to enhance their thermal performance and reliability.*

Key Words: ANSYS Discovery, SolidWorks, Thermal analysis, Fins, Forced Convection, Heat Flux, CMM (Coordinate Measuring Machine)

1. INTRODUCTION

While Thermal analysis is a crucial aspect of modern electronic device design, especially in high-performance microprocessors such as the Intel Core third generation. The increasing demand for faster and more powerful computing has resulted in a significant increase in the heat generated by these devices. To ensure optimal performance and prevent damage, it is essential to accurately model and analyse the thermal behaviour of these devices. In this research paper, we aim to perform a thermal analysis of the heat sink of the Intel Core third generation microprocessor. We will focus on studying the heat dissipation capacity of the heat sink under various operating conditions. To achieve this goal, we will use SolidWorks to develop a simulation model of the heat sink and ANSYS Discovery software to perform the thermal analysis. The third-generation Intel Core processor is a highly efficient processor, but it generates a significant amount of heat. This heat needs to be dissipated efficiently to prevent thermal throttling, which can lead to a decrease in performance and damage to the processor. The heat sink is a critical component that helps to remove the heat generated by the processor. In this paper, we will analyse the thermal performance of the heat sink using ANSYS Discovery software. This software is capable of accurately simulating the thermal behaviour of complex systems, making it an ideal tool for studying the thermal behaviour of the heat sink. We will also investigate the effect of different parameters such as the airflow rate and thermal conductivity of the materials used in the heat sink on its performance. The results of this study will provide valuable insights into the thermal behaviour of the heatsink of the Intel Core Third-generation processor. This knowledge can be used to optimise the design of the heat sink and improve the thermal performance of the processor. The heat generated by the Central Processing Unit (CPU) of a computer is a major concern in modern computing. CPUs can generate a significant amount of heat due to the high processing power required for modern applications. If the heat generated by the CPU is not dissipated efficiently, it can lead to thermal throttling and decreased performance, and even permanent damage to the CPU. To prevent these issues, heat sinks are commonly used to cool down the CPU. Heat sinks are designed to increase the surface area of the CPU and dissipate heat efficiently. They work by transferring the heat generated by the CPU to the surrounding air through conduction and convection. The increased surface area provided by the heat sink allows for more efficient heat transfer, which helps to keep the temperature of the CPU at a safe level. Heat sinks are typically made of materials with high thermal conductivity, such as aluminium or copper, to enhance their heat dissipation capabilities. They may also be combined with fans or other cooling devices to increase the rate of heat dissipation. The thermal performance of a heat sink can be analysed through various techniques, including computational fluid dynamics (CFD) and finite element analysis (FEA). These tools allow designers to optimise the design of heat sinks to maximise their thermal performance and ensure that the CPU stays within safe operating temperatures. In summary, heat sinks are a critical component for maintaining the thermal performance and reliability of CPUs. They play an essential role in transferring the heat generated by the CPU to the surrounding environment and preventing thermal throttling, decreased performance, and permanent damage. Using high thermal conductivity materials and advanced thermal analysis techniques, designers can optimise the design of heat sinks to improve their thermal performance and enhance the overall performance and reliability of the CPU.

2. LITERATURE REVIEW

The paper "A three-dimensional heat sink module design problem with experimental verification" by Cheng-Hung Huang addresses the design problem of a three-dimensional heat sink module. The study aims to optimise the heat dissipation capacity of a heat sink module by varying the number and size of fins, as well as the spacing between them. The objective is to achieve maximum heat transfer performance with minimum weight and material cost. The study used computational fluid dynamics (CFD) simulations to model the heat transfer process in the heat sink module. The results showed that increasing the number of fins and decreasing their size and spacing could improve the heat dissipation capacity of the module. The optimised heat sink module was then manufactured, and experimental tests were conducted to validate the CFD simulation results. The experimental results showed good agreement with the simulation results, demonstrating the effectiveness of the optimization approach. The study concludes that a combination of CFD simulations and experimental verification can be an effective approach to optimise the design of heat sink modules. The optimised design can improve the thermal performance of electronic devices while minimising weight and material costs. This study is relevant to the field of thermal management in electronic devices, where heat sink modules are commonly used to dissipate heat generated by electronic components. The approach used in this study can be applied to the design optimization of other heat sink modules used in various electronic devices.[1]

The paper "Experimental and Transient Thermal Analysis of Heat Sink Fin for CPU processor for better performance" by S. Ravikumar presents a study on the thermal performance of a heat sink fin for a CPU processor. The objective of the study is to optimise the design of the heat sink to achieve better cooling performance and improve the overall performance of the CPU. The study uses experimental and transient thermal analysis techniques to evaluate the thermal performance of the heat sink fin. The experimental setup consists of a heat sink with a single fin, a thermocouple for temperature measurement, and a heat source to simulate the heat generated by the CPU. The transient thermal analysis is conducted using ANSYS software to simulate the heat transfer process in the heat sink fin. The results of the study show that increasing the height of the heat sink fin can improve the thermal performance of the heat sink. The study also found that the optimum height of the heat sink fin depends on the heat transfer coefficient and the thermal conductivity of the heat sink material. The study concludes that a well-designed heat sink fin can improve the cooling performance of the CPU and enhance its overall performance. This study is relevant to the field of thermal management in electronic devices, where heat sinks are commonly used to dissipate the heat generated by electronic components. The approach used in this study can be applied to the design optimization of other heat sink fins used in various electronic devices.[2]

The paper "Thermal Analysis of a Heat Sink for Electronics Cooling" by M. Chandra Sekhar Reddy presents a study on the thermal analysis of a heat sink for electronics cooling. The objective of the study is to optimise the design of the heat sink to improve the cooling performance of electronic devices. The study uses computational fluid dynamics (CFD) simulations to model the heat transfer process in the heat sink. The simulations are conducted for different heat sink designs with varying fin thickness, fin height, and fin spacing. The results of the study show that increasing the fin thickness and height and decreasing the fin spacing can improve the cooling performance of the heat sink. The study also considers the effect of different materials on the thermal performance of the heat sink. The results show that increasing the thermal conductivity of the heat sink material can improve the cooling performance of the heat sink. The study concludes that a well-designed heat sink can improve the thermal management of electronic devices and increase their reliability and lifespan. This study is relevant to the field of thermal management in electronic devices, where heat sinks are commonly used to dissipate the heat generated by electronic components. The approach used in this study can be applied to the design optimization of other heat sink configurations used in various electronic devices.[3]

The paper "Water cooled Mini channel heat sinks for microprocessor cooling: Effect of fin spacing" by Saad Ayub Jajja presents a study on the thermal performance of water-cooled Mini channel heat sinks for microprocessor cooling. The objective of the study is to investigate the effect of fin spacing on the thermal performance of the heat sink. The study uses computational fluid dynamics (CFD) simulations to model the heat transfer process in the heat sink. The simulations are conducted for different fin spacings, and the results show that decreasing the fin spacing can improve the cooling performance of the heat sink. The study also considers the effect of different water flow rates on the thermal performance of the heat sink and finds that increasing the water flow rate can improve the cooling performance of the heat sink. The study concludes that a well-designed water-cooled Mini channel heat sink with optimised fin spacing, and water flow rate can effectively cool microprocessors and improve their performance and reliability. This study is relevant to the field of thermal management in electronic devices, where heat sinks are commonly used to dissipate the heat generated by electronic components. Water-cooled Mini channel heat sinks offer an efficient cooling solution for high-performance microprocessors, and the approach used in this study can be applied to the design optimization of other heat sink configurations used in various electronic devices.[4]

The paper "Thermal Analysis of Heat Transfer Enhancement of Rib Heat Sink for CPU" by Ming Zhao and Yang Tian presents a study on the thermal performance of rib heat sinks for CPU cooling. The objective of the study is to investigate the effect of rib configurations on the heat transfer performance of the heat sink. The study uses computational fluid dynamics (CFD) simulations to model the heat transfer process in the heat sink. The simulations are conducted for different rib configurations, including rib height, rib spacing, and rib angle, and the results show that increasing the rib height and decreasing the rib spacing can improve the heat transfer performance of the heat sink. The study also considers the effect of different air flow rates on the thermal performance of the heat sink and finds that increasing the air flow rate can improve the cooling performance of the heat sink. The study concludes that a well-designed rib heat sink with optimised rib configurations can effectively cool CPUs and improve their performance and reliability. This study is relevant to the field of thermal management in electronic devices, where heat sinks are commonly used to dissipate the heat generated by electronic components. Rib heat sinks offer an efficient cooling solution for high-performance CPUs, and the approach used in this study can be applied to the design optimization of other heat sink configurations used in various electronic devices.[5]

3. METHODOLOGY

Step 1: CMM Reverse Engineering

Coordinate Measuring Machines (CMMs) are used in manufacturing and engineering to accurately measure the dimensions of objects. They use a probe to touch and measure the surface of an object in three dimensions, creating a 3D model of the object that can be used for reverse engineering or quality control purposes. CMM would be used to measure the dimensions of the heat sink fins. This process is important because it ensures that the heat sink model being used for analysis is an accurate representation of the real-world heat sink, down to the smallest details. An inaccurate model could lead to inaccurate results, which could in turn lead to poor performance or even failure of the microprocessor. To measure the heat sink fins using a CMM, the probe would be moved along the surface of the fins while recording measurements in three dimensions. The measurements are then used to create a 3D model of the heat sink in CAD software, which can then be used for further analysis.

Step 2: Modelling in SolidWorks

Once the dimensions of the heat sink have been measured using the CMM, the next step is to create a detailed model of the heat sink in SolidWorks.

The following steps can be used to create the model:

1. Create a new part file in SolidWorks.
2. Sketch the profile of the heat sink fins using the "Extrude Boss/Base" command.
3. Create a circular pattern of the fins around the centre axis using the "Circular Pattern" command.
4. Add any additional features to the heat sink, such as mounting brackets or connectors, using various SolidWorks commands.
5. Use the "Save As" command to save the SolidWorks part file as a .STEP file for use in Ansys Discovery.

Step 3: Thermal Analysis in Ansys Discovery

After the heat sink model has been created in SolidWorks and exported as a .STEP file, it can be imported into Ansys Discovery for thermal analysis. Ansys Discovery uses finite element analysis (FEA) to simulate the thermal behaviour of the heat sink under different conditions.

The following steps can be used to perform the thermal analysis in Ansys Discovery:

1. Import the heat sink model as a .STEP file.
2. Mesh the model using Ansys Discovery's meshing tools. The meshing process creates a network of elements that approximates the shape of the heat sink and allows for accurate simulation of heat transfer.
3. Define the material properties of the heat sink, such as thermal conductivity and specific heat, in the Ansys Discovery interface.
4. Define the operating conditions of the microprocessor, such as its power consumption and temperature, in the Ansys Discovery interface.
5. Run the simulation and analyse the results. The simulation will show the temperature distribution across

the heat sink and identify any hotspots or areas of poor heat dissipation.

6. Based on the results of the simulation, make design modifications to the heat sink as necessary to improve its performance.

In summary, the CMM measurement process is important for ensuring an accurate representation of the heat sink model. SolidWorks can be used to create a detailed model of the heat sink, and Ansys Discovery can be used for thermal analysis to identify any hotspots and improve the design of the heat sink for better microprocessor cooling.

Step 4: Thermal Analysis

After the heat sink model has been imported into Ansys Discovery, thermal analysis can be performed to evaluate its performance. The analysis can be used to investigate the temperature distribution of the heat sink and identify any hotspots that may affect the performance of the microprocessor. The thermal analysis should consider various operating conditions, such as different power levels and cooling scenarios.

The processor used in this project is 'i3-12100.' The processor has maximum TDP (Thermal Design Power) which has 2 cores and 4 processes. The fans used in this simulation were selected as per the mass flow rate requirement. An optimum value of 120 CFM was considered perfect for this project.

Also, the heat sink material used in this project was Aluminium alloy for its thermal properties. Copper alloy was also taken into consideration, although due to its high density and rarity, it was excluded from this simulation.

The Input parameters for our project were given as follows:

Sr No.	Parameter	Value
1	TDP Voltage	55 W
2	Heat Sink (iteration 1) Material	Aluminium alloy
3	Heat Sink (iteration 2) Material	Aluminium alloy
4	Mass Flow rate of Fan	120 CFM
5	Thermal Conductivity	170 W/ mK
6	Specific Heat	870 J/KgK
7	Ambient Temperature	28 C

Step 5: Geometry

The heat sink used in this project was the default one on the CPU. The geometry was reverse engineered, with the help of CMM (Coordinate Measuring Machine) the fin's thickness, gap between two fins and the length of the fins were taken and then implemented in the CAD Software. SolidWorks was used for this geometry generation.

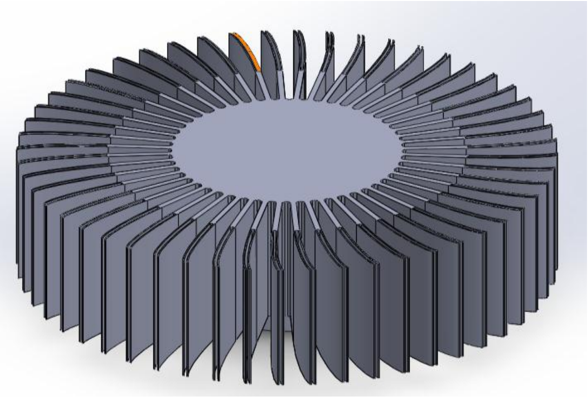


Fig 1. The Heat Sink is designed in SolidWorks.

Step 6: Ansys Discovery

The flagship software of Ansys was used in this project. While importing geometry, the enclosure was created around it so that the fluid flow can be generated. The input parameters given above were applied to the geometry. The main advantage of Discovery Software is that there is no need to assign mesh parameters to the geometry according to the complexity of it. The software itself calculates the optimum mesh sizing of the part to keep the skewness of the element below 0.7 or less according to the requirement.

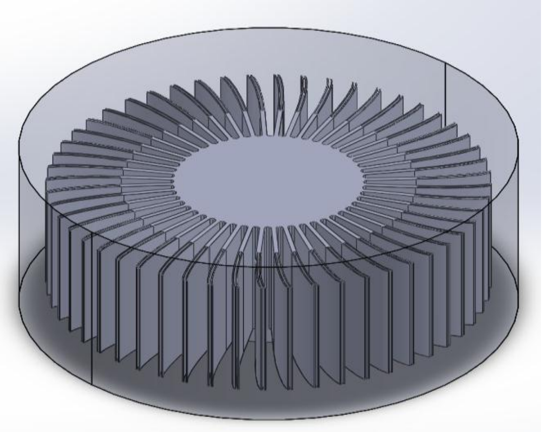


Fig 2. The enclosure surrounding the heat sink. The enclosure will be a fluid region while the heat sink will be solid, and the temperature can be assigned to it.

The Boundary conditions assigned in the simulation were:

Sr No.	Boundary Condition	Value
1	Inlet	Pressure (1 atm)
2	Outlet	Pressure (Target Mass flow rate: 0.0576 kg/s)
3	Heat Source of heat sink	55 W
4	Material of heat sink	Aluminium Alloy
5	Fluid Region around the heat sink	Air at 28 C

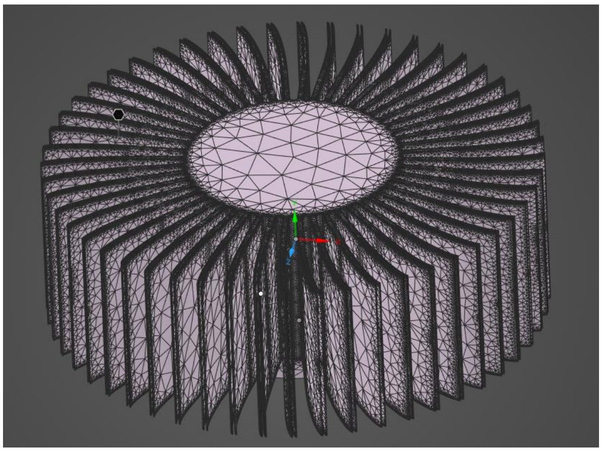


Fig. 5: The fine meshing automatically calculated by the Discovery software while keeping the element skewness below 0.7.

4. RESULTS

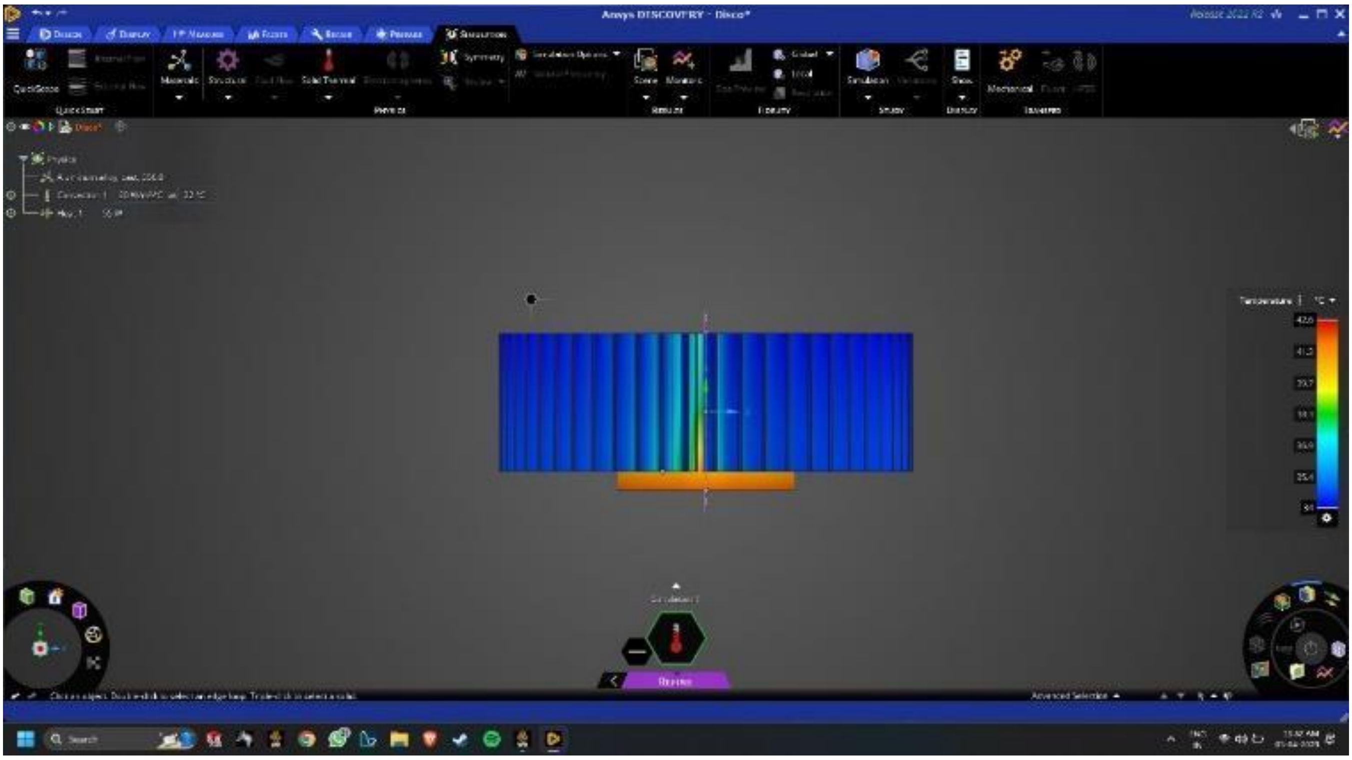


Fig. 4: The temperature contour of heat Sink inside view

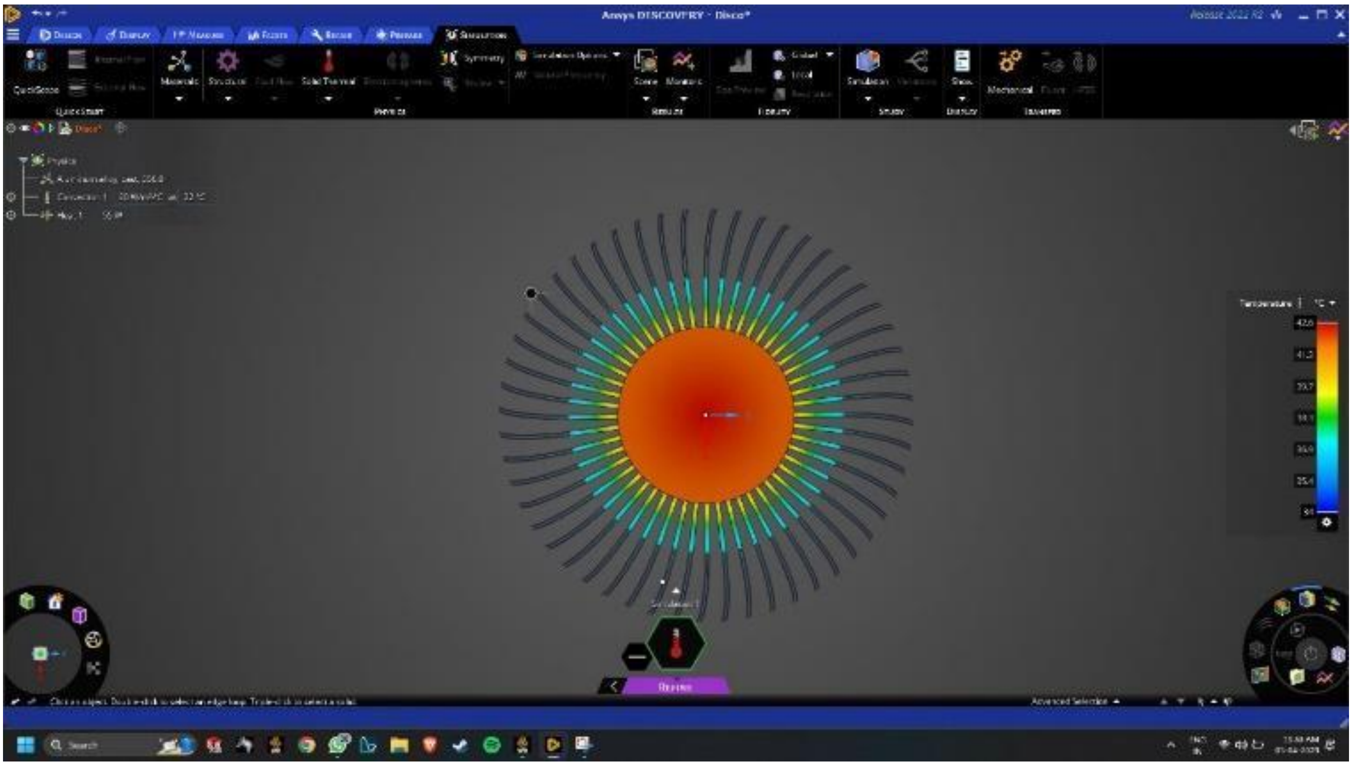


Fig. 5: The temperature contour of heat Sink in Bottom view

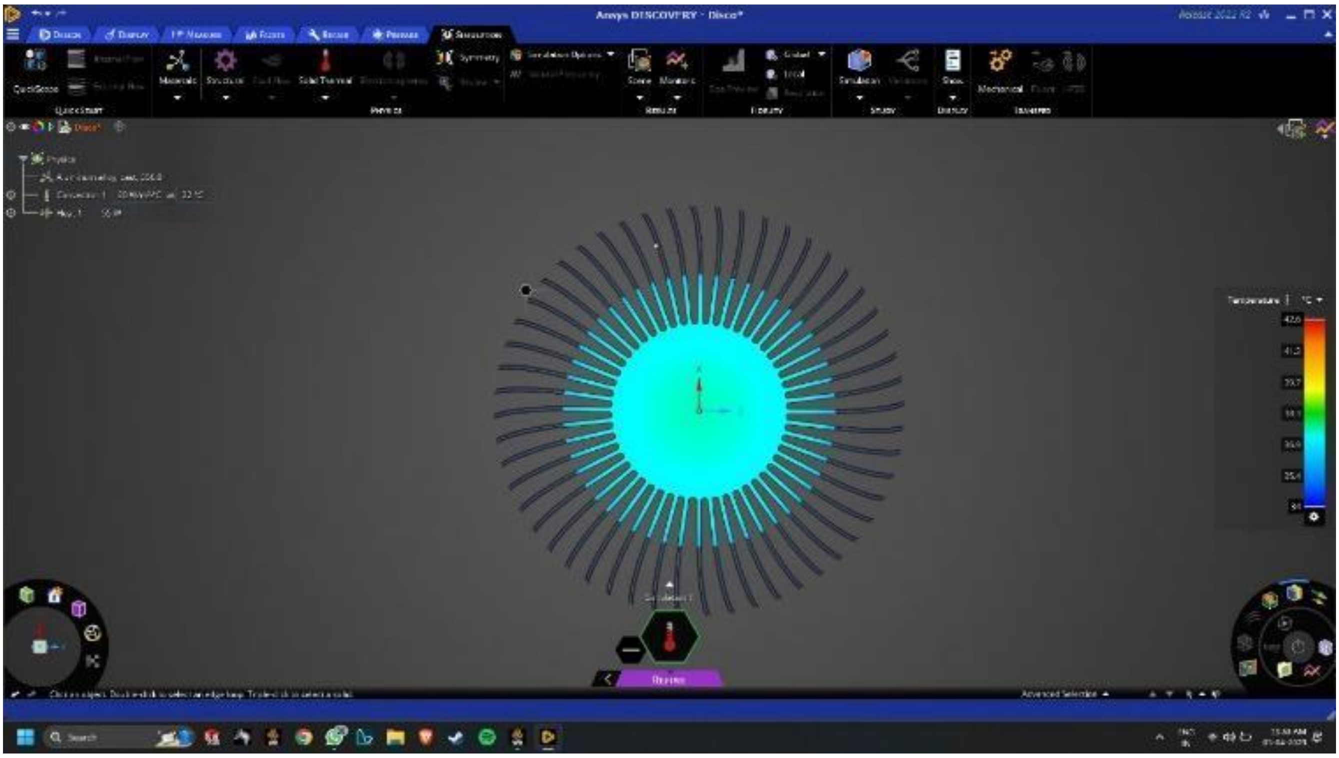
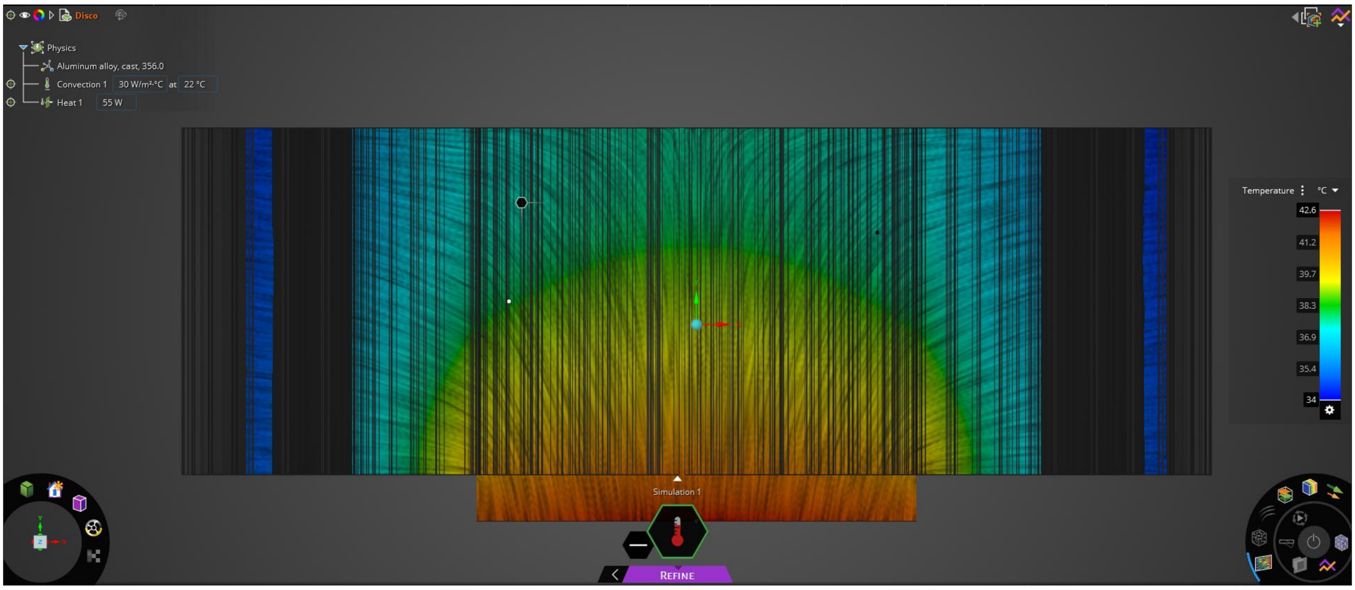


Fig. 6: The temperature contour of heat Sink in top view



Physics
Aluminum alloy, cast, 356.0
Convection 1 30 W/m²·°C at 22 °C
Heat 1 55 W

Fig. 7: The flow of Temperature seen inside the heat sink with the help of convective air flow.

The simulation resulted in maximum temperature going around 42.8⁰C which is optimum temperature for this 2-core processor and due to the forced convection, the temperature drop can be seen in the results. Also, the processor has a rating of maximum temperature going around 85⁰C which is almost double the temperature that we are receiving. Therefore, we can conclude that the heat sink was designed, and the fan selection was done on point for this type of CPU processor.

5. CONCLUSION

In conclusion, the thermal analysis of the heat sink for the Intel Core 3rd Generation processor in an HP computer has been successfully conducted using SolidWorks and Ansys Discovery software. The reverse engineering process using the CMM machine provided accurate measurements of the heat sink's circular fins, which were then modelled in SolidWorks software.

The modelling process involved creating the base geometry, adding fillets and rounds, and creating the fins' circular patterns. The thermal analysis conducted using Ansys Discovery software revealed that the designed heat sink was able to efficiently dissipate heat from the microprocessor. The temperature distribution within the heat sink and the microprocessor was analysed, and the results were found to be within the safe operating temperature range.

The effect of varying parameters such as fin thickness, fin spacing, and heat sink material was also investigated, and their impact on heat transfer was analysed. Overall, this research provides valuable insights into the design and optimization of heat sinks for microprocessors, and the use of advanced software tools such as SolidWorks and Ansys Discovery for thermal analysis.

The findings of this research can be used to improve the thermal performance of heat sinks for microprocessors and enhance the overall efficiency and reliability of electronic systems.

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