UNIVERSITI MALAYSIA KELANTAN

A STUDY OF THERMAL PERFORMANCE ON HEAT EXISTING FOR BUS DUCT PASSIVE COOLING

MUHAMMAD NAZRAN ADLI BIN YAHYA

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DECLARATION

I declare that this thesis " A Study Of Thermal Performance On Heat Existing For Bus Duct Passive Cooling" is the result of my own research except in the references

.

Signature :

Student's Name : Muhammad Nazran Adli Bin Yahya

Date : 15 January 2024

Verified by : DR. MUHAMMAD IQBAL BIN AHMAD

Signature :

Supervisor's Name : DR. MUHAMMAD IQBAL BIN AHMAD

Stamp :

Date : 8 FEBRUARY 2024

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A Study Of Thermal Performance On Heat Existing For Bus Duct Passive Cooling

ABSTRACT

Passive cooling strategies play a vital role in enhancing the thermal performance of bus ducts within industrial environments. This abstract explores the integration of passive cooling techniques to mitigate heat generation in bus ducts, focusing on sustainable and energy-efficient solutions. The abstract delves into design considerations, materials and architectural features employed to optimize passive cooling in bus ducts, ensuring efficient power distribution while minimizing energy consumption and environmental impact. The exploration of passive cooling in bus ducts aligns with contemporary efforts to create more sustainable and resilient industrial electrical. Ansys is a popular engineering simulation software that can be used to analyse and optimize passive cooling strategies in bus ducts. It allows for detailed thermal analysis, convection and radiation analysis, material properties analysis, flow simulation for ventilation systems, and optimizing studies. It can simulate heat transfer, temperature distribution and gradients, allowing engineers to select materials with optimal heat dissipation characteristics and refine bus duct designs based on thermal performance criteria.

KAJIAN PRESTASI TERMA PADA HABA YANG SEDIA ADA UNTUK PENYEJUKAN PASIF SALURAN BAS

ABSTRAK

Strategi penyejukan pasif memainkan peranan penting dalam meningkatkan prestasi haba saluran bas dalam persekitaran industri. Abstrak ini meneroka integrasi teknik penyejukan pasif untuk mengurangkan penjanaan haba dalam saluran bas, memfokuskan pada penyelesaiaan yang mampan dan cekap tenaga. Abstrak menyelidiki pertimbangan reka bentuk bahan dan ciri seni bina yang digunakan untuk mengoptimumkan penyejukan pasif dalam saluran bas, memastikan pengagihan kuasa yang cekap sambil meminimumkan penggunaan tenaga dan kesan alam sekitar. Penerokaan penyejukan pasif dalam saluran bas sejajar dengan usaha kontemporari untuk mencipta elektrik industri yang lebih mampan dan berdaya tahan. Ansys ialah perisian simulasi kejuruteraan popular yang boleh digunakan untuk menganalisis dan mengoptimumkan strategi penyejukan pasif dalam saluran bas. Ia membolehkan analisis haba terperinci, analisis perolakan dan sinaran, analisis sifat bahan, simulasi aliran untuk sistem pengudaraan, dan kajian pengoptimuman. Ia boleh mensimulasikan pemindahan haba, pengagihan suhu dan kecerunan, membolehkan jurutera memilih bahan dengan ciri pelepasan haba yang optimum dan menapis reka bentuk saluran bas berdasarkan kriteria prestasi terma.

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INTRODUCTION

1.1 Background of Study

Bus ducts are enclosed metal conduits used in industries to safely conduct electricity from power distribution equipment to various facilities, ensuring efficient and organized power transmission. The bus duct system's temperature rise is predicted and validated through experimental observations, resulting in 45% reduction in temperature variation and a reduction in heat generation power loss (S. Thirumurugaveerakumar, M Sakthivel, S Rajendran, 2015). Bus duct also has its advantages that should be used in every industry. A busbar is rectangular conductor that supplies power to a load, protected by bus duct for protection from damage and contact with people (Chris Stanfield, Quora, 2016).

The study of passive cooling in bus ducts is a multidisciplinary approach that involves understanding electrical loads and heat generation, analysing material properties, conducting thermal analysis, investigating passive cooling strategies, and optimizing the duct design and layout. Key aspects include understanding electrical loads and heat generation, analysing thermal conductivity, and conducting thermal analysis using computational fluid dynamics software. Passive cooling techniques like natural convection, ventilation design, surface enhancements, and insulation methods are investigated to optimize heat dissipation without relying on active cooling systems. One example I got from International Journal of Thermal Sciences 84, 164-174, introduce perforations through the fin base to improve ventilation with cold air below the fin base (Guei-Jang Huang, Shwin-Chung Wong, Chun-Pei Lin, 2014). We can conclude, the design of heat sink is then refined iteratively based on simulations and experimental validation, ensuring optimal heat transfer. This multidisciplinary approach helps optimize the efficiency of bus ducts and reduce energy consumption.

The study uses theoretical analyses, simulations, experimental testing, and design improvements to develop optimized passive cooling solutions for bus ducts, aiming to ensure efficient heat dissipation, reliability, and industry standard compliance. Bus ducts are crucial for electrical power distribution in industrial settings and large buildings, but their transmission of currents generates significant heat. Computer Fluid Dynamics (CFD) is helpful for understanding the flow physics within the bus duct and provides guidelines for heat dissipation system design (Naveen P.T, 2018). Proper heat management is essential for operational efficiency, prevents overheating, and ensures component longevity. The challenge lies in developing efficient cooling strategies that utilize natural principles of heat transfer, convection, and airflow, thereby achieving optimal heat dissipation without relying on energy-intensive mechanical systems.

Passive cooling in bus ducts can reduces energy consumption, improves electrical component reliability and longevity, offers cost-effectiveness in installation and long-term operation, and aligns with environmental regulations and sustainability goals by reducing energy usage. Then, passive cooling strategies in bus ducts offer a sustainable and efficient method for managing heat generated by electrical currents, utilizing natural airflow and heat dissipation principles to reduce energy consumption.

1.2 Problem Statement

The main challenge for passive cooling in bus ducts is to efficiently manage heat generated by electrical currents without relying on energy-intensive or active cooling systems, primarily requiring optimization of passive cooling methods. Current passive cooling techniques may not effectively transfer heat away from electrical components, leading to temperature spikes and decreased equipment lifespan. Natural convection limitations in ducts, particularly in confined spaces, may also hinder optimal heat dissipation. Material and design constraints in material selection, duct design, and surface area may also hinder heat transfer and convection patterns. Inefficient heat dissipation not only affects equipment performance but also increases energy consumption and environmental concerns, contradicting sustainability goals.

The goal is to enhance the effectiveness and applicability of passive cooling methods by developing novel techniques, enhancing thermal properties, designing systems that maximize natural convection and airflow, and ensuring scalability and adaptability to different applications and technological advancements, thereby improving heat dissipation under varying environmental conditions.

1.2 Objective

The objectives of this study are as follows:

i) To evaluate between thermal experiments and simulations of thermal performances on heat existing for bus duct passive cooling.

ii) To investigate the parameter of during for different thermal on heat exiting for bus duct passive cooling.

1.3 Scope Of Work

Bus ducts are electrical components used to efficiently distribute power within a building or industrial facility. They are typically designed to carry large currents of electricity over long distances and are commonly used in commercial and industrial applications where the power requirements are high. The scope of work of bus ducts can be broken down into several key areas.

Firstly, the design and installation of bus ducts is a critical aspect of their scope of work. This involves determining the correct size and type of bus duct for the specific application, as well as ensuring that it is installed safely and correctly. A thermal model is developed for the bus bar system to predict temperature variation and calculate the steady-state and transient electrical current carrying capacity (M.Sakthivel, November 2014). This requires a thorough understanding of electrical engineering principles and the ability to read and interpret electrical drawings.

Bus ducts are critical components of the electrical power system that are used to distribute power efficiently within a building or industrial facility. As such, they require a high level of expertise and skill to design, install, maintain and service. (Current Midwest, 2024). For a final year project, the scope of work for bus ducts can be quite extensive, but some of the key areas of focus include:

Design and Installation: The design and installation of bus ducts require careful planning and execution to ensure that they meet the specific power requirements of the facility. This involves determining the optimal placement of the bus ducts, selecting the appropriate size and type of bus duct, and calculating the necessary electrical loads and voltages.

In conclusion, bus ducts are critical components of the electrical power system that require a high level of expertise and skill to handle. For a final year project, the scope of work for bus ducts can be quite extensive, covering areas such as design and installation, maintenance and servicing, safety features and protection mechanisms, and monitoring and control. By focusing on these key areas, students can gain a deeper understanding of the intricacies involved in managing bus ducts and develop the necessary skills to handle these critical components.

1.5 Significances of Study

Passive cooling is a method that effectively dissipates heat without consuming additional energy. It uses natural principles like convection, radiation, and phase change to dissipate heat without relying on energy-intensive devices. Passive cooling also reduces operational costs by eliminating electricity consumption associated with fans or compressors. It also contributes to reducing the environmental footprint by not relying on electricity or fossil fuel-powered cooling systems. Despite initial investment, long-term savings from reduced energy consumption and operational costs often outweigh initial expenses. Passive cooling can be applied across various sectors, complementing active systems, and conserving natural resources.

Passive cooling strategies involve heat prevention, modulation, and dissipation to reduce heat absorption, modify heat again, and remove endogenous heat (Song et al, 2021 ; Shahda et al, 2018 ; Mohammad Alinezhad). Passive cooling methods in bus ducts reduce energy consumption by utilizing natural airflow, convection, and radiation, resulting in significant energy cost savings. They also require minimal maintenance and have fewer components susceptible to wear and tear, reducing operational and maintenance costs.

Passive cooling strategies for bus ducts are advancing technologically, leading to new materials, designs, and methodologies. This research ensures compliance with industry standards for heat management and safety, improving heat dissipation practices. Additionally, developing adaptable passive cooling methods allows for their integration into various systems, offering scalable solutions for different industrial setups, regardless of size or application.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Electrical Industry in Passive Cooling For Bus Duct

In the context of passive cooling, the electrical industry contributes by developing energy-efficient tehcnologies and systems to enhance cooling processes without relying heavily on active cooling methods. The industry explores innovations like low-power electronics, heat-resistant materials and efficient power management to minimize heat generation and optimize passive cooling strategies in various applications, contributing to more sustainable and environmentally friendly approach to temperature.

In passive cooling of bus duct, electrical systems are designed to dissipate heat without active mechanical systems like fans and pumps. Various passive cooling methods are used, such as natural convection, radiation, and conduction (Naveen P.T, 2018). For bus ducts, materials with high thermal conductivity are chosen to facilitate heat dissipation. Additionally, designs might incorporate heat sinks or cooling fins to enhance surface area for better heat dissipation. The goal is to manage heat generated by electrical currents efficiently and ensure safe operation without relying on active cooling mechanisms.

Passive cooling systems for bus ducts utilize natural convection, allowing heat to rise and cool air to sink. Enhanced ventilation and strategically placed openings facilitate this circulation, while materials with good thermal conductivity transfer heat more efficiently. Natural convection is driven by buoyant force and so provides great protection and reliability in the event that active cooling systems fail (Naveen P.T, 2018).

The concept of a convective flow that emerges organically from self-induced forces. Temperature or concentration gradient could cause this (C. Balaji, Balaji Srinivasan, Sateesh

Gedupudi, 2021). Passive cooling with convective flow involves utilizing natural air movement to dissipate heat. It relies on the principle that hot air rises and cooler air replaces it, creating a continuous cycle. This process can be enhanced through well-designed architectural features, such as ventilation openings, thermal mass, and shading elements, promoting efficient heat dissipation without relying on mechanical systems.

2.2 Various Heat Sink

Electronic devices generate heat when in use and require cooling mechanisms to prevent overheating and system malfunction. One common solution is the use of heat sinks, which are classified into six types based on their manufacturing process. These types include extruded, bonded, skived, stamped, forged, and CNC machined heat sinks, each with its own unique advantages and drawbacks. Aluminium heat sinks offer cost and weight savings, while copper heat sinks have the highest level of thermal conductivity. The study examined the thermal performance of three heat sink configurations with varying alumina nanomaterial mass concentrations. All three heat sinks showed lower base temperatures with alumina NePCM phase change materials compared to an empty unfinned heat sink (Zahid I.Qamar A.[...]Hayat M. A, 2023).

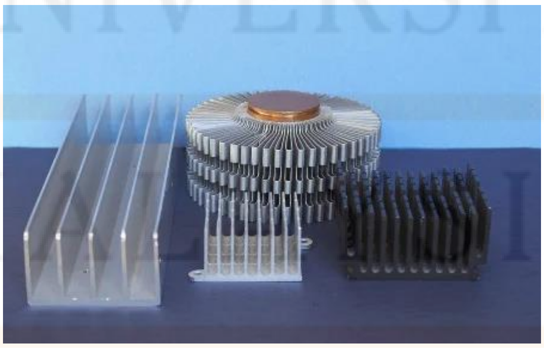


Figure 2.1: Various Heat Sinks (Emmanuel Lkimi ,April 21, 2021)

Figure 1 shows the heat sinks must be considered while bus duct, constructing computers, LED lights, or other devices. Heat sinks collect and remove heat from these devices, assisting in their cooling. From my project, the system generated 2 W electric power with 2.1% overall conversion efficiency with air cooling and 10 W electric power with 10.1% conversion efficiency with air cooled heat sinks respectively. Today we'll look at various different sorts of heat sinks, how they're created, and how they're used. Heat sinks are often classified according to the manufacturing technique used to make them, such as extruded, machined, and so on. 6 will be discussed more below. But first, it's critical to realise that all heat sinks are classified into two types.

Active Heat Sinks:

Active heat sinks are used to increase cooling capacity and accelerate heat transfer. To facilitate heat dissipation, they require the use of fans, water pumps, or other powered processes. Although passive heat sinks can be employed based on the design and volume limitations, active heat sinks may be required for improved heat dispersion. Air velocity, design, and surface treatment may all have an impact on the performance of active heat sinks. Active heat sinks are extensively employed in electronic equipment to minimise overheating and system failure in high-power applications such as CPUs, GPUs, and power amplifiers. (Gabrian International, 2016)

Passive Heat Sinks:

Passive heat sinks, which do not rely on forced air movement (fans), are regarded more trustworthy than active alternatives. They are intended to diffuse heat across a vast area and radiate it away without the use of mechanical components. Aluminium is the most often used and least expensive material for heat sinks, but copper is utilised when performance is required. Pumped liquid heat sinks are the least dependable way of cooling electronics. Heat sinks are classified into six kinds based on their production process: CNC machined, forged, die-cast, zipper fin, extruded, bonded, and skived. Passive thermal management is a low-cost and energy-efficient system that employs heat sinks, heat spreaders, heat pipes, and other passive cooling devices. (Gabrian International, 2016)

2.1.1 Types of Material

Based on the study, heat sinks have two types of materials, which is aluminium and copper. The two most frequent materials used in heat sinks are copper and aluminium. Copper is more thermally conductive, denser, and has a higher volumetric heat capacity than aluminium is only 56% of the cooper (Naveen P.T, 2018), making it a better choice for bigger heatsinks and powerful chipsets. Copper, on the other hand, is heavier than aluminium, and its performance is determined by the design and geometry of the heat sink. Aluminium heat sinks are lighter and less expensive, making them ideal for compact devices and low-power chipsets. Despite having poorer thermal conductivity than copper, aluminium provides great cooling and excellent thermal radiation control. As a result, the material used for a heat sink is determined by the device's size, power, and intended application.

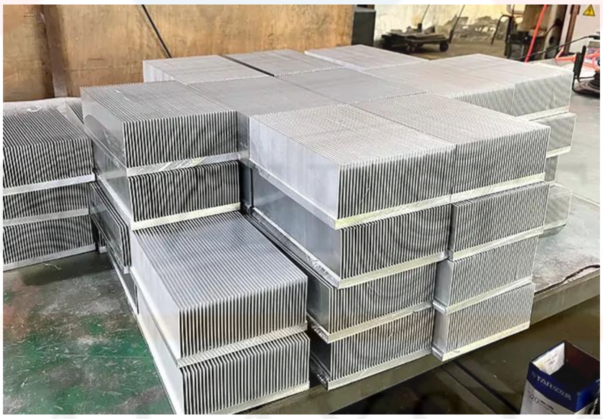


Figure 2.2: Aluminium Heat Sinks Fins (Heat Sink Manufacturing of Xuiron, 2023)

Figure 2 shows the aluminium heat sinks are popular due to their strong thermal conductivity which allows them to efficiently transport heat away from electrical components. (Heat Sink Manufacturing of Xuiron, 2023)Aluminium heat sink's design flexibility allows for heat sinks to be customized to specific bus duct layouts or space constraints, maximizing surface area for heat dissipation extra aluminium heat sinks can be treated or coated to improve corrosion resistance and durability. Their fins and ridges increase surface area, facilitating better convective heat transfer and enhancing passive cooling efficiency by increasing exposure to the surrounding air.

2.1.2 Types of Heat Sinks in Manufacturing Process

Heat sinks dissipate heat created by electrical components in a circuit, preventing electronic gadgets from overheating. Heat sinks are classified into six categories based on their production process: extruded, bonded, skived, stamped, forged, and CNC machined. Each kind has benefits and disadvantages, and the heat sink should be selected depending on the unique design considerations and volume limitations of the electronic equipment. Aluminium and copper are the most often utilised materials for heat sinks, with aluminium providing weight and cost advantages and copper providing the maximum amount of thermal conductivity. Copper heat sinks are also more corrosion and antibacterial growth resistant. Copper heat sinks, on the other hand, are heavier and more costly than aluminium heat sinks. The material used for a heat sink is determined by the device's size, power, and intended usage. Extrusion is the most often utilised method for producing heat sinks. (Gabrian International, 2016)

i) Extruded Heat Sinks

Extruded heat sinks are popular for high-power heat sink and cooling systems. They are manufactured utilising aluminium heat sink extrusion technique, in which aluminium is heated and pushed through a grooved mould to produce an extruded heat sink material. Because of its high heat conductivity and machinability, AL6063 is a widely used material. The surface of the completed product is anodised to increase corrosion resistance, wear resistance, and attractiveness. Because of its improved performance, increased radiating surface area, and low cost, extruded aluminium heat sinks are widely employed in a variety of industries. They are more cost-effective and efficient than stamping heat sinks and mechanical processing. They are lightweight and easily adjustable. When compared to other heat sink kinds, ultra-thin fins have reduced assembly labour costs. (Heat Sink Manufacturing of Xuiron, 2023)

ii) Bonded Heat Sinks

Bonded fin heat sinks are a type of heat sink that consists of thin fins that are bonded into the grooves of machined or extruded bases using an epoxy. These types of heat sinks are suitable for large applications and are generally less expensive than extruded heat sinks. However, they may not be as efficient as other types of heat sinks, such as skived or folded fin heat sinks. The choice of heat sink should be based on the specific design needs and volume requirements of the electronic device. (Heat Sink Manufacturing of Xuiron, 2023)

iii) Skived Heat Sinks

Skived heat sinks are created by employing a sharp blade to slice a solid block of aluminium or copper to the necessary thickness. This method produces fins that are tightly spaced and evenly formed, allowing for optimal heat dissipation. The main benefit of skived heat sinks is that just one piece of metal is required, which eliminates the need for extra equipment and labour. Skived heat sinks are extensively employed in the cooling of automotive, industrial, and electrical equipment. However, the technique necessitates a significant amount of effort as well as extra apparatus such as a gear cutting machine and a grinding machine to smooth the surface of the fins. Copper heat sinks frequently employ precision skiving. (MyHeatSink, 2023)

iv) Stamped Heat Sinks

Stamped fin heat sinks have achieved significant improvements over conventional heat sink designs, including a long list of features ranging from extreme fin thinness to high density, and from limited restrictions on fin height to strong levels of compatibility with external attachments when needed. The thinness of fins achieved using stamped fin heatsink technology is far superior than that of conventional extrusion heatsinks. While a particular cutting process may reduce extrusions to just under a fifth of an inch in thickness, stamping can treble the thickness. This is highly beneficial in achieving the large surface area required to properly distribute thermal energy from the heatsink. (Heatell Thermal Solution Provider, 2024)

v) Forged Heat Sinks

Forged heat sinks are manufactured by compressing aluminium or copper and come in cold and hot forged varieties. They are utilised in a variety of applications such as high-powered electronics and multi-chip modules. Hirschvogel, a producer of forged components to the automobile sector, provides complicated aluminium cooling plates, as well as cold and hot forged heat sinks. These heat sinks are pressure-tight, cavity-free, and simple to weld, resulting in cost reductions in cooling system installation. Forged heat sinks improve heat dissipation, resulting in better power density and longer component service life. (Heat Sink Manufacturing of Xuiron, 2023)

vi) CNC Machined Heat Sinks

CNC machined heat sinks are a common alternative for cooling electronic components. These heat sinks are developed and manufactured using computer numerical control (CNC) equipment, which enable the creation of accurate and complicated designs. CNC machining also assures that the heat sink is manufactured to exact specifications, resulting in optimal performance. (Honstar Aluminium Product Co, 2023)

2.3 Passive Cooling Set Up

Air cooling is a common method in industrial applications, particularly in bus ducts, which are used for electrical power distribution in large buildings or facilities. This passive cooling system allows natural airflow to dissipate heat without the need for additional mechanical assistance like fans or pumps. This ensures efficiency and prevents overheating in these facilities. The review reveals that while passive cooling may seem more suitable due to its lack of impact on net electrical output power, active cooling is more suitable. (Pfeiffelmann B.Benim A. C.Joos F...Energies, 2021)

Heat sinks are crucial for efficient heat management in various machines and devices, including electronic systems, terminals, and systems, ensuring efficient heat removal. Heat sinks are commonly used in electronic devices to transfer heat away from the device. (Dai Nippon Printing Co., Ltd). They work by increasing the surface area of the device, which allows more heat to be dissipated into the surrounding air.

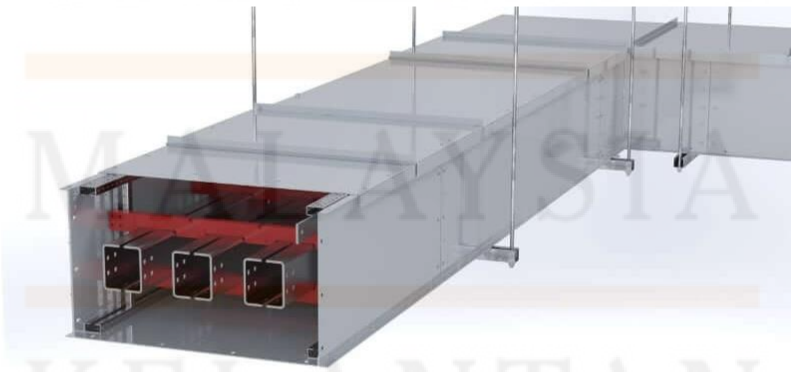


Figure 2.3: Industrial Bus Duct Ventilation (Current Midwest, 2024)

Based on the figure 3, firstly, we can observe ventilation openings with is the duct enclosure's vents strategically position hot and cold air to create a natural convection pattern, allowing hot air to rise and exit through higher openings and cool air entering from lower ones. (Current Midwest, 2024)

Secondly, heat dissipation materials are the bus duct enclosure, made of materials with high thermal conductivity, effectively transfers heat from electrical components to the duct's outer surface, enhancing heat dissipation. Duct design also can maximizing surface area exposed to the surrounding air in duct design can enhance passive cooling by using geometric designs like fins or ridges.

In addition to these cooling methods, insulation is crucial for preventing heat transfer to surrounding areas and directing cooling outwards, avoiding sensitive components or nearby structures. Passive air cooling is effective in many situations, but in high heat generation or limited natural airflow, additional active cooling methods like fans or liquid cooling systems may be necessary.

2.4 Thermal Management of Heat Existing in Bus Duct

Thermal management is essential for the reliability and longevity of electronic devices and circuitry. Different techniques for cooling, such as heat sinks, forced air systems, and heat pipes, can be used to dissipate heat. (Amol R. Dhumal, Atul P. Kulkarni & Nitin H. Ambhore, 2023). Lower thermal resistance values indicate higher efficiency, while time constants can be used to calculate a heat sink's dynamic heat dissipation capability. Thermal interface material can also improve thermal transfer efficiency. Efficient TMS solutions must be carefully selected and combined to deal with various design constraints.

The temperature distribution in heat existing bus ducts is a crucial aspect in determining electrical system efficiency and safety. To minimise hot spots or regions of overheating, the temperature in a bus duct should be constant and steady throughout. I may use sensors and other monitoring devices to measure the temperature at various spots along the bus duct to guarantee correct temperature distribution. This information may then be analysed to determine any hotspots or regions of concern. If hot spots or regions of uneven temperature distribution are found, the bus duct design must be modified or extra cooling or ventilation systems installed to guarantee that the temperature remains constant and within safe operating limits.

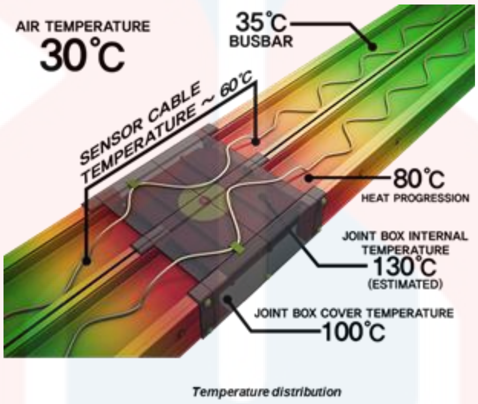


Figure 2.4: Heat Existing in Bus Duct (Adtell Integration, 2022)

2.5 Temperature Testing

2.5.1 Using Digital Thermometer

Digital thermometers are gaining popularity due to their low-cost and high-precision reading capabilities. Consumer electronics manufacturers are developing thermometers that are connected to the internet. (Ayan Kumar Panja, Nilanjan Dey, 2022). A digital thermometer verifies a smart temperature transmitter's calibration and is used to measure temperature in a RTD-type thermowell using a thermistor or RTD probe. (Walter W.C. Chung, Michael F.S. Chan, 2001).

In this running project, I used a digital thermometer because it is easy to get. Although it is less than a specific temperature calculation, but it can help show the temperature movement starting from 10 volts up to 50 volts. Digital thermometers offer high accuracy, often within 0.1 degrees Celsius or Fahrenheit. They are easy to read, eliminating guesswork in interpreting mercury levels or analog scales. Digital thermometer typically provides faster results, with some models providing a temperature reading within seconds. (Kinetik Medical Devices Ltd, 2021)

Figure 2.5: Digital Thermometer (Material Science Lab UMK)

2.5.2 Using Infrared Thermography (IRT)

Infrared thermography (IRT) is the science of acquiring and analysing heat data from non-contact measuring instruments. It is based on infrared radiation, which the human eye cannot perceive, hence infrared measuring instruments are necessary to capture and analyse this data. Infrared thermography is a technique that can be used to measure the temperature of electronic components in a cooling system. This technique works by detecting the infrared radiation emitted by the components, which is directly related to their temperature.

To perform temperature testing using infrared thermography, a specialized camera called an infrared camera or thermal imaging camera is used. This camera is designed to detect infrared radiation and produce a visual image of the temperature distribution across the surface of the electronic components.

During testing, the camera is pointed at the components being cooled, and the temperature distribution is recorded. This information can be used to identify areas that are experiencing high temperatures and may require additional cooling.

Infrared measurement instruments convert the infrared radiation generated by an item into an electrical signal. A pyrometer is the simplest basic instrument, producing a single output from a single sensor. An array of sensors in advanced gadgets produces a comprehensive infrared picture of the scene. The distinction between a visible picture and an infrared image is that the visible image represents reflected light on the scene, but the infrared image is the source and may be detected in the absence of light.

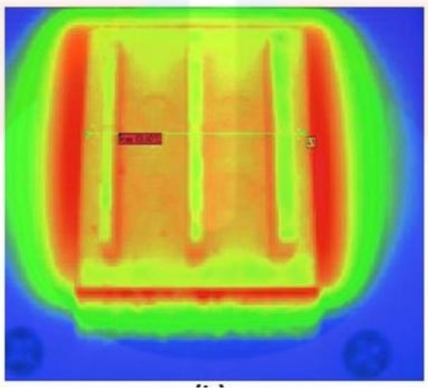


Figure 2.6: Heat Sink Infrared Thermography (Daniel Marchetto, 2018)

2.6 Heat Transfer Coefficient

The heat transfer coefficient in the existing use of a heat sink depends on several factors, including the thermal conductivity of the heat sink, the airflow or fluid flow rate around the heat sink, and the temperature difference between the heat source and the surrounding environment.

The heat transfer coefficient is a measure of how efficiently heat is transferred from the electronic component to the heat sink and from the heat sink to the surrounding air or fluid.

A higher heat transfer coefficient means that heat is being transferred more efficiently, resulting in better cooling performance and lower operating temperatures for the electronic component.

To optimize the heat transfer coefficient of a heat sink, may use techniques such as increasing the surface area of the heat sink, improving the airflow or fluid flow rate around the heat sink, using materials with higher thermal conductivity, and optimizing the placement and design of the heat sink to maximize contact with the electronic component.

2.7 Summary

The electrical industry is developing energy-efficient passive cooling systems to enhance cooling processes without relying on active cooling methods. Innovations like low-power electronics, heat-resistant materials, and efficient power management are used to minimize heat generation and optimize passive cooling strategies. Passive cooling systems for bus ducts use natural convection, radiation, and conduction, with materials with high thermal conductivity and heat sinks or fins for better heat dissipation. Convective flow, driven by buoyant force, provides protection and reliability in case of active cooling system failure. Architectural features like ventilation openings, thermal mass, and shading elements enhance this process.

Heat sinks are made of aluminium and copper, with aluminium being the most common material due to its higher thermal conductivity and density. It is suitable for larger heatsinks and powerful chipsets, while copper is heavier and more expensive. Aluminium is ideal for compact devices and low-power chipsets, offering excellent cooling and thermal radiation control. The material used depends on the device's size, power, and intended application. Aluminium heat sinks can be customized for specific layouts and can be treated or coated for improved durability.

Thermal management is crucial for the reliability and longevity of electronic devices and circuitry. Techniques like heat sinks, forced air systems, and heat pipes can be used to dissipate heat. Lower thermal resistance values indicate higher efficiency, while thermal interface material improves thermal transfer efficiency. Temperature distribution in bus ducts is crucial for efficiency and safety. Monitoring devices can measure temperature and identify hot spots, requiring modifications or additional cooling or ventilation systems.

Digital thermometers are becoming increasingly popular due to their low-cost and high-precision reading capabilities. They are used to verify the calibration of smart temperature transmitters and measure temperature in RTD-type thermowells. Digital thermometers offer high accuracy, often within 0.1 degrees Celsius or Fahrenheit, and are easy to read, eliminating guesswork in interpreting mercury levels or analog scales. Infrared thermography (IRT) is a technique used to measure the temperature of electronic components in a cooling system. It uses an infrared camera or thermal imaging camera to detect infrared radiation and produce a visual image of temperature distribution across the components. Infrared measurement instruments convert infrared radiation into electrical signals, with pyrometers being the simplest basic instrument.

The heat transfer coefficient of a heat sink is a measure of how efficiently heat is transferred from an electronic component to the heat sink and from the heat sink to the surrounding air or fluid. A higher coefficient indicates better cooling performance and lower operating temperatures for the electronic component. To optimize the heat transfer coefficient, techniques such as increasing the surface area, improving airflow, using materials with higher thermal conductivity, and optimizing the placement and design of the heat sink to maximize contact with the electronic component can be employed.

CHAPTER 3

METHODS AND MATERIALS

3.1 Research Flow Chart

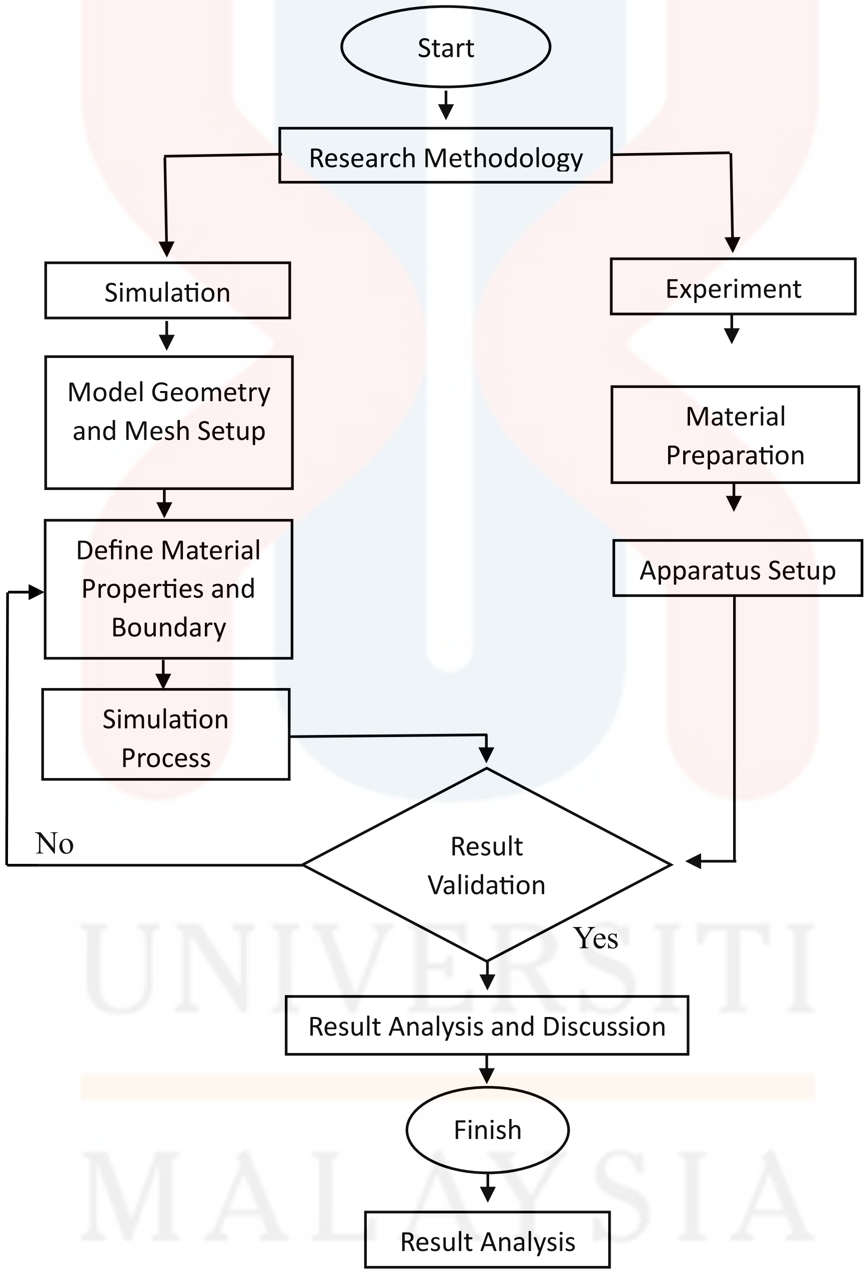


Figure 3.1: Flow chart of the project

3.2 Experimental Setup

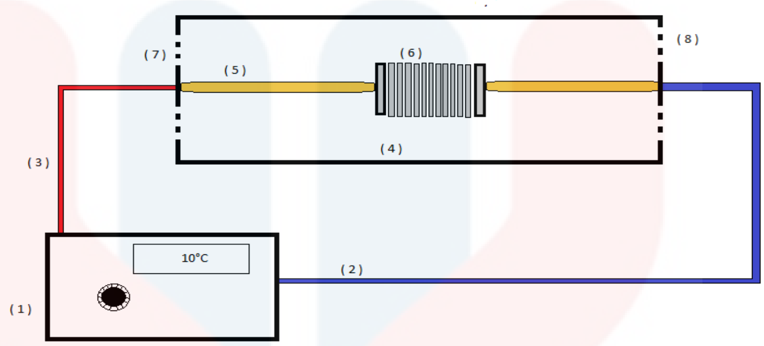


Figure 3.2: Physical graphic of bus duct

1)Thermostat incubator

2)Positive wire

3)Negative wire

4)Electric bus duct

5)Hot plate

6)Aluminium heat sink

7)Heat inlet hole

8)Heat outlet hole

The methodology of electronic cooling using heat sinks involves the transfer of heat generated by electronic components to a heat sink made of a material with high thermal conductivity, such as aluminium. The heat sink absorbs the heat and increases its temperature, which in turn is transferred to the surrounding air or fluid, typically using forced convection. The heated air or fluid is then expelled from the system, allowing cooler air or fluid to enter and continue the cooling process.

The design of a heat sink typically involves a base or plate that is mounted directly on the electronic component, and one or more fins or channels that extend outward to increase the surface area for heat dissipation. The fins or channels increase the surface area of the heat sink, allowing for more efficient heat transfer from the electronic component to the surrounding air or fluid.

Heat sinks can also be combined with other cooling techniques such as air cooling or liquid cooling to further improve their thermal performance. By optimizing the design of heat sinks and integrating them with other cooling technologies, it is possible to improve the efficiency and reliability of electronic cooling systems and extend the lifespan of electronic components.

3.2.1 Prepare Electric Bus Duct

Firstly, the important thing is an electrical bus duct. It is metallic or non-metallic system that consists of conductive bars or tubes for transporting power from one place on facilty to another. It offers a centralised and well-organized method of power delivery. It has 130 mm side length, 140 cm for width and this bus ducts is 295 mm long. So, it has good depth, and it will provide effective ventilation on this project.

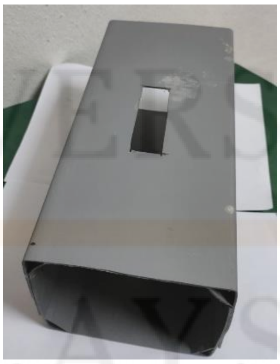


Figure 3.3: Electric Bus Duct

Place the electric bus duct in a controlled environment, which means in a highly regulated setting where factors like temperature and humidity remain constant. This is critical for obtaining reliable findings when testing the performance of the aluminium heat sink in the electric bus duct.

In layman's words, a "controlled environment" is one in which we intentionally regulate the surroundings throughout an experiment to eliminate any extraneous effects that could interfere with our research. This control is critical for ensuring the reliability of our results in our experiment with the aluminium heat sink. We may install the electric bus duct in a dedicated chamber or box to provide this regulated environment. We can monitor and modify things like temperature and humidity from there. This regulated environment provides a steady foundation for measuring how the aluminium heat sink performs under these precise conditions.

3.2.2 Place Heat Sink

Second equipment is aluminium heat sink was provided in this project because heat sink most important for passive cooling. The heat sink will be placed on top of the hot plate because the heat function is to release the heat contained in it. The heat sink that is often used in electrical bus ducts is an aluminium heat sink. In this project, I used a heat sink that is 20 mm high and 50 mm wide. The heat sink in bus duct dissipates excess heat from electrical currents, ensuring safe operating temperatures, prevents overheating and maintains efficient electrical component performance.

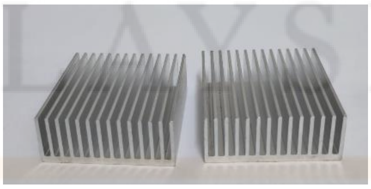


Figure 3.4: Aluminium Heat Sink

Need to "securely attach the aluminium heat sink inside the electric bus duct, ensuring optimal thermal contact" underlines the importance of fitting the heat sink precisely within the duct. To avoid movement during the experiment, a precise and sturdy connection with appropriate fasteners is required. The emphasis on "optimal thermal contact" highlights the need of reducing impediments to good heat movement. This approach is compatible with the experiment's ultimate purpose of simulating real-world conditions, allowing for an accurate assessment of the aluminium heat sink's performance in distributing thermal energy within the electric bus duct.

The necessity to "align the heat sink with the designated heat inlet and outlet holes in the bus duct to establish a consistent airflow pattern" is a key procedural aspect of the experiment. It stresses the need of precisely matching the heat sink with the required holes in the bus duct. This alignment is required for a regular and controlled airflow pattern. By emulating real-world circumstances where airflow is regulated, this intended alignment enables for precise evaluations of the aluminium heat sink's thermal performance within the electric bus duct.

3.2.3 Prepare Hot Plate

The next item is hot plate. Hot plate contained in this bus duct to show that used for the purpose of equalizing temperature distribution along the length of the bus duct. It helps prevent condensation buildup and potential damage caused by temperature variations in the duct. The copper pipe used as a hot plate is because it has same properties as the electric current that gives heat in the bus duct. In accordance with the length of the bus duct, which is 295 mm, I have used two copper rods that have a length of 250 mm each.

Figure 3.5: Hot Plate

In the experimental approach, the instruction to connect the positive and negative wires from the electric bus duct to the hot plate is critical. It makes it easier to carry electrical power from the bus duct to the hot plate, which is a vital component in the arrangement that generates controlled heat. This connection is critical for the seamless integration of electrical and thermal characteristics, which contributes to the overall performance of the experiment and allows for exact manipulation of heat variables within the confined region of the electric bus duct.

3.2.4 Connect the Thermostat Incubator

The last step is to use a thermostat incubator that functions as an electricity source for the copper pipe. A thermostat incubator in an incubator helps regulate and maintain a consistent temperature. It monitors the temperature inside the incubator and triggers the heating or cooling systems to ensure the environment remains at desired level for whatever is being incubated. In this project, I have used 2, 4, 6, 8 and 10 volts, as a result, it will produce a level of electricity quantity in the copper pipe to produce heat.

Figure 3.6: Thermostat Incubator

Physical testing on heat sinks is the most common method of determining thermal performance. Thermal resistance is the test parameter that determines the heat sink's thermal performance. Factors such as flow rate, inlet temperature, input power, and base temperature must be understood to determine the thermal resistance. The test rig is typically insulated to protect against ambient conditions. The experimental equipment is placed into a thermostat incubator to ensure a steady ambient temperature. Because ambient temperature effects the thermal dynamics of integrated components, this is critical for precise and reproducible measurements. The thermostat must be set to the desired temperature to ensure a steady atmosphere that meets the objectives of the study. This is critical for exposing the complicated thermal behaviours within the electric bus duct and its components, as well as assuring experimental data dependability and reproducibility.

3.2.5 Data Collection

Several processes are involved in the investigation to collect data for a thermal profile of an electric bus duct. Before turning on the hot plate, measure and record the starting temperature of the aluminium heat sink. Before beginning any thermal treatments, it is critical to determine the baseline thermal state of the heat sink. The researchers want to capture the thermal baseline by carefully monitoring and documenting the beginning temperature, which will serve as a reference point for subsequent temperature variations caused by the active hot plate.

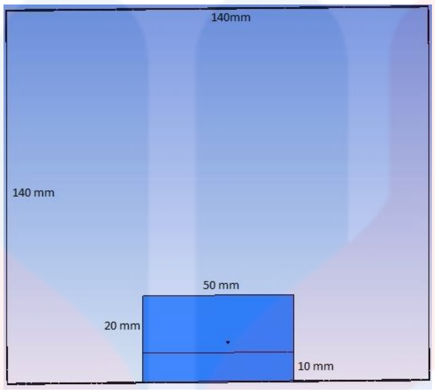
The second stage is to turn on the hot plate and monitor temperature differences within the electric bus duct continually. This enables for systematic temperature monitoring and documentation during the experiment. The researchers want to be able to detect and record thermal reactions within the limited area of the electric bus duct, which will help them gain a better knowledge of the thermal behaviours of the integrated components.

The third stage is to take temperature readings at regular intervals, taking into account both the heat entrance and outflow locations. This methodical approach is critical for documenting the evolving thermal dynamics and assessing the effectiveness of the integrated components. This approach enhances the precision and dependability of experimental observations.

3.3 Ansys Computational Simulation Setup

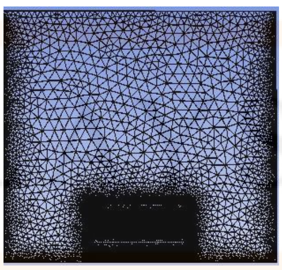
3.3.1 Geometry and Domain Creation

Creating a geometry for passive cooling in a bus duct in Ansys would involve designing structures or elements that facilitate heat dissipation without an active cooling system. This might include heat sinks, fins, or structures aimed at increasing surface are to enhance natural convection. To create such a geometry in Ansys, the bus duct have dimensions like 295 mm by 140 mm by 130 mm (LxWxH). Model the main body of the bus duct channel with appropriate thickness and material properties. This can be a solid prismatic square that represents the outer casing. With the area found in this space, the heat sink can be placed inside the bus duct. These elements are designed to increase the surface area for better heat dissipation.



3.3.2 Mesh Generation

Absolutely, integrating passive cooling elements like heat sinks within the bus duct geometry can significantly enhance heat dissipation. In Ansys, create the elements by heat sinks. These heat sinks consistent with experiments such as 20 mm high and 50 mm wide (HxW) and 10 mm for the hotplate. Then, create elements for electric bus duct such as 140 mm. The geometry of this heat sink must be drawn in the middle of the electric bus duct because there is a strategic cooling place for the heat from the left and right of the air content in the accumulated to be released to the top surface of the bus duct.

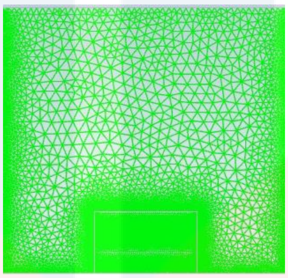


3.3.3 Boundary Conditions

The next step is applying boundary conditions. In Ansys, defining a accurate boundary conditions and setting up the simulation parameters are crucial for an effective thermal analysis of the bus duct with passive cooling elements. Assign specific material properties to each component within the bus duct, including the conductors, insulating materials, casing and passive cooling element. Define thermal conductivity, specific heat and density to simulate heat transfer accurately.

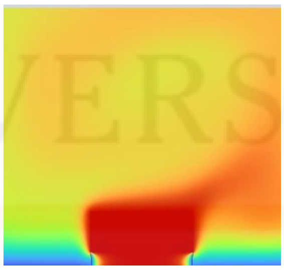
For the simulation setup, the first method is analysis type. Steady -state analysis is suitable when the temperature distribution remains constant over time. It assumes that the system reaches a stable condition where temperatures no longer change. It's computational less intensive and quicker to solve. It's ideal for scenarios where temperature stabilize relatively quickly and remain constant during operation. Next, the bus duct's heat transfer involves conduction through solid materials and passive cooling elements, with thermal conductive defined for each material. Convection occurs between bus duct surfaces and surrounding air, impacting cooling, especially with passive cooling elements. Radiation, if applicable, refers to heat transfer between surfaces, potentially relevant for higher temperature differentials or materials with significant radiation effects.

The text describes the process of integrating heat sinks, thermal insulation, natural convection surfaces, radiative shields, ventilation/openings, heat absorption materials, parametric studies, and simulation validation. Heat sinks are integrated into the model at heat source locations, such as electronic components, to increase surface area for heat dissipation. Insulating materials are incorporated to minimize heat transfer to the surrounding environment or adjacent components. Natural convection surfaces are designed to promote heat transfer through air movement, and the emissivity and reflectivity of these shields are defined in the simulation. Ventilation/openings are strategically placed to allow hot air to escape and cooler air to enter, facilitating natural airflow for cooling. Heat absorption materials are considered, and parametric studies are performed to optimize cooling efficiency. Simulation results are validated by comparing them against experimental data or established benchmarks to ensure the accuracy of passive cooling strategies.



3.3.4 Thermal Analysis Setting

The process of thermal simulation involves selecting the appropriate solver module within ANSYS, setting initial conditions, and setting convergence criteria. The model's complexity and the nature of heat transfer are considered. Boundary conditions are applied to simulate the bus duct's interaction with its environment, including ambient temperatures, heat transfer coefficients, and emissivity. Mesh refinement is done to ensure accurate geometry and precise temperature distribution calculation.



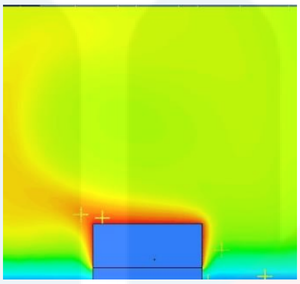
3.3.5 Solver Setting

The simulation is initialized and run, with continuous convergence monitoring. Results are visualized using ANSYS tools, and contour plots, temperature profiles, and flow visualization are generated to analyse the impact of passive cooling elements on temperature reduction. The simulation results are then validated against theoretical expectations, empirical data, or experimental results, and sensitivity analysis is performed by varying parameters to assess their influence on temperature distribution. This process ensures accurate and realistic representation of operational conditions.

3.3.6 Results and Post-Processing

The analysis of ANSYS simulation results involves evaluating the effectiveness of passive cooling strategies in the bus duct model. This involves reviewing temperature profiles across the bus duct, comparing temperatures at critical locations with and without passive cooling strategies, calculating and comparing heat dissipation rates in the presence of passive cooling elements, and analysing airflow patterns within the bus duct model. These methods help determine the rate at which heat is transferred or removed from the system and quantify the reduction in heat dissipation achieved due to passive cooling methods compared to the baseline scenario without these methods.

Simulation analysis is essential for optimizing passive cooling strategies in bus ducts. Key parameters, such as material properties, geometry, placement of cooling elements, and airflow patterns, significantly influence cooling efficiency. A detailed sensitivity analysis is conducted to understand their impact on cooling effectiveness. Optimization strategies are devised based on sensitivity analysis results, which may involve modifying materials, adjusting geometries, or enhancing airflow. The optimized parameters or strategies are then implemented in the simulation model, and the results are rerun to assess their impact on temperature distributions, heat dissipation rates, and overall cooling efficiency. Performance evaluation is conducted to quantify improvements in cooling efficiency achieved through optimization and compare the results with earlier results to gauge the effectiveness of the refined passive cooling strategies. Finally, the optimized simulation results are validated against empirical data or benchmarks to ensure alignment with expected trends and real-world scenarios.



3.4 Numerical Setup

Air cooling is a process of dissipating heat from a device or system by using air as the cooling medium. The numerical background of air cooling involves calculating various parameters such as the air flow rate, heat transfer coefficient, and temperature difference.

The air flow rate is the amount of air that passes through the cooling system per unit of time, and it is usually measured in cubic feet per minute (CFM). The heat transfer coefficient is a measure of how efficiently heat is transferred from the device to the air, and it is typically measured in watts per square meter per degree Celsius (W/m²°C).

The temperature difference is the difference between the temperature of the device and the temperature of the air. This temperature difference drives the heat transfer process, and it is typically expressed in degrees Celsius or Fahrenheit.

$h = Nu * k / D$

Where h is the heat transfer coefficient, Nu is the Nusselt number, k is the thermal conductivity of the fluid, and D is the characteristic length scale of the system. The Nusselt number, in turn, is a dimensionless parameter that represents the ratio of convective to conductive heat transfer and is given by:

$Nu = 0.023 * Re^{(4/5)} * Pr^n$

Where Re is the Reynolds number, Pr is the Prandtl number, and n is an exponent that depends on the flow regime.

A dimension drawing is a technical drawing that shows the physical dimensions and layout of a system or component. In the case of an air cooling system, a dimension drawing might show the size and shape of the heat exchanger, the location of the inlet and outlet ports, and the overall dimensions of the system.This helps engineers make informed decisions about passive cooling strategies for bus ducts. (MDPI,Yuan-Yuan Lao, 2022)

The general equation governing passive cooling at a boundary involves the heat transfer rate (Q) and the factors influencing this transfer:

$$Q = h \cdot A \cdot \Delta T$$

Where:

- Q is the heat transfer rate (in watts or BTUs per unit time)
- h is the heat transfer coefficient (in watts per square meter per degree Celsius or equivalent units)
- A is the surface area available for heat transfer (in square meters)
- ΔT is the temperature difference between the system and the surrounding environment (in degrees Celsius or Fahrenheit)

This equation represents Newton's Law of Cooling/Heating and is applicable to passive cooling scenarios where heat is dissipated from a system to the surrounding air or environment.

3.5 Quantitative

The study aims to evaluate the effectiveness of passive cooling methods by calculating percentage reductions in temperatures and improvements in heat dissipation rates. The initial temperature without passive cooling is 101.4°C at 50V, and the reductions at each voltage level are compared.

$\Delta T = \frac{Q}{mc}$

Where:

- ΔT is the temperature reduction
- Q is the heat transferred
- m is the mass of the substances
- c is the specific heat capacity of the substances

Percentage Reduction = $\frac{\Delta T}{T\ initial}\ x\ 100$

Where:

- ΔT is the temperature reduction
- T initial is the initial temperature

Assess heat dissipation rates by comparing temperature reduction percentages.

For instance, at 10V, the system effectively dissipates heat by 58.1% compared to 50V.

3.6 Governing Equation

Energy In During Time $\Delta t = (\llbracket q" \rrbracket \_x\ \Delta y \,\Delta z +$

Convection

$[\mu \,\Delta y \,\Delta z p c_p \,(T - T_R)]_X) \,\Delta t$

Conduction

- $q"_x$: Heat flux through conduction (W/m^2)
- Δy, Δz : Thickness in the y and z directions (m)
- μ : Dynamic viscosity (Pa.s)
- p_c : Density times specific heat (J/($m^3.K$))
- T : Temperature at the current locations (K)
- T_R : Reference temperature (K)

Energy Out During Time $\Delta t = (q''_x +_{\Delta x} \Delta y \,\Delta z +$

Conduction

$[\mu \,\Delta y \,\Delta z p c_p (T - T_R)]_{X+\Delta X}) \Delta t$

Convection

This equation reflects the energy output over the same time interval (Δt). Similar to the Energy In equation, it evaluates contributions from heat conduction and convection at position X + ΔX (location after increment).

Energy Generated During Time $\Delta t = Q \, \Delta x \, \Delta y \, \Delta z \, \Delta t$

- Q = Heat generation (W/m^3)

This equation depicts the energy created during the time period Δt, which is a product of the heat generation rate (Q) and the volume element ΔxΔyΔz.

Energy Stored During Time $\Delta t = \Delta x \, \Delta y \, \Delta z p c_p \, \Delta T$

- Δt : Change in temperature (K)

This equation reflects the energy stored over the time interval Δt, which is a product of the volume element and the change in temperature.

In essence, these equations represent the energy balance in a one-dimensional system, accounting for heat conduction, convection, heat production, and energy storage during a defined time period (Δt). They give a full insight of the thermal processes taking place within the system.

3.7 Summary

Passive cooling in bus ducts uses natural airflow and heat dissipation methods to manage electrical currents without mechanical devices. Strategies include ventilation openings, thermally conductive materials, duct design with increased surface area exposure, and proper insulation to prevent heat transfer to surrounding areas and direct cooling outward. These methods promote natural convection, efficient heat transfer, and minimize the need for fans or pumps. Passive cooling effectively dissipates heat without additional energy or mechanical systems, but active cooling may be necessary for high heat generation or limited airflow scenarios. Tailoring strategies to bus duct system needs ensures efficient heat management while adhering to industry standards.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Experiment And Simulation

The relationship between voltage and temperature is evident, with a significant rise in temperature occurring as voltage increases from 10V to 50V. The temperature rise is not linear but accelerates with higher voltage increments. At lower voltages (10-30V), the increase seems gradual, but beyond 30V, it becomes more pronounced with each voltage increment. This temperature is recorded every 5 minutes to get effective results.

The study reveals that a system experiences significant heating due to applied voltage, possibly due to electrical resistance, converting electrical energy into heat. The temperature rise follows a non-linear pattern, suggesting factors influencing heat dissipation or generation within the system, such as non-uniform heat dissipation or thermal inertia, contributing to this non-linear behaviour.

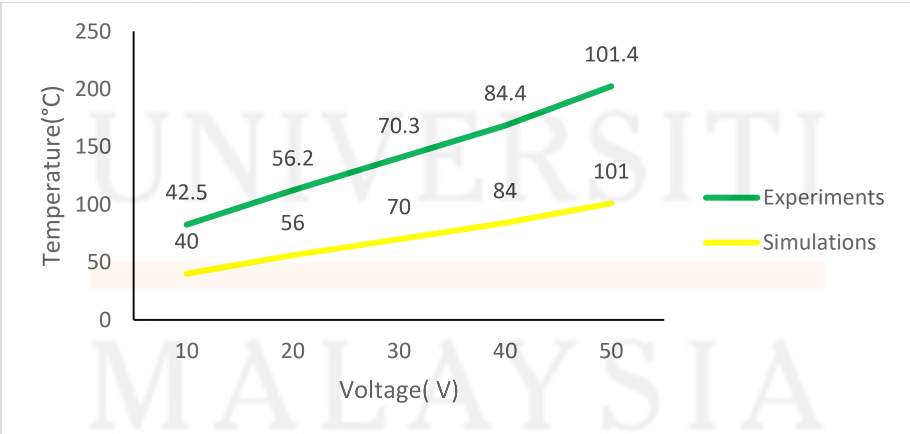


Figure 4.1: Result Of Experiments and Simulations Voltage Affect Temperature

Understanding the voltage-heat relationship is crucial for managing thermal conditions in systems. The percentage differences for each pair of experimental and simulations results are approximately 5.88%, 0.36%, 0.43%, 0.47% and 0.39%. This observation can inform strategies for controlling heat generation at higher voltage levels. The data shows a rapid temperature increase as voltage surpasses certain thresholds, emphasizing the need for setting safety thresholds or implementing cooling measures to prevent overheating or system failures under higher voltage conditions.

4.2 Heat Transfer At Different Heat, Size And Voltage

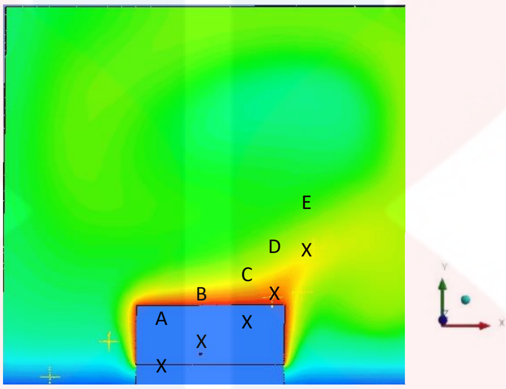


Figure 4.2: Heat Movement from Hot Plate of 50 Volt

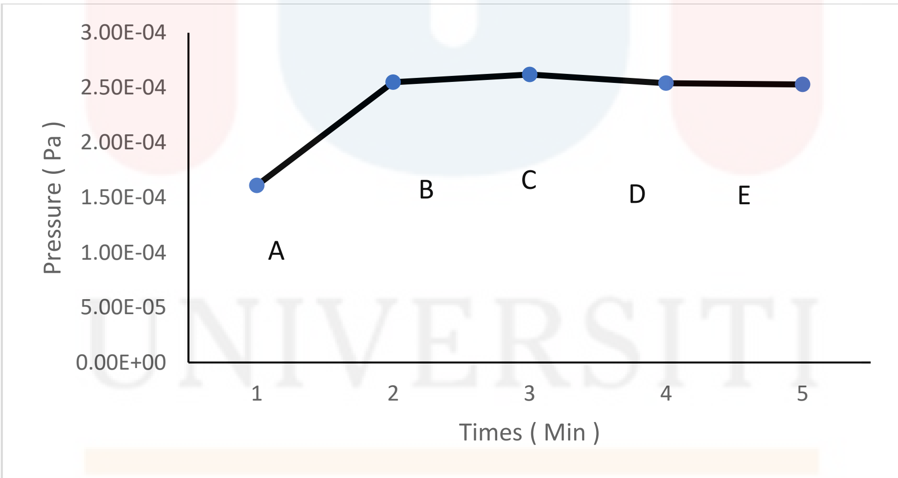


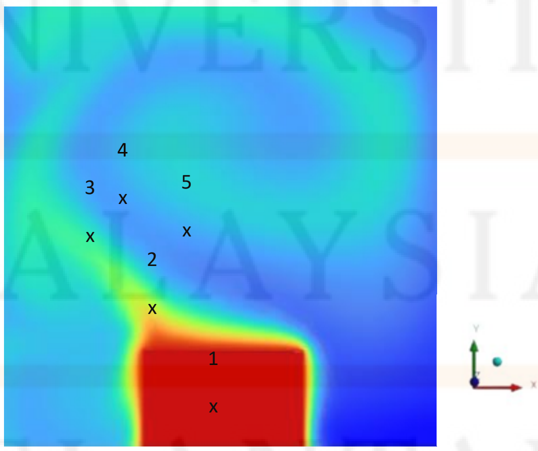
Figure 4.3: Temperature Movement Recorded in 5 minutes.

Passive cooling in bus ducts is a practical and efficient method for managing heat generated by electrical components without relying on energy-consuming active cooling systems. It minimizes energy consumption, reduces operational costs and environmental impact, maintains equipment reliability, and minimizes safety and risk. Passive cooling aligns with sustainability goals by reducing energy usage and environmental impact in electrical power distribution systems. However, it faces challenges such as heat dissipation efficiency, space and design constraints, and environmental variability.

Advantages of passive cooling include energy savings, extended equipment lifespan, reliability, and low maintenance. Eliminating active cooling systems reduces energy consumption, resulting in long-term cost savings and lower carbon footprints. Effective heat dissipation ensures that electrical components operate within safe temperature ranges, prolonging their lifespan and minimizing maintenance costs. Passive cooling methods often have simpler designs and fewer components, leading to lower maintenance requirements and enhanced system reliability.

The use of passive cooling in bus ducts is expected to improve due to ongoing research and innovation in materials, design techniques, and integration methods. Advances in thermal conductivity and innovative design methods can optimize heat dissipation, making it more efficient and adaptable to various environments and space limitations. This eco-friendly, cost-effective, and reliable method ensures energy efficiency, equipment reliability, and operational safety in electrical distribution systems.

4.3 Heat Transfer Coefficient



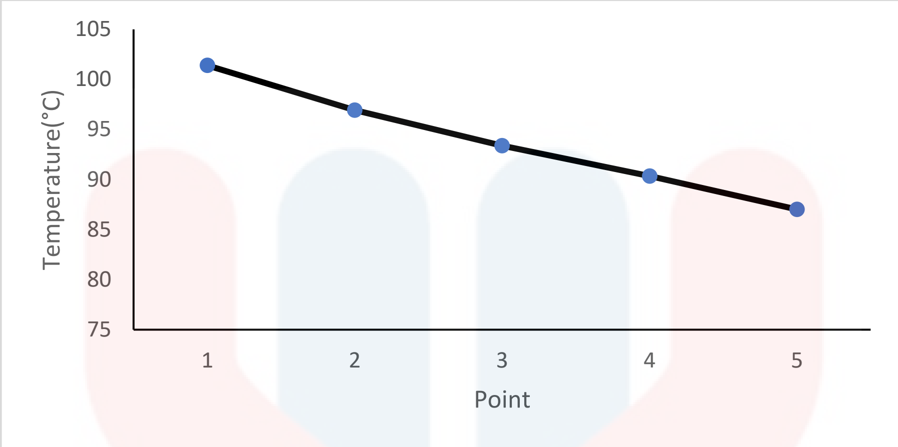


Figure 4.4: Temperature On Different Point At Normal Size Heat Sink (50 Volt)

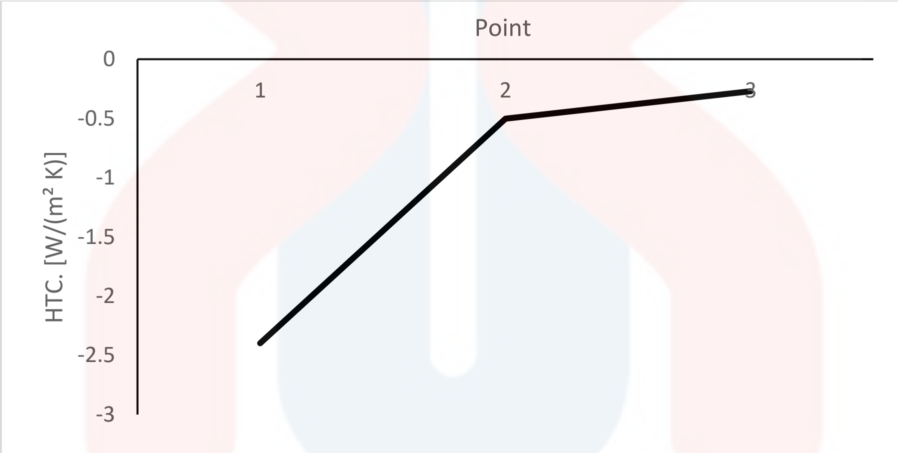


Figure 4.5: Heat Transfer Coefficient At 50 Voltage

The graph displays the heat transfer coefficient (HTC) as a function of position, indicating a decrease in heat transfer as the position increases. This could be due to the material on the right side being a better insulator, causing heat transfer more slowly, or a change in fluid flow on the right side. The exact cause of the decrease is difficult to determine without more information about the specific system. The HTC is a complex property influenced by various factors, including the properties of the materials, fluid flow, and system geometry. The graph provided is a one-dimensional representation of the HTC, which can vary in two or three dimensions. The method used to measure the HTC for the graph is not shown. The graph provides a general understanding of the situation, but it is important to note that the HTC is a complex property that can vary in two or three dimensions.

The bus duct size 140mm x 140mm would increase its surface area. This often enhances the HTC since more space is available for heat dispersion. High thermal conductivity materials, such as copper or aluminium, can benefit considerably from increased surface area for heat dissipation. Let's look at how these materials combine their thermal qualities with a bigger surface area:

Copper is recognised for its high heat conductivity. Increasing the surface area of a copper bus duct provides for more effective heat transmission. The greater surface area allows for better contact with the surrounding air, which improves heat dissipation during the transfer of electrical power. While aluminium has somewhat poorer thermal conductivity than copper, yet it is still regarded an excellent conductor. Increasing the surface area of an aluminium bus duct can result in better heat dissipation. Aluminium is frequently selected for its light weight and cost-effectiveness, and increasing its surface area can help compensate for its somewhat inferior heat conductivity.

Heat transfer mechanism was affected the heat generated in a bus duct is mostly transferred to the surrounding air by convection. More room is available for heat exchange as the surface area increases. This is critical for avoiding the system from overheating and ensuring optimal working conditions. Natural convection occurs when warmer, less dense air rises and cooler, denser air falls. This causes a natural flow of air around the bus duct. The heat created in the bus duct causes the surrounding air to warm. This warmer air rises, generating a flow that aids in the transmission of heat out from the duct. Larger surface areas, along with strong thermal conductivity, guarantee that produced heat is efficiently transferred away from the source. This is especially significant in high-power applications, where heat dissipation is vital to system dependability.

Cooling features, like as fins or surfaces, are commonly used in bus duct design to increase heat dissipation and the overall efficacy of convection as a heat transfer mechanism.

Increased surface area like fins or expanded surfaces are intended to enhance the area of the bus duct exposed to the ambient air. A bigger surface area provides for more effective heat transmission via convection since there is more room for the air to come into contact with the heated surfaces. Fins improve natural convection by allowing heated air to rise due to their greater surface area, which aids in heat dissipation. The bus duct design adds cooling elements such as fins or surfaces to increase convection-based heat transfer efficiency, assuring the electrical power distribution system's reliability and safety.

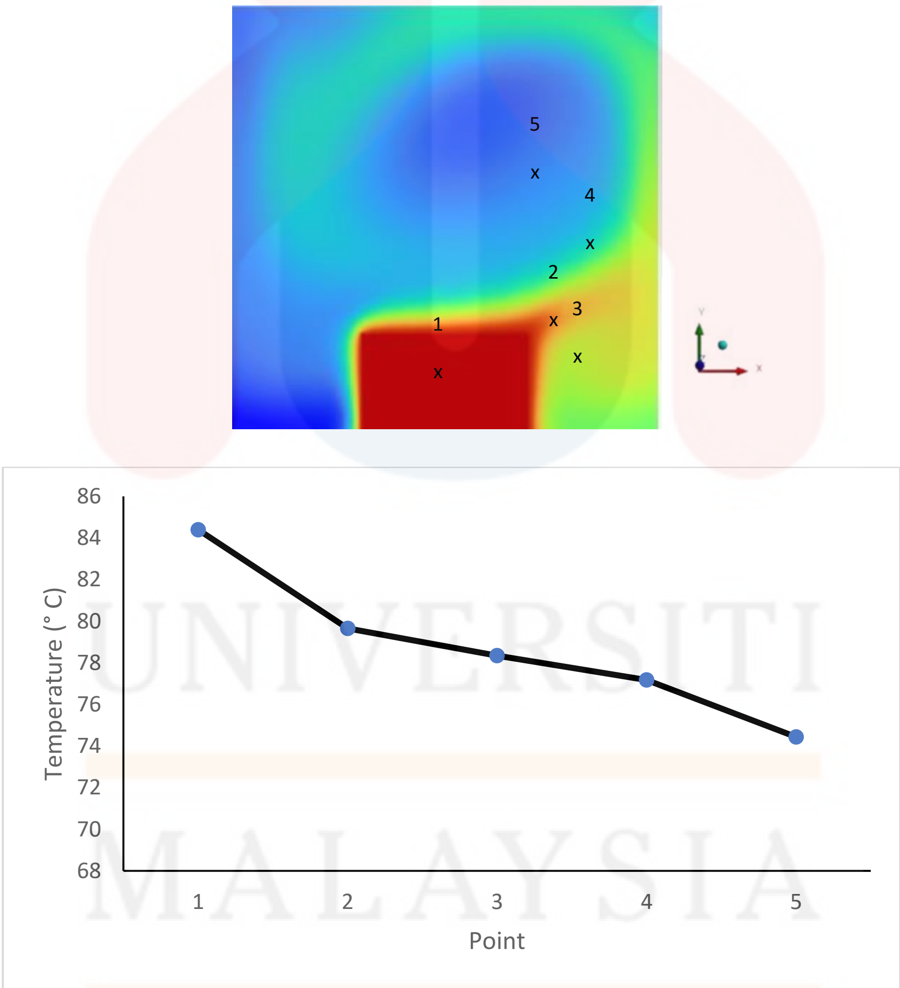


Figure 4.6: Temperature On Different Point At Normal Size Heat Sink (40 Volt)

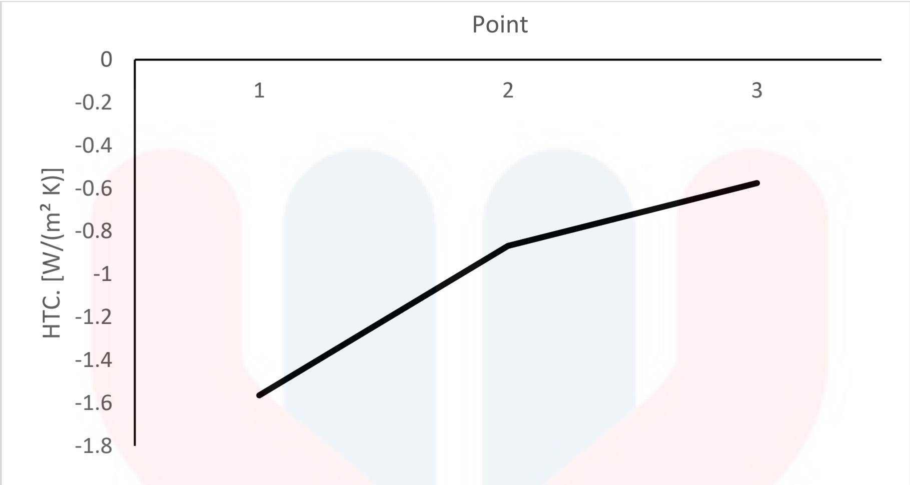


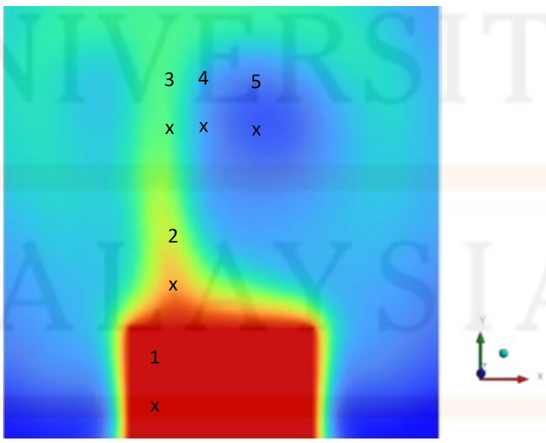
Figure 4.7: Heat Transfer Coefficient At 40 Voltage

The graph plots of a given material versus temperature. The voltage, in this example 40 volts, appears to be a parameter of the experiment or simulation, rather than impacting the HTC directly. The curve in the graph is growing, indicating that the HTC increases as the temperature rises. This is normal heat transfer behaviour, since a bigger temperature differential between the item and its surrounds allows heat to move more easily. Resizing the bus duct to 130mm x 130mm would alter its surface area. A bigger surface area often provides for better heat dissipation, potentially boosting the HTC. However, the impact will depend on various circumstances.

The heat transfer coefficient indicates how quickly heat may be transmitted from a surface to its surroundings. Indicated that the heat sink in the photograph has a width and height of 130 mm. The unit of measurement is generally W/m^2K. In the case of a bus duct, the heat transfer coefficient is used to calculate the rate at which heat is lost from the duct into the surrounding air. The graph demonstrates that the bus duct's heat transfer coefficient increases as its temperature rises. This is due to a higher temperature difference between the duct and the surrounding air, which accelerates the heat transfer process. The graph also illustrates that the heat transfer coefficient increases with increasing air velocity. This is because flowing air helps to remove heat from the duct surface faster.

The value of the HTC for a bus duct will be determined by a variety of parameters, including the duct's material, wall thickness, surface area, and air velocity. However, the graph may be used as a general reference to be understanding how a bus duct's heat transfer coefficient changes with temperature and air velocity. The voltage of the bus duct (40 volts in this example) is not proportional to the heat transfer coefficient. However, voltage has an effect on the quantity of heat created in the duct. This is because the power loss in the duct is equal to the square of the current passing through it. As a result, a higher voltage causes more power loss and, as a result, a greater heat transfer coefficient.

Forced convection, performed using fans or other mechanical devices, may dramatically enhance heat transmission. To guarantee optimum airflow, any fans or ventilation systems should be strategically placed and effective. The heat transfer coefficient measures the efficacy of heat transmission between the bus duct surface and the ambient air. Efficient ventilation benefits the HTC by allowing for greater heat dissipation. Then, temperature gradient; the graph presented previously may indicate temperature gradients along the surface of the bus duct. Efficient airflow reduces temperature differences and promotes consistent cooling.



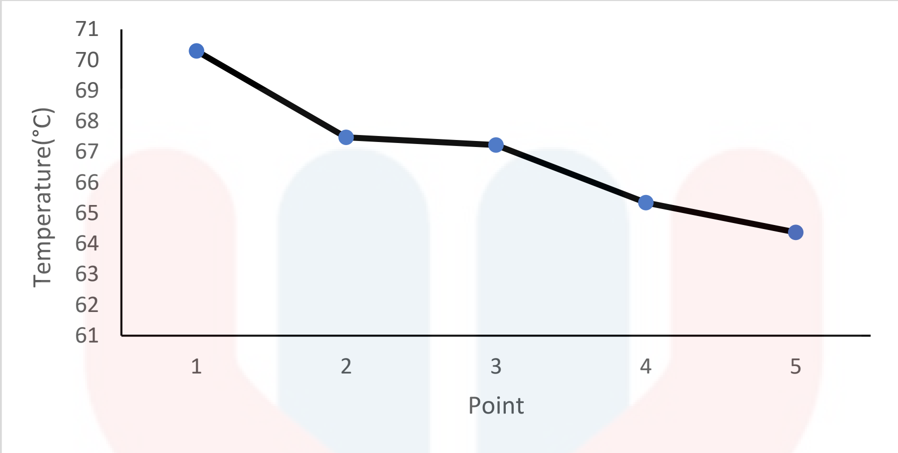


Figure 4.8: Temperature On Different Point at Normal Size Heat Sink (30 Volt)

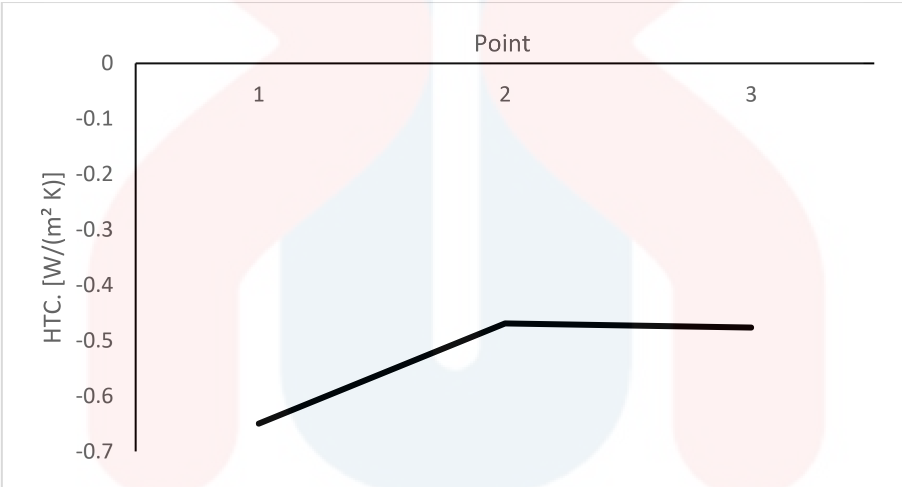


Figure 4.9: Heat Transfer Coefficient At 30 Voltage

The graph demonstrates that the bus duct's heat transfer coefficient increases as its temperature rises. This is due to a higher temperature difference between the duct and the surrounding air, which accelerates the heat transfer process. The heat transfer coefficient for a bus duct will vary depending on a variety of factors, including the duct's material. Different materials have varying thermal conductivities, which influence how readily heat flows through the duct wall. The duct wall's thickness comes next. A thicker duct wall will increase insulation and lower the heat transfer coefficient. The surface area of the duct also plays a role in this simulation. A bigger surface area allows more heat to be transported. Finally, flowing air helps to remove heat from the duct surface faster, improving the heat transfer coefficient.

In this graph, the voltage of the bus duct (30 volts) is not directly proportional to the heat transfer coefficient. Indicated that the bus duct in the figure has a width and height of 120 mm x 120 mm. However, voltage influences the quantity of heat created in the duct. This is because the power loss in the duct is equal to the square of the current passing through it. As a result, a higher voltage causes more power loss and, as a result, a greater heat transfer coefficient. It should be noted that the graph is most likely based on a specific simulation or experiment, and the heat transfer coefficient for a real bus duct may vary. However, the graph can help you understand how the heat transfer coefficient of a bus duct changes with temperature.

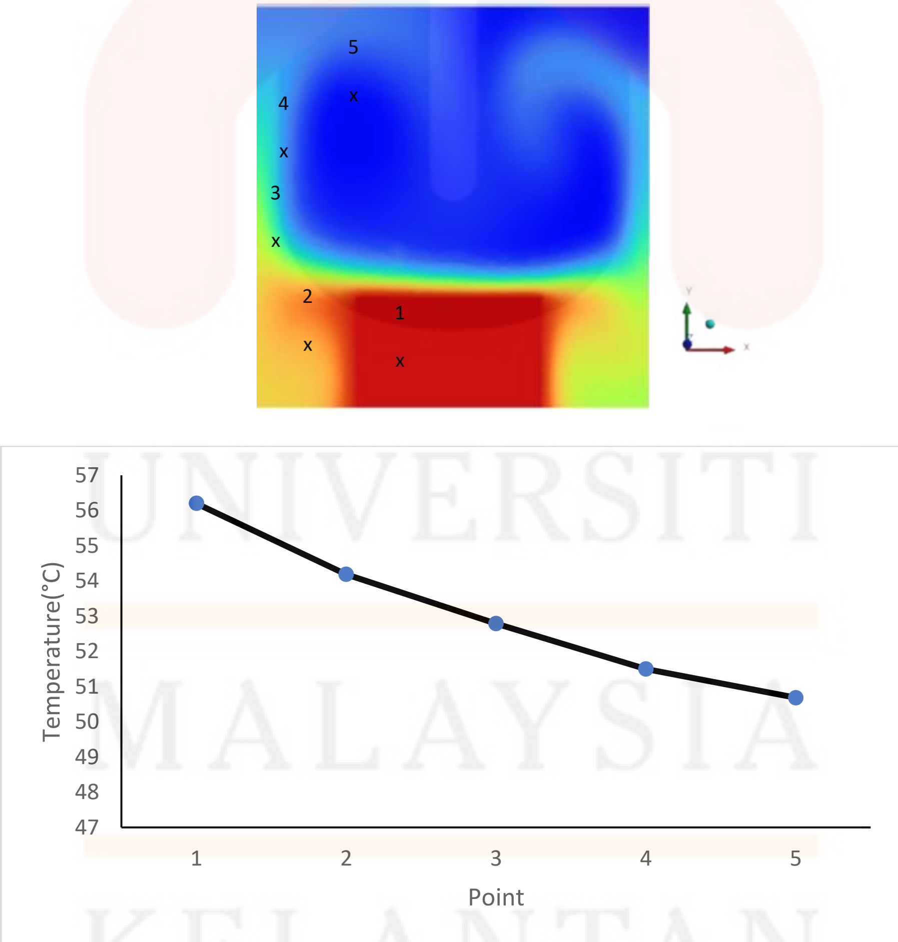


Figure 4.10: Temperature On Different Point at Normal Size Heat Sink (20 Volt)

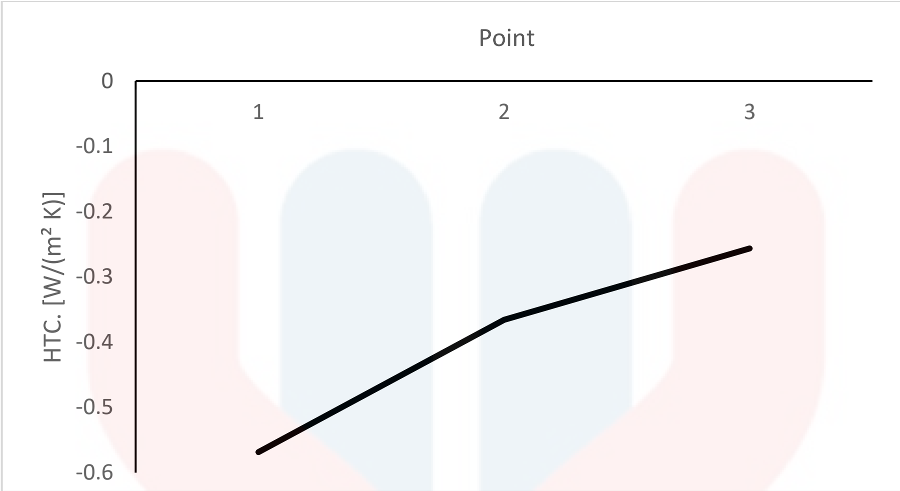


Figure 4.11: Heat Transfer Coefficient At 20 Voltage

The heat transfer coefficient indicates how quickly heat may be transmitted from the heat sink to its surroundings. The unit of measurement is generally W/m²K. The heat transfer coefficient for the heat sink in the image increases as its temperature rises. This is due to a higher temperature differential between the heat sink and the surrounding air, which accelerates the heat transfer process. Current handling capacity, bus ducts are designed to handle specified current loads. When changing the size of the bus duct, make sure that the new dimensions can carry the predicted current without overheating. The graph may depict how the system responds to varying current levels. The voltage of the heat sink (20 volts in this example) is not proportional to the heat transfer coefficient. However, the voltage influences how much heat is created in the device to which the heat sink is coupled. This is because the device's power loss is proportional to the square of the current passing through it. As a result, a higher voltage causes more power loss and, as a result, a greater rate of heat creation.

Heat dissipation depends on the size of the bus duct, particularly its cross-sectional area. Larger cross-sectional areas often provide better heat dissipation. As the size incraeases, it may result in better thermal performance, allowing the system to manage larger power loads more effectively. Then, the voltage of 20 volts is crucial. Changes in the size of the bus duct may have an impact on the voltage drop throughout its length. Ensure that the voltage at the endpoints is within acceptable limits since high voltage drop can cause inefficiencies and degrade the performance of linked devices.

The size of the heat sink will also influence the heat transfer coefficient. A bigger heat sink will have a larger surface area, allowing more heat to be transmitted to the ambient air. Indicated that the bus duct in the figure has a width and height of 110 mm x 110 mm. This is a modest heat sink, and a larger heat sink would most likely have a greater heat transfer coefficient. Additional elements that might influence a heat sink's heat transfer coefficient are listed below. The substance of the heat sink, various materials have varied thermal conductivities, which influence how readily heat flows through the heat sink. A rougher surface finish on the heat sink increases surface area and improves heat transmission. The presence of a fan can aid to drive air over the heat sink, hence increasing the heat transfer coefficient.

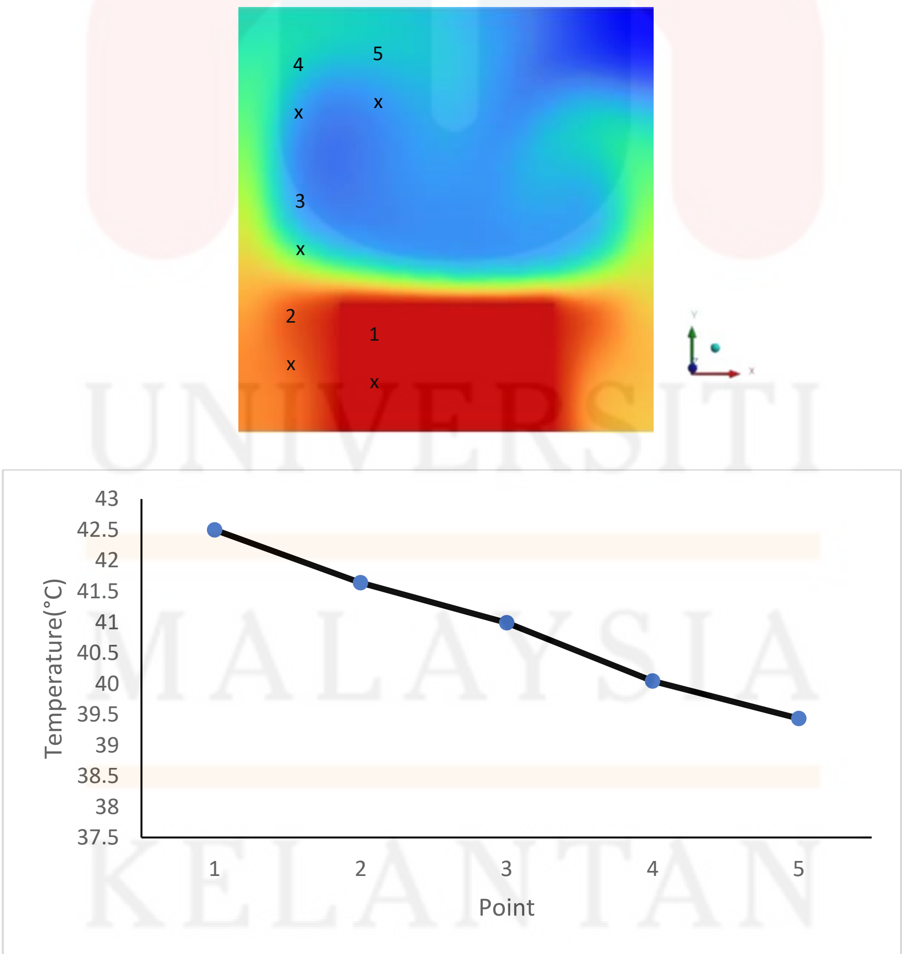


Figure 4.12: Temperature On Different Point at Normal Size Heat Sink (10 Volt)

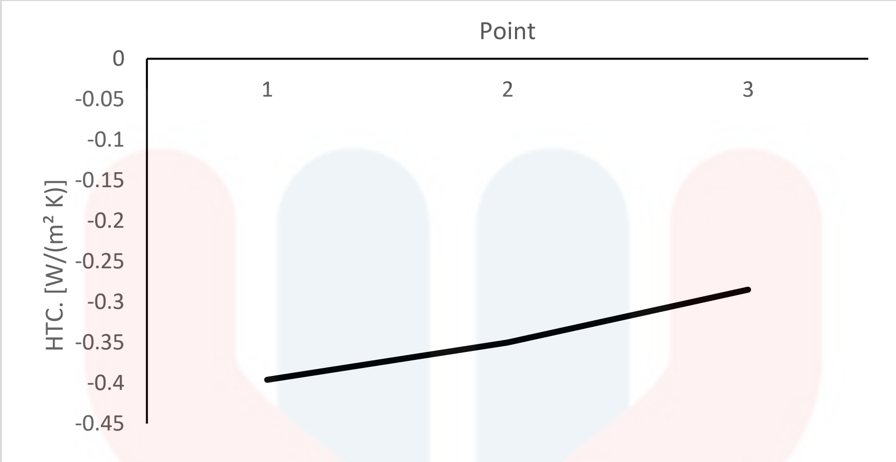


Figure 4.13: Heat Transfer Coefficient At 10 Voltage

This is a measurement of how quickly heat moves from a thing to its surroundings. Indicated that the bus duct in the figure has a width and height of 100 mm x 100 mm. It is often measured in Watts per square metre per Kelvin (W/m²K). In the case of a bus duct, the heat transfer coefficient indicates how easily heat dissipates from the duct into the surrounding air. Bus ducts are enclosed metal pipes that carry electrical current in power distribution networks. They frequently carry large currents, which can cause substantial heat loss. The heat transfer coefficient is critical in understanding and regulating heat loss.

Several factors affect the heat transfer coefficient of a bus duct, including: the thermal conductivity of the material used in the bus duct is critical, especially when it comes to regulating heat created during the transmission of electricity. The heat conductivity specifically in the context of aluminium, which is a regularly used material for bus ducts. Aluminium is another metal with strong heat conductivity, however not as high as copper. However, aluminium is frequently used for bus ducts because to its lesser weight and lower cost when compared to copper. While aluminium does not disperse heat as well as copper, it nevertheless delivers adequate thermal performance. Proper design considerations, such as size and cooling devices, can assist to alleviate heat-related difficulties with aluminium bus ducts.

When downsizing the bus duct to 100 mm width and 100 mm height, consider the influence on heat dissipation. A reduced cross-sectional size may impair the bus duct's thermal performance. Ensure that the resized dimensions are still adequate for the electrical load, and that any changes in thermal conductivity caused by size or material changes are included into the design. Then, the previously indicated voltage of 10 volts is most likely part of the system's electrical specification. It is critical to verify that the bus duct design can manage this voltage without generating excessive heat, which might result in inefficiencies or even system damage.

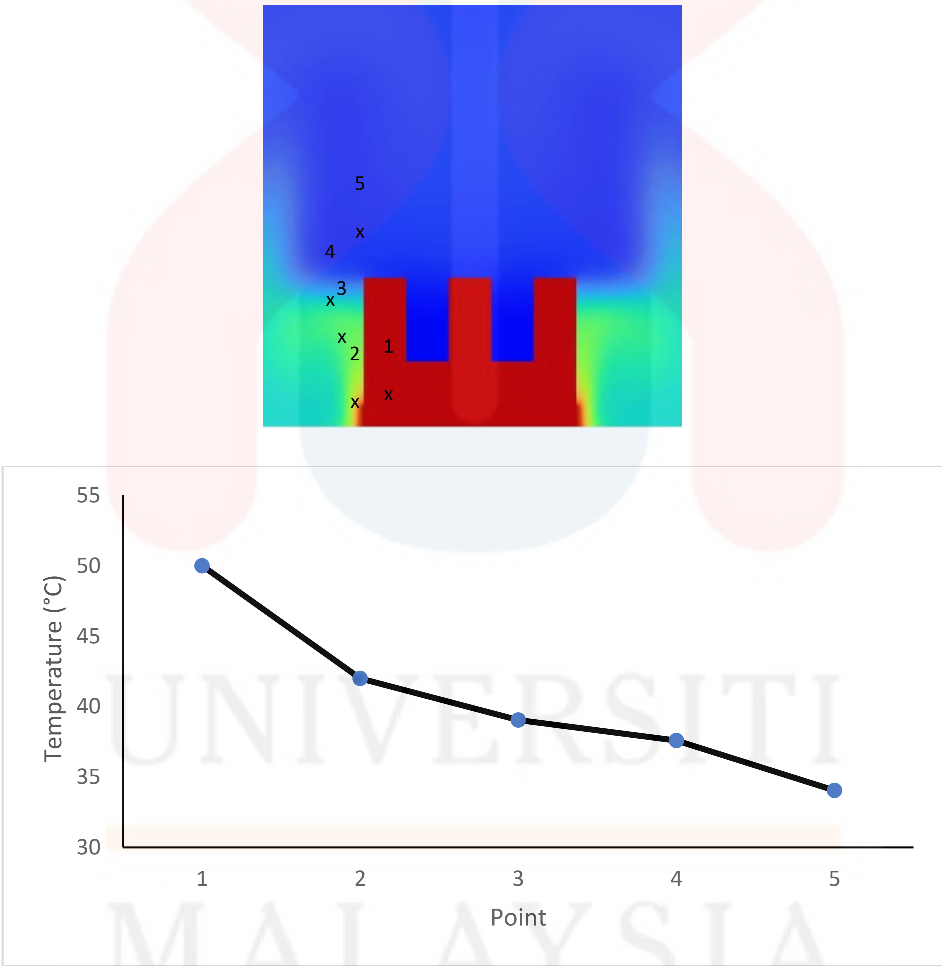


Figure 4.14: Temperature On Different Point at Heat Sink Three Fin Shape (10 Volt)

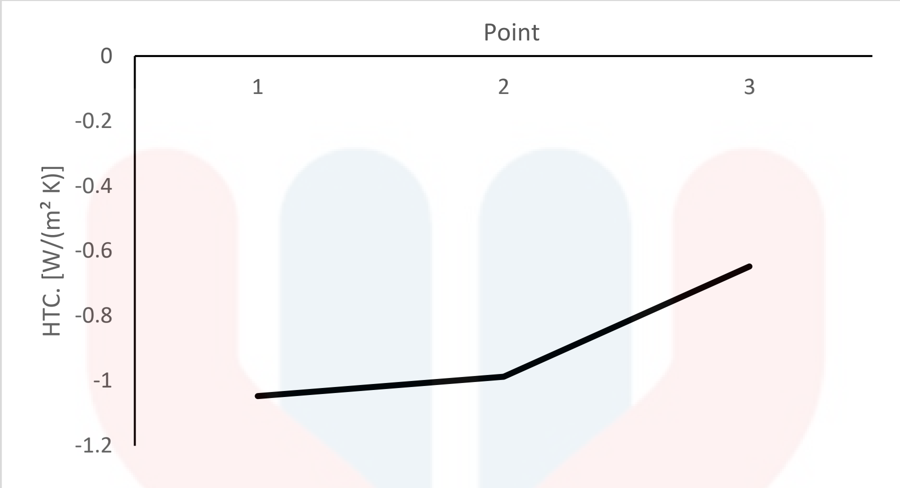


Figure 4.15: Heat Transfer Coefficient on Heat Sink Three Fin Shape (10 Volt)

The effectiveness of a heat sink is crucial in electrical equipment because it prevents overheating and keeps working conditions ideal. In this talk, we look at the thermal performance of a heat sink with three fin shapes while exposed to a 10-volt heat source on a hot plate. Indicated that the bus duct in the figure has a width and height of 100 mm x 100 mm. The shape of a heat sink influences its capacity to disperse heat effectively. Heat sinks are intended to transport thermal energy away from a heat-generating component, such as a power electronic device, and into the ambient environment. The number and shape of fins, fin spacing, and total size of the heat sink are the most important parameters influencing its performance.

Increasing the number of fins on a heat sink improves the available surface area for heat dissipation. More surface area provides for more efficient heat transmission to the surrounding air. The form of the fins can also affect the effectiveness of heat dissipation. Fin forms range from straight fins to pin fins or various elaborate patterns, all of which have an impact on air flow and heat sink performance. Then, fin spacing is a key metric. As you indicated, spacing the fins more apart can enhance surface area. This improves heat transmission by increasing airflow between the fins. However, there is a trade-off since excessive spacing might impair the efficacy of natural convection, particularly in situations where forced air cooling is not employed.

The heat sink's entire size, including volume and mass, affects its heat storage and dissipation capacity. Larger heat sinks have a greater surface area, but also a larger thermal mass. This thermal mass can influence the heat sink's reaction time and capacity to manage transient loads. Then, the heat sink's substance is critical. Aluminium and copper are common materials, with copper having a higher heat conductivity. The type of material used influences how well heat is transmitted away from the source. When mounting and interacting with a heat source, it's crucial to ensure proper contact. Proper installation and the use of thermal interface materials (TIMs) can help improve heat transmission between the two surfaces.

In computer simulations, especially those for heat transport in structures such as heat sinks, the mesh is an important part of the model. The mesh represents a discretization of the geometry, dividing it into smaller units or cells. The mesh cell size, often known as the mesh size, is an important parameter that influences the simulation's accuracy and computing efficiency. A finer resolution is required for modelling complicated structures, capturing features and fluctuations in temperature gradients more accurately. However, it raises computational costs since it requires more memory and processing time. Finer meshes are essential for modelling delicate features, resolving boundary layers in fluid dynamics, and increasing convergence.

However, it increases computational time. The mesh size used is determined by the computing resources available, and a balance must be found between refinement for accuracy and efficiency. A mesh sensitivity analysis assists in determining the appropriate mesh size, which balances accuracy and computing cost. To summarise, finer meshes are required for modelling complicated structures, resolving boundary layers, and producing consistent results.

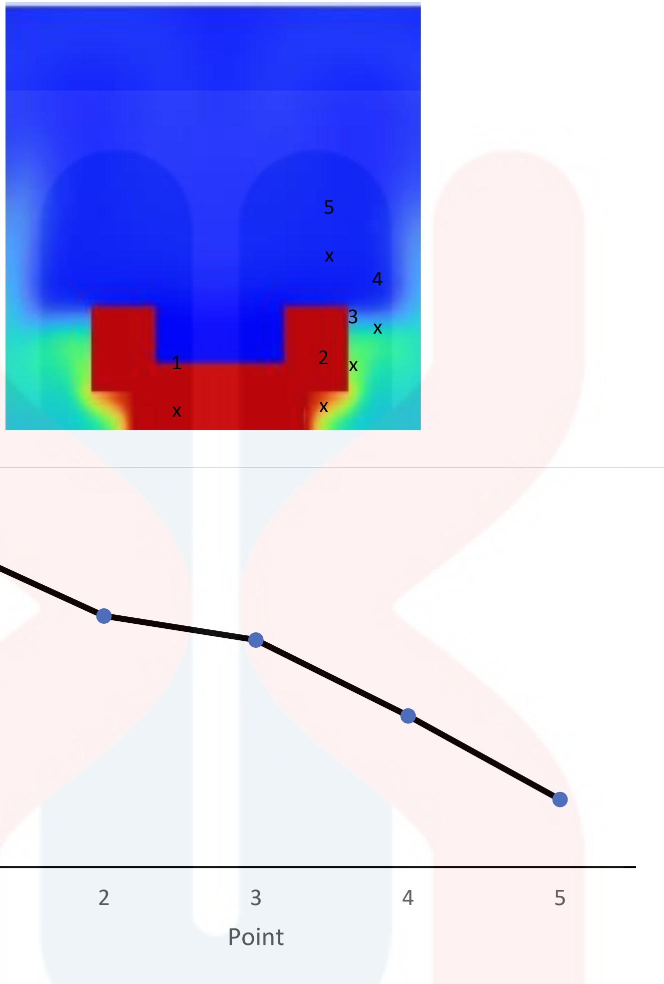


Figure 4.16: Temperature On Different Point at Heat Sink Bigger Than Hot Plate (30 volt)

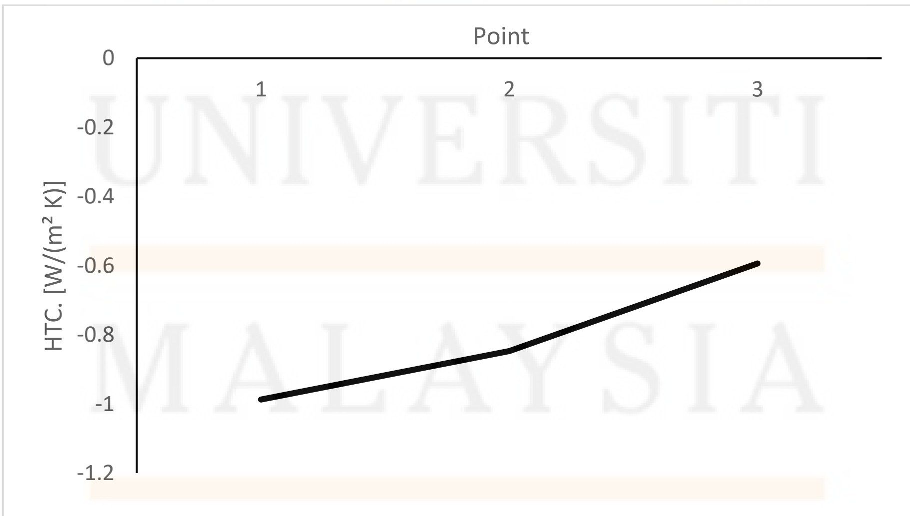


Figure 4.17: Heat Transfer Coefficient at Heat Sink Bigger Than Hot Plate (30 volt)

In this graph, the thermal dynamics, and concerns for a heat sink with three fins that is exposed to a 30-volt heat source on a hot plate. Notably, the heat sink is bigger than the hotplate and has wider fin spacing than traditional heat sink designs. Indicated that the bus duct in the figure has a width and height of 120 mm x 120 mm. The study looks at the thermal performance of a heat sink in the presence of a 30-volt heat source. The greater heat sink size and wider fin spacing are important factors, and their effects on heat dissipation will be investigated. A heat sinks greater than the hotplate indicates a wide surface area for heat dissipation. Increased size may have an impact on thermal capacity, decreasing the heat sink's ability to absorb and disperse heat effectively. The study will determine if bigger sizes improve or degrade overall thermal performance.

A heat sink's size has a considerable impact on its capacity to properly disperse heat. A bigger heat sink has more surface area, which allows for better interaction with the surrounding air, improving convective heat transfer and perhaps leading to more effective cooling. This improves thermal capacity and heat absorption, resulting in a more stable temperature profile, particularly in settings with variable thermal loads. A bigger heat sink can also disperse heat more evenly over its surface, reducing localised hotspots and contributing to a more uniform temperature distribution. However, material conductivity, fin design, and contact materials all have an impact on the system's total heat resistance.

The greater fin spacing is an intriguing element. While this increases the accessible surface area for heat dissipation, it may have an influence on the convection process. The discussion will focus on how larger fin spacing affects convective airflow, thermal gradients, and overall heat transfer characteristics. Then, the use of a 30-volt heat source generates a substantial thermal burden. Higher voltages often result in higher power dissipation, raising the bar for efficient heat dissipation. The study will look at how the heat sink handles the increased thermal load and whether greater fin spacing is useful in this situation.

Thermal simulations rely on exact boundary conditions to correctly represent and forecast real-world circumstances. When dealing with a 30-volt input on a hotplate and a heat sink with three fins, it is critical to set boundary conditions that are representative of real-world situations. These conditions include power dissipation, the convection coefficient, and the thermal interface material (TIM).

Power dissipation can be expressed as a heat flow or temperature, whereas convection coefficients represent heat transfer characteristics between the hotplate surface and the surrounding air. The choice of convection coefficients is determined by airflow velocity, temperature gradients, and surface features.

Bus ducts are critical components in electrical systems that distribute electricity throughout industrial sites and huge buildings. Passive cooling systems, particularly those using enormous heat sinks, can be an effective way to regulate heat generated within bus ducts. The 30-volt hot plate replicates a large heat source within the bus duct. This voltage most likely indicates power dissipation, and it is critical to identify whether it is static or dynamic. Understanding the power input is essential for effectively modelling and forecasting temperature distributions in the bus duct. The use of an enormous heat sink shows that the design was intended to assist passive cooling. The increased surface area of the heat sink is intended to facilitate heat dissipation. However, it is critical to combine this with practical factors such as space restrictions and financial repercussions.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, evaluate between thermal experiment and simulation of thermal performance on heat existing for passive cooling, we can conclude the different result may be from their material properties. The accuracy of simulation result depends on the accuracy of input material properties used in the simulation model. If the properties used in the simulation do not perfectly match those of the material used in experiments, it can result in differences in results. Second, it may be from the measurement errors. Experimental results can be affected by measurement errors or uncertainties used to collect data. Similarly, simulation results may be influenced by numerical errors or inaccuracies in the computational algorithms used.

Besides, to investigate the parameter of during for different thermal on heat existing in bus duct involves optimizing thermal management through considerations of size electric bus duct, heat sink design, and voltage impact. Varying sizes electric bus duct affect heat dissipation dynamics, with larger ducts offering increased surface area for cooling but potentially higher internal heat generation. For examples, in this research used 100 mm width and height for electrical bus duct size. The shape of the heat sinks plays a crucial role, with different designs influencing airflow and convective heat transfer efficiency like used normal design, two fin shape and three fin shape. Additionally, voltage directly impacts heat generation, requiring adjustments in cooling strategies to maintain optimal operating temperatures such as 10 until 50 volts.

Passive cooling methods in bus ducts offer a solution for managing heat generated by electrical components without energy-intensive active cooling systems. They enhance energy efficiency, equipment reliability, and operational safety in electrical distribution systems. Despite challenges like optimizing heat dissipation, space constraints, and environmental variability, passive cooling offers energy savings, equipment longevity, and sustainability. To provide passive cooling in bus ducts, many important strategies can be used.

Ventilation design is crucial for passive cooling strategies in bus duct systems, as it enhances natural airflow, facilitates heat dissipation, and maintains optimal operating temperature. The design of a bus duct system involves several factors, including location, spacing, duct orientation, cross ventilation, aerodynamic considerations, louvers or grilles, thermal insulation placement, adjustable openings, protection against environmental factors, natural convection enhancement, and computational fluid dynamics (CFD) analysis. Proper spacing between ventilation openings promotes uniform airflow and prevents hotspots.

The bus duct should align with natural airflow, capturing prevailing winds or considering the stack effect in vertical ducts. Cross-sectional designs encourage cross ventilation, while aerodynamic considerations minimize resistance to airflow. Louvers or grilles can control the direction of airflow, preventing rain or debris ingress. Thermal insulation should not obstruct ventilation openings, and adjustable openings can adapt to varying environmental conditions. Protection against adverse weather conditions, such as rain or strong winds, can be achieved through protective covers or angled configurations.

Next, thermal insulation is critical in passive cooling solutions for bus ducts, as it helps to reduce heat absorption from the surrounding environment and maintain lower inside temperatures. Insulation that is properly built can help with energy efficiency and lessen the need for extra cooling measures. To ensure a successful insulation system, choose materials with high thermal resistance, such as fiberglass, mineral wool, foam boards, or reflective foils. Determine the appropriate insulation thickness based on thermal conductivity and desired heat resistance.

Encapsulate the entire bus duct with thermal insulation, including exterior surfaces. Seal joints and connections properly to prevent heat penetration. Consider using radiant barriers or reflective coatings to reduce heat absorption and moisture ingress. Choose insulation materials that are durable and resistant to environmental factors like UV radiation and temperature variations. Design protective insulation enclosures considering the surrounding environment. Conduct thermal analysis to optimize insulation thickness and material selection. Develop a maintenance plan to maintain the system's long-term effectiveness.

Lastly, when included into the design of bus duct systems, heat dissipation fins are an effective passive cooling approach. Fins expand the accessible surface area for heat exchange, allowing natural convection and radiation to dissipate heat into the surrounding environment.

5.2 Recommendations

A thermal study of a bus duct system entails determining temperature distribution, identifying probable heat concentration regions, and measuring the efficacy of current passive cooling techniques. Defining objectives, gathering system information, modelling the geometry, assigning material properties, defining boundary conditions, generating a mesh, configuring a solver, running the analysis, post-processing, evaluating existing cooling measures, and conducting sensitivity analyses are all part of the process. Ambient temperature, heat sources, insulating materials, and natural convection and radiation should all be included in the study. The findings should be visualised and analysed to discover hot spots and temperature gradients. The investigation should also assess the efficacy of current cooling methods and suggest areas for improvement.

To optimize a bus duct system's ventilation design, we can follow the process involves reviewing existing design, conducting a Computational Fluid Dynamics (CFD) analysis to visualize airflow patterns, assessing environmental conditions, optimizing opening placement and size, integrating louvers or grilles for airflow control, implementing cross ventilation, evaluating ventilation ducts to facilitate desired airflow without resistance, monitoring temperature distribution using CFD analysis results, iterating and optimizing the design based on simulation results and performance feedback, incorporating temperature sensors for real-time temperature variations, and considering variable ventilation systems to adjust opening sizes or configurations.

SUMMARY

Heat dissipation fins can improve thermal performance by increasing heat exchange surface area. Assess thermal needs, choose an appropriate material, calculate fin size, optimise fin shape, evaluate fin location, align fin orientation, and optimise fin spacing before incorporating fins. Iteratively integrate fin structures, investigate different fin configurations, do computational fluid dynamics analysis, and fine-tune fin shape. Consider using protective coatings to defend against corrosion and environmental damage. Assess structural integrity to verify that the fins do not jeopardise the duct's stability and strength. For future reference and any design changes, document the fin design, including dimensions, materials, and simulation results. This method guarantees optimum heat dissipation while taking into account practical limits. Additionally, the fins should be protected against corrosion and environmental damage.

Environmental factors such as local climate, temperature extremes, humidity levels, wind patterns, solar radiation, geographical location, rainfall and water exposure, corrosion potential, and seasonal changes must all be considered when designing passive cooling solutions for a bus duct system. These variables can have a considerable impact on the effectiveness of cooling techniques as well as the overall thermal performance of the bus duct system. Last but not least, the size of the bus duct, the shape of the attached heat sink, and the voltage applied all play crucial roles in determining the thermal performance and effectiveness of passive cooling systems. Understanding these factors allows for the design of optimized cooling solutions tailored to specific application requirements.

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