STUDY ON BODY TEMPERATURE EFFECT TOWARDS WORKERS THAT WORKS IN HOT AMBIENT BY USING COOLING FAN

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (REFRIGERATION AND AIR CONDITIONING SYSTEMS) WITH HONORS

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Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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**A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (Refrigeration And Air Conditioning Systems) With Honors**

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical and Manufacturing Engineering Technology

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2022

DECLARATION

I declare that this thesis entitled "Study On Body Temperature Effect Towards Workers That Work in Hot Ambient By Using Cooling Fan" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

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Date : 17/01/2022

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APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Refrigeration And Air Conditioning Systems) With Honors

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DEDICATION

I would like to dedicate my work to my beloved parents

Mohamad Sukairi Bin Sohot and Zaleha Binti Anuar

Thank you for your warmest and softness in taking care of me, supporting, advisory and

That gives my life happiness all the time.

To my supervisor, Ts. Azman Bin Ibrahim and all my friends,

Thanks for all the supports.

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ABSTRACT

The term global warming refers to the increase in the global average temperature. Global warming is expected to produce a 2-5 degrees Celcius increase in the Earth's temperature by the end of the 21st century. As a result, long-term exposure to hot and humid surroundings makes workers feel uncomfortable and causes excessive sweating, affecting their performance. Personal electric cooling fans are one of the potential solutions to increase the productivity and efficiency of the workers. Previous research and innovation are studied throughout this research. The objective is to learn the effect of prolonged exposure of direct sunlight towards body temperature and develop an optimization design concept of the Fabric Duct Fan Belt. This research will be using Mini Hanging Waist Fan as the main supply and fabric duct design as the design concept. This study aimed to examine the effects of temperature body with and without Fabric Duct Fan Belt using an electric cooling fan as the main supply. Subjects aged 24 underwent six 20 minutes experiments with body temperature recorded every 30 seconds. The investigation is conducted with an ambient temperature of 37 ºC, 60% relative humidity, 0.3m/s air velocity, and 450 W/m^2 of solar radiation. Subjects were given a bottle of water with 350ml that could be drunk during the ongoing experiment. Ambient temperature and temperature of the front and back of the body are aiming to be measured. The analyses prove that continuous air flows circulating the body can reduce and maintain body temperature. This research used a C shape to balance the airflow throughout the body in terms of shape. Finally, the minimum number of holes for the Fabric Duct Fan Belt is 25. If less than 25 holes, the temperature will rise and does not in the control condition.

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ABSTRAK

Istilah pemanasan global merujuk kepada peningkatan suhu purata global. Pemanasan global dijangka menghasilkan peningkatan 2-5 darjah Celcius dalam suhu Bumi menjelang akhir abad ke-21. Akibatnya, pendedahan jangka panjang kepada persekitaran yang panas dan lembap menyebabkan pekerja berasa tidak selesa dan menyebabkan berpeluh berlebihan yang boleh menjejaskan prestasi mereka. Kipas penyejuk elektrik peribadi adalah salah satu penyelesaian yang berpotensi untuk meningkatkan produktiviti dan kecekapan pekerja. Penyelidikan dan inovasi terdahulu dikaji sepanjang penyelidikan ini. Objektifnya adalah untuk mengkaji kesan pendedahan berpanjangan cahaya matahari langsung terhadap suhu badan dan untuk membangunkan dan mengoptimumkan konsep reka bentuk Tali Kipas Saluran Fabrik. Penyelidikan ini akan menggunakan Kipas Pinggang Gantung Mini sebagai bekalan utama dan reka bentuk saluran fabrik sebagai konsep reka bentuk. Kajian ini bertujuan untuk mengkaji kesan suhu badan dengan dan tanpa Fabric Duct Fan Belt menggunakan kipas penyejuk elektrik sebagai bekalan utama. Subjek yang berumur 24 tahun menjalani eksperimen enam 20 minit dengan suhu badan yang direkodkan setiap 30 saat. Eksperimen dijalankan dengan suhu ambien 37 ºC, 60% kelembapan relatif, halaju udara 0.3m/s, dan 450 W/m² sinaran suria. Subjek diberi sebotol air dengan kuantiti 350ml yang boleh diminum semasa eksperimen dijalankan. Suhu ambien dan suhu depan dan belakang badan bertujuan untuk diukur. Keputusan daripada analisis membuktikan bahawa aliran udara berterusan yang beredar dalam badan boleh mengurangkan dan mengekalkan suhu badan. Dari segi bentuk, kajian ini menggunakan bentuk C untuk mengimbangi aliran udara ke seluruh badan. Akhir sekali, bilangan lubang minimum untuk Tali Kipas Saluran Fabrik ialah 25. Jika kurang daripada 25 lubang, suhu akan meningkat dan tidak berada dalam keadaan kawalan.

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In the Name of Allah, the Most Gracious, the Most Merciful

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LIST OF SYMBOLS AND ABBREVIATIONS

D,d	-	Diameter
WGBT	-	Wet Bulb Globe Temperature
AC	-	Alternating Current
DC	-	Direct Current
DOSH	-	Department Occupational Safety and Health
HVAC	-	Heating and Ventilation Air Conditioning
IAQ	-	Indoor Air Quality
ASHRAE	-	American Society of Heating, Refrigeration, and Air-Conditioning
OSHA	-	Occupational Safety and Health Administration
HIRARC	-	Hazard Identification, Risk Assessment, and Risk Control
PPE	-	Personal Protective Equipment
TLVs	-	Threshold Limit Value
BEIs	-	Biological Exposure Indices
ACGIH	-	American Conference of Governmental and Industrial Hygienists
T_{db}	-	Dry Bulb Temperature
T_{nwb}	-	Natural Wet Bulb Temperature
T_g	-	Globe Temperature
Rh	-	Relative Humidity
V	-	Air Velocity
PCM	-	Phase Change Materials
HCV	-	Hybrid Cooling Vest
TPU	-	Thermoplastic Polyurethane film
CAD	-	Computer-Aided Design

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CHAPTER 1

INTRODUCTION

1.1 Background

The term global warming refers to the increase in the global average temperature. In other words, it is the process of our entire world heating up. The planet warmed by an average of 1°C during the previous century. This may not appear to be a massive change, but it has the potential to significantly influence people and animals all over the world at present and in the future. Global warming is expected to produce a 2-5 degrees Celcius increase in the Earth's temperature by the end of the 21st century. And, as a result of climate change, our weather will become more unpredictable, threatening the extinction of many species and making life much more difficult.

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The greenhouse effect causes climate change, a natural phenomenon. Humans have consumed enormous amounts of fossil fuels like oil and gas since the industrial revolution. Fossil fuels release massive amounts of carbon dioxide into the atmosphere. During this process, the gases released into the atmosphere act as an unseen "blanket" warming the Earth and trapping heat from the Sun. The "Greenhouse Effect" is the name for this phenomenon. Not only that, deforestation contributes significantly to global warming. Trees take a large quantity of carbon dioxide from the air and release oxygen back into it. Unfortunately, people are cutting down many rainforests to manufacture furniture and paper and create highways, oil mining, dams, and urban development. As a result of reducing the number of trees and forests, carbon dioxide stays in the atmosphere and warms the planet.

There are many sectors of the industry affected by global warming. One of the affected sectors is outdoor workers such as manufacturing, mining, quarrying, construction, and agriculture. Mostly, all of this sector can’t be avoid working under the hot temperature. Working in higher temperatures are the risk that employees confront due to climate change. Heat-related illnesses, stress, and tiredness can put these employees at risk of harm. Workers may also have less control than the broader population over their exposure to high temperatures (Smith, 2016).

As the problem of climate change is increasing, Schuyler Wheeler invented the first electric fan in 1886 (Tech, 2014). This innovation has sparked a revolution in the world. Initially, early fans were made all DC powered. Fans using AC motors began to be manufactured after the 1890s. GE introduced a version with overlapping blades in the late 1920s, which made the fans significantly quieter. Other materials, such as nylon and wood, were utilized in the designs as the decades advanced. After the 1920s, there were additional colours and styles. Previously, fans were only available in black.

However, due to the large size of the fans, they cannot be taken anywhere into the sites or hot environment by outdoor workers. Therefore, the innovation of fans has been thriving toward modern fans. Modern fans are composed mainly of plastic and contain far fewer materials. The use of rare-earth elements in motor magnets, such as cobalt-iron alloys, allows sure high-end fans to be compact and powerful.

This research aims to develop a design and fabricate for Fabric Duct Fan Belt that has been modified for improvement from conventional fans. This research will be using a mini hanging waist fan as the main supply for cooling the body temperature. This device will be using a fabric duct as the design concept. The Fabric Duct Fan Belt will be measured on human subjects to get physiological data and subjective comfort.

1.2 Problem Statement

Workers in hot environments are at risk of developing severe heat-related sickness, leading to fatal incidents. Therefore, from an emotional and financial standpoint, it is essential to protect workers from heat-related sickness. Ilangkumaran et al. (2015) stated that hot environment sectors include foundries, steel mills, and glass manufacturers, require workers to operate near furnaces and extremely hot or molten metal. According to Aryal et al. (2017), the hot environment sectors generally involve physically tricky jobs frequently done in harsh environments, leading to tiredness, poor judgment, poor job quality, an increased risk of accidents, and lack of job satisfaction.

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Workers forced to work in extreme temperatures while performing complicated physical tasks in direct sunlight are more likely at risk of heat stress (Jungsun Park, Yangho Kim, and Inbo Oh, 2017). Heatstroke, heat exhaustion, heat syncope, heat cramps, heat rashes, and even death resulting from long-term exposure to extreme temperatures. Due to global temperatures being predicted to rise due to global climate change, heat-related sickness will become a more significant issue for outdoor workers (Rebekah A I Lucas et Al. 2014). Recent studies reported that working in higher temperatures is the risk employees confront due to climate change. Workers may also have less control than the broader population over their exposure to high temperatures (Smith, 2016).

The ability to provide comfort is getting more difficult because of global warming. Therefore, Innovation is required to cool the body temperature of outdoor workers to provide comfortable working environments in warm or hot weather. The previous study has utilized various personal and local cooling techniques to minimize heat stress on outdoor workers (Ouahrani et al., 2017). Moving air across the skin with devices like electric fans provides an individual-level cooling method. In other words, it can avoid the problem associated with refrigerant gases and reduce power consumption by 30% (Morris et Al. 2021).

Concerning the current 35ºC threshold for fan usage is based on the fact that once the ambient temperature reaches skin temperature, fan use increases the rate of convective heat gain to the body from the surrounding environment. This factor can significantly increase sweat evaporation (Morris et Al. 2021). However, fan usage is usually prohibited at critical ambient temperatures ranging from as low as 32.3 ºC with 35% relative humidity to between 35.6 ºC and 37.2 ºC without humidity specified. Surprisingly, these suggestions do not appear to be founded on any experimental data since the Cochrane Collaboration recently stated that no evidence presently exists in the literature supporting or opposing the usage of electric fans during climate change (Morris, 2014).

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1.3 Objective of Research

This research aims to develop personal cooling using electric fans as the main power and using the belt and fabric duct as the conceptual design. Specifically, the objectives are as follows:-

i) To study the effect of prolonged exposure of direct sunlight towards body temperature

ii) To study the effect of body temperature with and without Fabric Duct Fan Belt.

iii) To fabricate and optimization design concept of Fabric Duct Fan Belt

1.4 Scope of Research

The limitation of this project is based on the following scopes:

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- Fabricate of fabric duct fan belt is only available for 3-4 hours usage using high-speed mode.
- Fabricate especially for outdoor workers that work in a hot and humid environment
- Fabricate of Fabric Duct Fan Belt is only for workers that have a range of waist circumstances around 28-40 inches

1.5 1.5 Rationale for Research

Thousands of research have been conducted to investigate various elements of climate change. However, this topic is far from being exhausted as a research field. New research in the field of climate change may be performed to examine the effects of cooling garments on workers like cooling vests using phase change material (PCM), cooling safety helmets using PCM, and Head-neck cooling using Peltier on outdoor workers applications. Alternatively, this research has specifically studied the hot environment outdoor workers face while performing a task. The effect of the hot climate of 2015-2021 may be examined in-depth manner. The same idea applies to almost every aspect of industry and economics.

This study evaluates experimentally electric fan cooling on the belt performance and fabric duct when incorporating two electric fan cooling units. The last study objective tackles the back body, neck, and head, while this research aims to vary air distribution on the front, back, and side bodies. In other words, this research aims to tackle all over the area body. Experiments on four volunteers were conducted to assess the cooling rate observed with the electric cooling fan after sunbathing in the middle of direct sunlight. The temperature of the body and airflow rate aim to be measured for 20 minutes, and the data will be recorded every 30 seconds. The experiment was conducted in an opening condition in a warm area with a temperature of 30-32ºC, 60% relative humidity, 0.3 m/s air velocity, and 450 W/m² of solar radiation.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This literature review chapter will cover information and summarize body temperature effects on workers who work in hot ambient and their characteristic. This section explains how to obtain and summarize relevant information using reviews of journals, books, internet tools, articles and, other sources. It provided context information for the studies and served as a reference for the project's later stages. Besides, this chapter will provide information on human comfort, type of jobs that exposed to heat, problems faced by the workers when working in hot ambient, the benchmark of the Department of Occupational Safety and Health (DOSH), where heat sources come from, how the body reacts to heat, and current innovation

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Working in a hot environment or being exposed to high temperatures for the long term can put the body under a lot of strain. Dehydration and fatigue can cause body disturbances when combined with physical activities. This can lead to severe health conditions for staff working in hot ambient, which may increase workplace accidents. The results of compliance exercises and heat stress tests at different workplaces revealed that many Malaysian workplaces with machinery or processes that operate at high temperatures are at risk.

Because of the Sun, occupational employees are at risk of heat stress. The mission requires physical exertion, hot working conditions, and clothing and tools for selfprotection. Cooling interventions aim to improve body heat dissipation through evaporation, conduction, and convection to prevent excessive heat accumulation and work efficiency disability. Previous experiments have used personal and local cooling approaches to minimize thermal stress on outdoor employees to have safe working spaces in hot or humid environments.

2.2 Human Comfort

Human comfort is the expression level of satisfaction with a matter condition in the environment. According to the perceptional of individuals, the most common maters are heat (thermal energy) and air purity, sound, and lighting. In an HVAC system, the aim is to provide human thermal comfort. Human thermal comfort is when people accept the thermal environment (environment) with the Indoor Air Quality (IAQ).

According to ASHRAE (1992), Thermal comfort is a physiological state that reflects pleasure with the thermal environment. Due to its importance in all aspects of life, human thermal comfort has gained worldwide popularity. Humans generally feel comfortable between 22 ºC to 27 ºC and relative humidity of 40% to 60 %. Humans are constant-temperature species, with an average of about 98.6ºF (37.0 ºC). Since heat is emitted in the body due to thermal activity, it can be regulated by altering metabolism. The body must reject heat at the correct rate to preserve thermal equilibrium.

The absence of discomfort is the most significant definition of comfort. When people are either hot or cold or when the air is odorous and stale, they feel uncomfortable. Positive comfort environments are uncomfortable weather, draughts, humidity, or other aspects of the environment. Ideally, people should not be aware of machinery noise, humidity, or air movement in an adequately conditioned room.

The eyes, ears, nose, tactile sensors, heat sensors, and brain all contribute to the sensation of comfort. Thermal comfort is the state of mind that is comfortable with the temperature of the environment, therefore the condition of minimal activation of the skin's heat receptors and the brain's heat-sensing section. Maintaining thermal comfort entails keeping them from being too hot or cold. This entails maintaining an appropriate range of temperature, humidity, airflow, and radiant sources. Our bodies produce heat due to this operation, which must be dissipated into the surrounding air of surfaces.

2.3 Type of Jobs That Exposed to Hot environment

Heat stress can affect workers subjected to excessive heat or work in hot conditions. Extreme heat can lead to work-related illnesses and accidents. Hot stroke, heat exhaustion, heat cramps, and heat rashes are all symptoms of heat stress. In addition, staff will be more exposed to harm due to sweaty palms, fogged-up safety glasses, and dizziness caused by the heat.

Workers exposed to the hot indoor environment or hot and humid conditions outdoors, especially those demanding work activities or wearing bulky or non-breathable protective clothing and equipment, are at risk of heat-related illness. In addition, according to the Department of Occupational Safety and Health (2016), some workers such as new workers, migrant employees, or those returning to work after a week or more leave may be at greater risk than others if they have not developed a tolerance for hot temperatures, or if they have such health problems. Examples of workplaces where people might suffer from heat stress because of the environment can be found in Table 1.

Table 2. 1 Activities Exposed To Heat by Economic Sector (Department of Occupational Safety and Health, 2016)

Sector	Example of workplaces	Activities
Manufacturing	Glass and rubber manufacturing plants, chemical plants, conventional and nuclear power plants	Foundries and smelting facilities, metal mining, and support oil and gas operations activities. Operation of boilers, sterilizers, and furnaces operations.
Mining and Quarrying	Limestone and granite quarries. Gold and bauxite mining	Blasting, loading, site clearing, hauling and crushing
Construction	Building and residential construction	Tunnelling, bricklaying, bar bending. Plastering, painting
Agriculture, Forestry, and Fishing	Palm oil plantations, paddy fields	Farming, logging, harvesting, seeding, animal feedings
Utilities	Gas processing plants, water processing plants, power plants	Heavy work under the hot Sun, cleaning
Transport, Storage, and Communication	Depot, telecommunication substation	Mail delivery, manual handling, vehicle maintenance, cable installation
Wholesale and Retail Trades	Warehouse	Stock transfer and replenishment, Manual handling
Hotels and Restaurants	Bakeries, commercial kitchen, confectioneries	Cooking, bread/cake baking
Finance, insurance, Real Estate, and Business Services	Laundries, Landfills, Waste-water treatment plants, office building	Dry cleaning, drying and pressing (ironing), domestic waste collection and segregation, cleaning/painting of an exterior building
Public Services and Statutory Authorities	Training centre (outdoor), federal/state road, government hospital	Field Training, Fire-fighting, road-traffic control, clinical waste collection

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2.4 Risk of Injuries Due to Heat Exposure

Working in hot conditions can cause heat stress and various illnesses ranging from heat rash to heatstroke. The cumulative heat load levied on the body is proportional to the number of environmental and physical labour factors that include the source of heat, level of work, the acclimatization of the worker, and the atmospheric conditions (Temperature Extremes the Workplace | Communications Workers of America, 2010). Zhang et Al. (2021) stated that the findings revealed that labour intensity and thermal radiation directly impacted the physiological parameters of the human body. Heat stress is shown by a rise in core temperature, linked to thermoregulation, physical activity, exhaustion, and increased health risks (Zhang et Al., 2021).

The acronym for heatstroke in the International Classification of Diseases, 9th Revision (World Health Organization, Geneva) is 992. Data was collected for three age ranges of males and females: 0-14, 15-64, and >65 years old (Piver et Al., 1999). Heat cramps, heat exhaustion, and severe heatstroke are all symptoms of heatstroke, which is defined by a core body temperature of more than 40.6ºC and multiple organ dysfunction (Piver et Al., 1999). D. Fang et Al. (2015) discuss that fatigue stage of 20 has been described as a threshold point at which fatigue effects begin to manifest. When a worker’s fatigue level is less than 20, fatigue has little impact on their safety results. There is a linear relationship between fatigue levels and error rates where a worker’s fatigue level reaches 20. By discriminating between two categories of errors, the study’s findings also indicate that while workers’ fatigue levels are above 20, their mistakes are primarily due to danger awareness loss. However, as exhaustion builds up, it directly affects workers' ability to monitor their movement (D. Fang et Al., 2015).

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Heatstroke is a general term for physical conditions that arise when the body's water and sodium equilibrium fails or when it cannot control its internal temperature in a high temperature and high humidity (Naoya Tamura and Takehiro Tanaka, 2016). Exposure to heat for an extended period can increase the risk of traumatic injuries in outdoor workers. Agriculture and construction are among the sectors in the United States with the highest rates of fatal accidents, so traumatic injuries are of particular concern to them (Spector et al., 2016).

Recently, A Filipino factory worker died after his head became trapped in a mould-making machine in Bukit Minyak, Bukit Tengah, Penang. The 35-year-old male victim was declared dead at the scene after suffering a severe facial injury at about 7 a.m (Astro Awani, 2017). A year after, a crane collapsed near Lebuhraya Lingkaran Tengah 2 (MRR2) in Ampang elicited a range of reactions from road users, who generally complained of heavy traffic congestion. The incident occurred at 9.45 a.m, causing four kilometres of traffic congestion between Hulu Klang and Ampang (Astro Awani, 2018). Another incident happened three years after that where two construction workers were killed, and two others were seriously wounded when a crane collapsed on a car at a highway construction site in Puncak Banyan, Persiaran Alam Damai, to reports (MSTAR, 2021). The car's driver, a Malaysian, was critically injured, and two construction workers died at the scene after falling 36 meters (120 feet) from the construction site (MSTAR, 2021). This is an example of workers who are increasingly losing focus due to fatigue.

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Figure 2. 1 A crane collapsed on a car at highway SUKE

2.5 Standard of DOSH (Department of Occupational Safety & Health)

The Ministry of Human Resources has a branch called the Department of Occupational Safety and Health (DOSH). This department is responsible for ensuring the protection, health, and welfare of people at work. Section 15 and 17 of the Malaysia law, OSHA 1994, stated that the employer must ensure that the worker and the workplace are in a safe working environment. As a result, the HIRARC operations must be carried out (Faculty of Engineering Technology, University Tun Hussein Onn, Batu Pahat, 2016).

As a fundamental to risk management, Hazard Identification, Risk Assessment, and Risk Control (HIRARC) have been essential to the discipline of planning, management, and execution of a company (H I R A R C • Department of Occupational Safety and Health • • Guidelines for Hazard Identification, Risk Assessment and Risk Control • Department of Occupational Safety and Health Ministry of Human Resources Malaysia 2008, n.d.). The purpose is to provide a comprehensive and analytical approach to identifying hazards and their related threats that can provide an objective assessment of the danger and a way to control the risk. Referring to the flowchart of the HIRARC Process, the first step is identifying the hazards that could be present during a work activity. When it is clear, the second move is to do a risk assessment until it is apparent. This is where you measure the risk and compare it to your risk tolerance. The final step is to consider the strategy or action that would be used to mitigate the dangerous impact. The stage is a risk-control mechanism that ensures the cause of danger will not affect the workers.

Department of Occupational Safety and Health (2016) found that heat stress assessment and compliance indicate that employees are subjected to heat stress due to high-temperature processes and equipment. The evaluation also found that employers and employees lack knowledge and awareness of heat pollution and its dangers to one’s health. Employees' clothing and personal devices are inappropriate, and there is no set daily routine for them. The results reinforced the need for Malaysian workers to be driven by criteria or recommendations for evaluating heat stress exposure at work (Department of Occupational Safety and Health, 2016).

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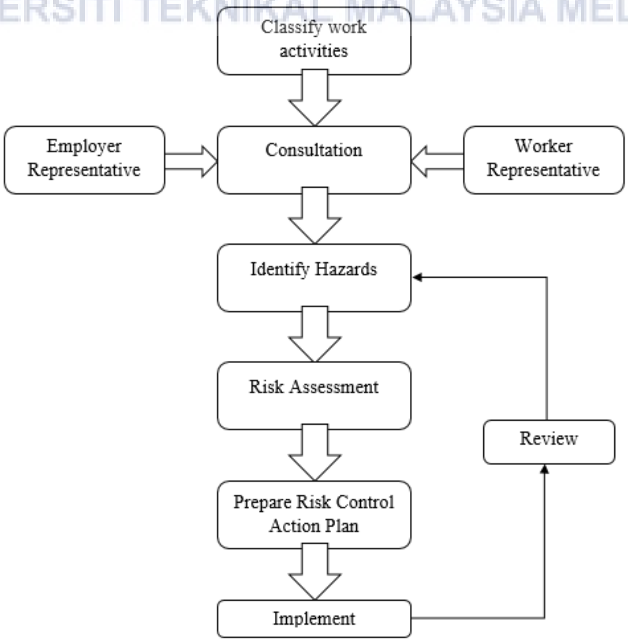
Flowchart of HIRARC Process



2.5.1 Measurement Parameters

Temperature, humidity, wind, clothes, shade, physical activity, and other aspects play a role in heat stress. Depending on the climate, the profession, and the particular worker, these variables may differ significantly. Heat stress was caused by a heavy workload, personal protective equipment (PPE), and other causes, making workers feel more uncomfortable in a hot and humid climate than in a hot and dry environment. Therefore, easy temperature metrics (e.g., normal high or minimum temperatures), composite indexes accounting for temperature, and other environmental factors such as humidity, core body temperature, and skin temperature have also been used to define heat stress.

This is because heat stress is described as a heat load caused by various factors such as weather conditions, physical activity, metabolic heat, and clothing thermal effects. WGBT (Wet Bulb Globe Temperature) is a widely used metric in the workplace that takes into account ambient temperature, humidity, radiant heat, and wind speed (P. Acharya, B. Boggess, and K. Zhang, 2017). The WBGT is also a commonly used heat index that underpins calculation of the Threshold Limit Values (TLVs) by the American Conference of Government and Industrial Hygienists, and it is a widely used heat index that underpins measurement of TLVs by the American Conference of Governmental and Industrial Hygienists (ACGIH).

Despite its shortcomings in calculating the impact of metabolic rate and wind direction, WGBT remains a valuable index for assessing heat effects. Although core body temperature and skin temperature are stronger markers of ambient heat than other indicators, they are not widely used due to medical and technical concerns and the fact that they enable individuals to consume or install a temperature sensor. According to ISO 7243, one calculation at 1.1 meters from the floor level where the heat stress is most significant is appropriate for determining the WGBT index quickly. Therefore, the equipment will be positioned as close to the heat source as possible (Department of Occupational Safety and Health, 2016).

The parameters to be measured are:

i. **Dry Bulb Temperature, T_{db}**

A thermal instrument insulated from overt radiant energy sources, such as mercury, was measured in a glass thermometer.

ii. **Natural Wet Bulb Temperature, T_{nwb}**

The results of evaporation and convection are measured by exposing a moist indicator, such as a wet cotton wick fitted over the bulb of a thermometer, to them. The airflow through the sensor is referred to as "normal".

iii. **Globe Temperature, T_g**

The temperature was determined within a blackened, hollow, and thin copper globe.

iv. **Relative Humidity, Rh**

The amount of water vapour contained in a given air volume to the amount of water available to saturate the air volume (at the same temperature).

v. **Wet Bulb Globe Temperature, WGBT**

The effect of temperature, humidity, wind speed, and solar radiation on humans is estimated using composite temperature. The WGBT is used to assess the degree of operation and sensitivity to acceptable high temperatures.

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vi. Air Velocity, V

The wind is the rate at which air travels in feet per minute (fpm) or meters per second (m/sec), and it plays an essential part in heat flow between the human body and the atmosphere due to its role in convective and evaporative heat transfer.

2.5.2 Wet Bulb Globe Temperature index

WGBT values are calculated using one of the following equations:

Equation 1

For indoor and outdoor conditions with no solar load, WGBT is calculated as

$$WGBT_{out} = 0.7\ T_{nwb} + 0.3\ T_g$$

Equation 2

For outdoors with solar load, WGBT is calculated as

$$WGBT_{out} = 0.7\ T_{nwb} + 0.2\ T_g + 0.1\ T_{db}$$

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2.5.3 Modification Factors of Clothing

Clothing ideally, free flow of cold, dry air over the skin's surfaces maximize heat reduction through evaporation and conduction in the perfect situation. TLV's and BEI's by ACGIH, 2015, stated that sweat evaporation from the skin is the most common method of heat reduction. Clothing impermeable to water vapour, air, fire, and encapsulating suits and several dress layers significantly limits heat removal. When the air temperature is deemed cold, metabolic heat will cause extreme heat strain because heat removal is hindered by clothes (TLV's and BEI's by ACGIH, 2015).

Table 2. 2 Clothing adjustment factors for some clothing ensembles (TLV's and BEI's by ACGIH, 2015)

Clothing Type	In addition to WGBT (ºC)
Limited use vapour barrier coveralls	11
Polyolefin coveralls	1
SMS polypropylene coveralls	0.5
Double-layer woven clothing	3
Cloth (woven material) coveralls	0
Work clothes (long sleeve shirt and pants)	0

2.5.4 Metabolic Rate

The complexity of an employee's role and the length of time exposed to heat at work affect their metabolic rate. Table 2.3 offers some general guidelines for deciding the job rate type to use in Table 2.4. The screening conditions for job and res allocations are listed in Table 2.4.

The parameters values in the table decline as metabolic rate (i.e., job demands increase), ensuring that most employees do not have a core body temperature above 30ºC. In evaluating heat stress, accurate work rate assessment is just as important as environmental assessment.

Table 2. 3 Metabolic Rate (TLV's and BEI's by ACGIH, 2015)

Work Category	Metabolic Rate (W)	Examples
Rest	115	• Sitting
Light	180	• Sitting with light physical work. • Standing, with some light arm work • Occasional walking
Moderate	300	• Moderate hand and arm work • Average arm and leg work • Light pushing and pulling • Walking as normal • Moderate lifting

Heavy	415	• Carrying, shovelling, manual sawing, pressing, and dragging heavy loads • Swift walking • Handling with bulky fabrics.
Very Heavy	520	• A very intense operation is carried out at a maximum pace.

Table 2. 4 Screening criteria for TLV and AL (TLV's and BEI's by ACGIH, 2015)

Screening Threshold Limit Value (TLV)					Screening Action Limit (AL)			
% Work	Light	Moderate	Heavy	Very Heavy	Light	Moderate	Heavy	Very Heavy
75-100	31.0	28.0	-	-	28.0	25.0	-	-
50-75	31.0	29.0	27.5	-	28.5	26.0	24.0	-
25-50	32.0	30.0	29.0	28.0	29.5	27.5	25.5	24.5
0-25	32.5	31.5	30.5	30.0	30.0	29.0	28.0	27.0

2.6 Weather In Malaysia

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Heat stress occurs as the body is exposed to temperatures higher than it can withstand without causing physiological damage. Outdoor jobs, such as those in agriculture and building projects, are particularly vulnerable to heat stress. It is a significant issue for many of the world's 1 billion farm workers and 66 million garment workers (many of whom live in factories and workshops without air conditioning), as well as workers in the garbage disposal, emergency repair work, transportation, tourism, and sports (Working on a WARMER planet, n.d.).

Temperatures above 39°C are lethal. Even if no one is killed, extreme heat will render many people unable to work or only able to work at a reduced pace. Forecasting the state of the atmosphere and possible environmental patterns is often a difficult task for meteorologists. Khalid Adam Ismail et al. (2016) described that weather is critical to humans in certain parts of their lives. They investigate how weather temperature evolves in a particular place or region. The universe can be helpful for a variety of reasons. Massive weather data must be processed, collected, and stored (Khalid Adam Ismail et al., 2016).

Asia and the Pacific is the world's most populous country, with around 4.2 billion people and a land area of approximately 32 million km^2. Because of its high exposure in some subregions, it is especially vulnerable to heat stress. In addition, the region's adaptive capability varies. Every year, the equivalent of more than 2 per cent of overall working hours will be missed globally by 2030, either because it is too hot to work or because employees world work at a slower rate. Since the 1960s, temperatures in Southeast Asia have been rising at a rate of 0.14°C to 0.2°C every decade, followed by an increase in the number of hot days and nights and a decrease in cooler weather (Working on a WARMER planet, n.d.).

Climate change and global warming are harming the world and humanity in many respects. One of the primary sources of global warming is industrial waste. As a result, businesses today face many obstacles in demonstrating that they are concerned with environmental emissions and are acting responsibly in this context (N. N. N. Ahmad & D. M Hossain, 2014). As a result, Malaysia has taken several measures to combat the detrimental impacts of climate change. Malaysia is a member of the United Nations Framework Convention on Climate Change (UNFCCC) and has ratified the Kyoto Protocol.

Mustafa, Kader, and Sufian (2012) state that industries such as iron and steel, metal, mineral, oil and gas, petrochemical, pulp and paper, power plants, and others are the

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primary sources of GHG emissions in Malaysia. So it can be said that commercial practice can be considered one of the causes of climate change and temperature increase in Malaysia. Though there is no legal provision for companies to report on social and environmental issues in Malaysia, Bursa Malaysia established a structure for companies to exercise corporate social responsibility in 2006. Therefore, writing on a company's social and environmental success is primarily voluntary. Climate change is listed as a significant global concern on the website of Bursa Malaysia (N. N. N. Ahmad & D. M Hossain (2014).

For the past century, a 0.7°C rise in temperature has been observed. Tawatsupa et al. (2013) concluded that heat stress was a problem to be considered very cautiously in some workplaces and was also a severe risk of many others in a study looking at the effect of heat stress on workers. Physical occupations were found to have a much higher risk of workplace injuries, as were people with pre-existing disabilities, those who worked at a quicker pace, those who slept insufficiently, and those with smaller wages (Working on a WARMER planet, n.d.).

Heat stress has also been shown to reduce labour productivity, with construction workers being 10% to 60% less efficient based on heat exposure levels (Langkulsen, Vichit-Vadakan, and Taptagaporn, 2010). Malaysia and other low- and middle-income countries, often experiencing rapid urban and industrial expansion, are especially vulnerable to heat stress. As the pressures on different industries increase, workers will be forced to work longer hours in humid, high-intensity environments.

2.7 How Does the Body React to Heat

Cramer and Jay (2016) state that the complex equilibrium between endogenous heat output and heat dissipation to the surrounding atmosphere allows humans to sustain a relatively stable core temperature. To promote higher rates of dry (primarily convection and radiation) and evaporative transfer from the body surface, the autonomic nervous system initiates cutaneous vasodilation and eccrine sweating in response to metabolic or environmental disruptions in heat balance (Cramer & Jay, 2016). However, on the other hand, total heat losses are controlled by the skins and environmental properties.

Heat causes the body to increase blood flow to the skin's surface and sweat. As sweat evaporates from the body's surface and heat is transported to the body's surface by increased blood flow, the body cools. Radiation and convection from the body's surface may also lose heat. As the body circulates blood to the skin, it raises skin temperature and helps the body to release heat. Muscles require more blood supply during heavy work, which decreases the amount of blood available to flow to the skin and release heat (Department of Occupational Safety and Health., 2016)

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The primary sources of heat generation are metabolic heat output and physical labour or exercise (T. Maurya et al., 2015). Heat loss is the transfer of heat from a high to a low temperature along a thermal gradient, and it is mainly caused by one or more of the four processes. First, sweat transfer as water on the skin into water vapour gas is called evaporation. At rest, this mechanism accounts for about 25% of heat loss, but it becomes the primary source of heat loss during heavy work in most environmental conditions (T. Maurya et al., 2015). Next, radiation, an indirect passage of heat in ultraviolet rays, accounts for about 60% of heat loss. Finally, heat can be lost if the skin temperature is higher than the ambient temperature, and it can be added if the skin is directly exposed to sunlight (T. Maurya et al., 2015).

T. Maurya et al. (2015) state that convection transfers heat from an object to surrounding liquid mediums such as flowing water, air, and internal body fluids, resulting in heat loss down a thermal gradient. In addition, convection happens as heat generated inside the muscle is transmitted to the neighbouring interstitial fluids during exercise. Finally, conduction is the flow of heat from two surfaces in close contact with one another, such as feet on the ground floor, down a thermal gradient (T. Maurya et al., 2015).

When victims are subject to heat or exercises with their age and physical health, they will develop heat-related diseases. When excessive heat strikes, it will kill by causing the human body to cool down beyond its limit, delaying the process of maintaining natural body temperature. Workers should not be exposed to extreme heat because it is dangerous, inefficient, and unproductive. Working in a hot atmosphere can affect a person's dexterity and coordination and his ability to stay alert during long and monotonous activities, observe erratic, subtle visual signals, and make fast decisions (T. Maurya et al., 2015).

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2.8 Researcher Who Study on Hot Environment

Morioka et Al. (2006) examined twelve male workers with specific steps that have already been implemented, such as taking breaks during work, erecting tents and electric fans, and drinking cold water to reduce heat stress. The time-motion analysis showed that one subject worked for more than 7 hours, while the other had no rest and drank no water while at work (Morioka et Al., 2006). Before lunch and after college, blood sugar levels were slightly higher. After work, the osmotic pressures of two subjects increased while the other two tended to raise their blood pressure while at work. Thus, the researcher suggests stricter work management and worker health insurance are needed, such as limiting working hours and regulating water consumption while on the job (Morioka et Al., 2006).

Referring to P. Acharya, B. Boggess, and K. Zhang (2017), construction workers are at an increased risk of heat stress due to the physically demanding nature of construction jobs, high-temperature working conditions, and a warming environment. In addition, the fact that little or no laws exist and are applied to protect these employees increases the risk of heat-related illnesses. Therefore, this research looked at the incidence of heat stress in construction workers, risk factors and co-morbidities associated with heat-related diseases in the construction industry, and the vulnerable communities (P. Acharya, B. Boggess, and K. Zhang, 2017). Therefore, the researcher recommends the role of social determinants and genetic and epigenetic factors in the development of heat-related health effects, exposure-response relationships across a wide variety of temperatures and locations, and creating more successful intervention and prevention strategies (P. Acharya, B. Boggess, and K. Zhang, 2017).

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Dutta et al. (2015) highlight that construction workers suffer from a high rate of heat-related pain and illness, particularly during the summer months. The construction sector in Gujarat and Western India is highly vulnerable due to rapid development, growing urbanization, and regular high heat events. This group should be a priority for heat illness reduction programs, and continued collaboration between the public and private sectors to protect the welfare of these vital workers should be welcomed (Dutta et al., 2015).

Al Sayed et al. (2016) states that heat exposure impacts workers exposed to hot and humid environments, affecting their concentration and eventually leading to a rise in occupational injuries. Therefore, protective devices, such as personal cooling clothes, should reduce heat stress. The benefits and drawbacks of individual cooling garments in a deep mining climate are discussed in this paper. It is reasonable to assume that each cooling technology has advantages and disadvantages. Hence, combining two or more innovations in a single hybrid garment may be the key to creating a more effective cooling apparel for the mining industry. This cooling garment should be thin, fit well with the miner's jobs, pose no health or safety risks, and greatly minimize heat stress. As a result, further research and studies on various combinations of cooling technology are needed to develop an optimized cooling garment for deep mine miners (Al Sayed et al., 2016).

Karkalic et Al. (2015) study on the effectiveness of a personal body cooling device that focused on passive evaporative technology and its impact on test subjects' psycho-physiological suitability during exertional heat stress in a hot climate. Furthermore, heart rate values and quantitative assessments of comfort thresholds point to the physiological wellbeing of the test participants, which is an essential finding in terms of morale and productivity in carrying out the assigned professional tasks. The advantages of a liquid circulation cooling vest in lowering thermal strain for installed test subjects were established by the findings of this research. As cooling was given during exposure to hot temperatures, tympanic temperature, a measure of thermal strain, and heart rate, a measure of cardiovascular stress, both decreased (Karkalic et al., 2015).

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2.9 Current Innovation

2.9.1 Innovation 1

Referring to Wentao Hu et Al. (2020), to avoid heatstroke and improve working conditions, it is critical to improve worker thermal comfort by maximizing the thermal atmosphere of safety helmets. The electric fan cooling system is the most widely used. A small electric fan is mounted on the front of the safety helmet, which rotates the fan blades to speed up the airflow within the helmet, increases the convective heat transfer rate between the air, and replaces the high-temperature airflow (Wentao Hu et Al., 2020). It can also improve the pace at which sweat evaporates from the head, making them feel more relaxed and comfortable.

Recently, Phase Change Materials (PCM) with high-temperature endothermic and low-temperature exothermic properties have been extensively used for cooling and heating (Hu et al., 2021). Wentao Hu et Al. (2020) conducted an experimental study based on the thermal properties of Phase Change Material (PCM) at high temperatures. Heat release in low temperature was used to create four different safety helmets. The operating conditions of four other helmet models in 30ºC and 16 ºC thermal conditions are measured using the air conditioning system. a multi-channel temperature measuring instrument and a temperature and humidity measuring device were used to measure the temperature and humidity values of four different safety helmet models in various settings (Wentao Hu et Al., 2020).

The interior of a standard helmet and a fan helmet were patched with the phase shift material patches to create four different helmet types, as seen in Figure 2.2. The Safety Helmet (a) is a standard safety helmet; the Safety Helmet (b) is a fan safety helmet; the

Safety Helmet (c) is made up of a standard safety helmet and a Phase Change Material patch (PCM), and the Safety Helmet (d) is a fan safety helmet and a Phase Change Material patch (PCM).

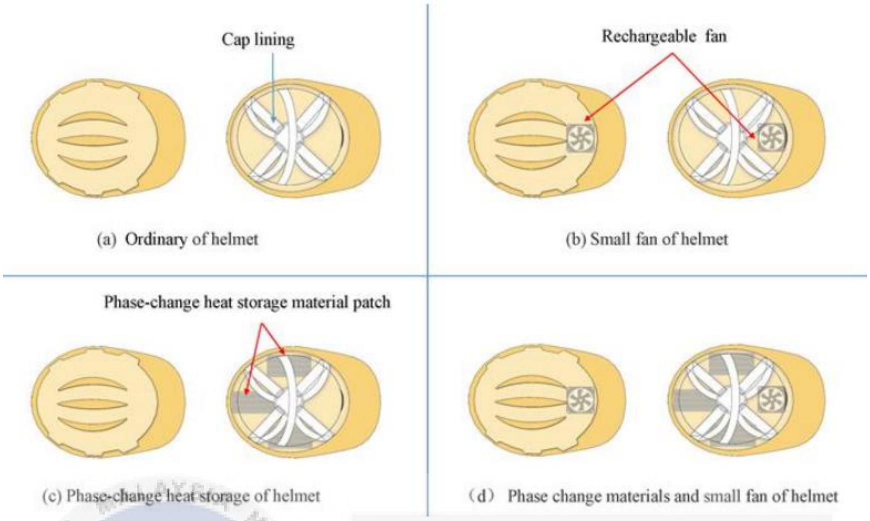

Figure 2. 2 Schematic diagram of the design model of four safety helmets: (a), (b), (c), and (d).

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As a result, the working conditions of construction workers wearing four enhanced safety helmets were stimulated in a 30°C thermal setting. Furthermore, the thermal comfort of four types of safety helmets was analyzed. The previous qualitative conclusions were taken to a degree based on the helmet's law of internal temperature and humidity (Hu et al., 2021). The cooling effect of the fan helmet is influenced by the temperature of area (b). The helmet with fan cooling technology has a cooling impact on a high-temperature setting in the early stages, but after 30 minutes, the cooling effect deteriorates. Next, the PCM safety helmet (c) provides adequate cooling in a hot environment. Still, inadequate ventilation causes sweat to stick to the scalp and hair, resulting in a poor user experience. Last but not least, it is defective to use a single PCM heat-absorbing cooling technology or fan cooling technology. Therefore, the helmet (d) integrates PCM heat-absorbing cooling technology with fan cooling technology to maximize the helmet's cooling effect and internal thermal climate stability, as well as the human body's thermal sensation.

2.9.2 Innovation 2

Many activities and occupations necessitate elevated levels of cognitive capacity in a hot climate while under physiological stress. For example, in the summer, occupational employees often perform specific physical tasks. Head-neck cooling is helpful in a variety of medical applications. Wang et Al. (2004) found that using a head-neck surface cooling garment, patients with severe brain trauma had an average temperature drop of 1.84 ºC. When body temperature, and possible brain temperature, are high, head-neck cooling technology can have beneficial effects on brain temperature in the athletic environment.

Kawakubo, et Al. (2013) has created an intelligent neck cooler, a wearable gadget that uses Peltier elements to cool the human body directly. Figure 2.3 shows the unit weight of 650 grams and consumes less than 27.95 Watts at full load. Three Peltier elements are located in the device's neck-worn portion, which will regulate the user's neck temperature linearly between 18 ºC and 28 ºC (Kawakubo et Al., 2013). It also has sensors that measure the temperature of the neck part, as well as the ambient temperature and humidity. A temperature difference is created between the two sides as a voltage is applied through the Peltier element. Controlling the path of the electric current allows you to cool the side closest to the surface, thereby freezing the entire body.

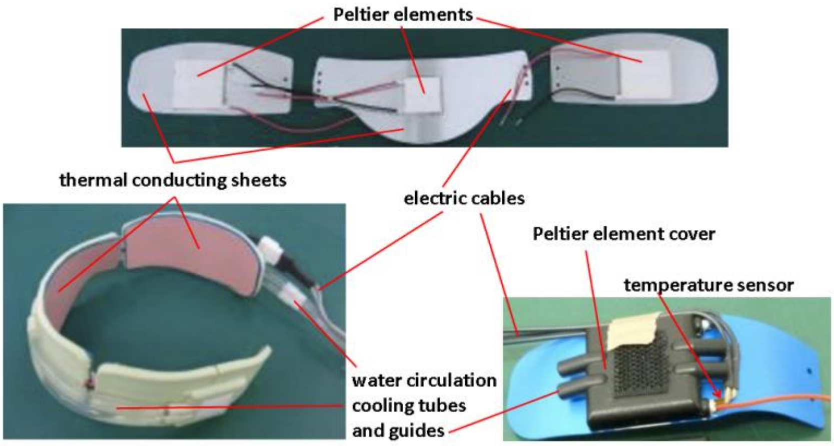

Figure 2. 3 A photo of the device's neck section, along with a summary of its components.

Since the Peltier element's opposite side is proportionally heating, a cooling water circuit (tubes and radiator) is needed. Sensor measurements of ambient temperature and humidity and neck temperature regulate the temperature of the Peltier components at the neck that prevents overheating and cooling (Lopez et Al., 2015). The package contains a microcontroller that can self-regulate the temperature of the neck component using a proprietary algorithm that estimates the discomfort index using a bi-linear equation of temperature and humidity (Wada et Al., 2013). Figure 2.4 shows schematics of the device's attachment (left) and mechanism (right).

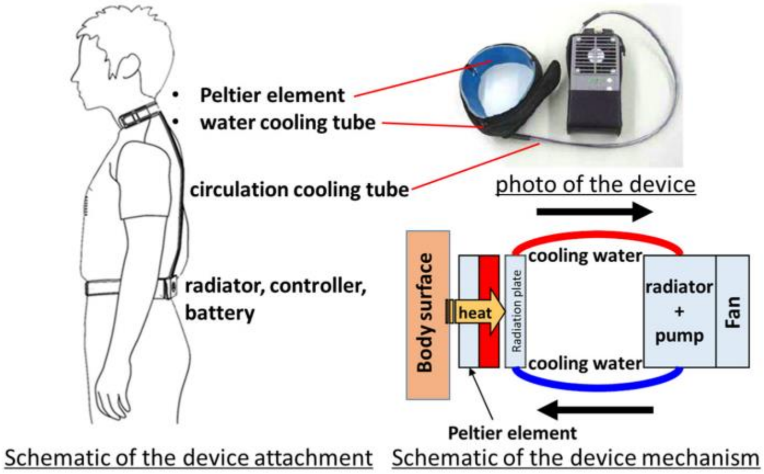

Figure 2. 4 The intelligent neck cooler prototype's attachment and mounting shape, as well as its mechanism's schematic.

As a result, the researcher observes that neck cooling affects both hot thermic and skin sweat sensations, causing them to become lower (Lopez et Al., 2015). Also, note that, even though participants were sweating continuously in a typical summer heat setting, sweating was intermittently prevented by neck cooling. Experiments on 16 stable subjects under artificial summer weather have proven two scientific findings.

1. Sweat amount, as well as constant sweat amount differences, have a significant effect on sweat sensation.
2. Adaptive neck ventilation reduces sympathetic nervous system operation, which results in improved thermal comfort.

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2.9.3 Innovation 3

Using appropriately constructed personal cooling vests for occasional cooling during job breaks may be a practical and effective field approach for workers to counter the harmful effects of heat stress with limited ergonomic issues (Chan et Al., 2017). As a result, Chan et al. (2017) created a Hybrid Cooling Vest (HCV) for construction staff. HCV focus on fabric heat-moisture output and cooling capacity of cooling sources. It remains to be seen if such a new cooling system will improve subsequent output as an intermittent cooling intervention during the mandatory rest time. This research aims to see how this recently developed HCV for cooling between two bouts of exercise affects subsequent exercise success in a hot and humid climate (Chan et Al., 2017).

Figure 2.5 shows the new cooling vest has eight Phase Change Material (PCM) packs uniformly distributed around the shoulders, stomach, and back sections, as well as two ventilation fans on the lower back area (Yi et Al., 2017). The melting temperature of the PCM pack is 28ºC, and the heat of fusion is 131 J/g. The PCM packs in the cooling vest weigh 0.64 kg each (0.08kf x 8). The ventilation fan has a maximum airflow rate of 20 L/s and can run for up to 7 hours when operated by a 7.4 V lithium battery. The ventilation unit (which includes a battery and two ventilation fans) weighs 0.35kg. The cooling vest weighs 1.26 kg in total. Fabrics with high water vapour permeability were chosen to aid sweat evaporation. The materials have excellent anti-static and anti-abrasive properties. The mesh inner layer has high air permeability, and the nylon taffeta outer layer, which has a high air resistance, allows enough air to circulate across the body (Yi et Al., 2017). The vest's exterior coating is UV tolerant and has a low solar absorptance value, making it ideal for outdoor use.

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Figure 2. 5 The newly designed Hybrid Cooling Vest (HCV)

According to the results of this review, wearing HCV between two bouts of exercise resulted in a significant reduction in thermoregulatory, neurological, and perceptual pressure during the rehabilitation session (Chan et Al., 2017). Wearing HCV also helped reduce visual strain, meaning that the wearers can feel less heat strain and heal faster from fatigue. In addition, as opposed to no transient cooling, HCV improved participants' subsequent exercise efficiency by a mean relative increase of 99.5 ± 89.5% in exercise time.

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Yi et Al. (2017) conclude that this report investigates the efficacy of a newly engineered hybrid cooling vest's precooling and post-exercise cooling measures in a hot and humid climate for construction workers. Precooling with a cooling vest decreased skin temperature and increased thermal sensation during exercise. Still, it did not relieve body heat stress, as shown by the lack of core temperature and heart rate (Yi et Al., 2017). The comparison and evaluation of a cooling vest's efficacy under various cooling methods provides realistic advice on incorporating a cooling vest in a particular work-rest protocol, which is critical for encouraging the use of cooling vests in the construction industry (Yi et Al., 2017).

CHAPTER 3

METHODOLOGY

3.1 Introduction

The advancement of technology in the workplace improves employee productivity and health, and well-being. This chapter provides information on the methodology used to choose the design fabric duct fan belt by comparing the airflow and body temperature. This project will use industrial design, enhancing a product's appeal to the human senses, particularly its aesthetic appeal becoming more artistic than engineering. The general form of the thing, the positioning of features, colours, texture, noises, and parts of product ergonomics are all included in design elements.

This project will use a conceptual design where it is a stage in the design process in which the broad contours of a product's purpose and shape are defined. Interactions, experiences, procedures, and tactics are all part of the process. It entails knowing what people want and how to address their requirements with products, services, and procedures. Concept drawings and models are common artefacts of conceptual design.

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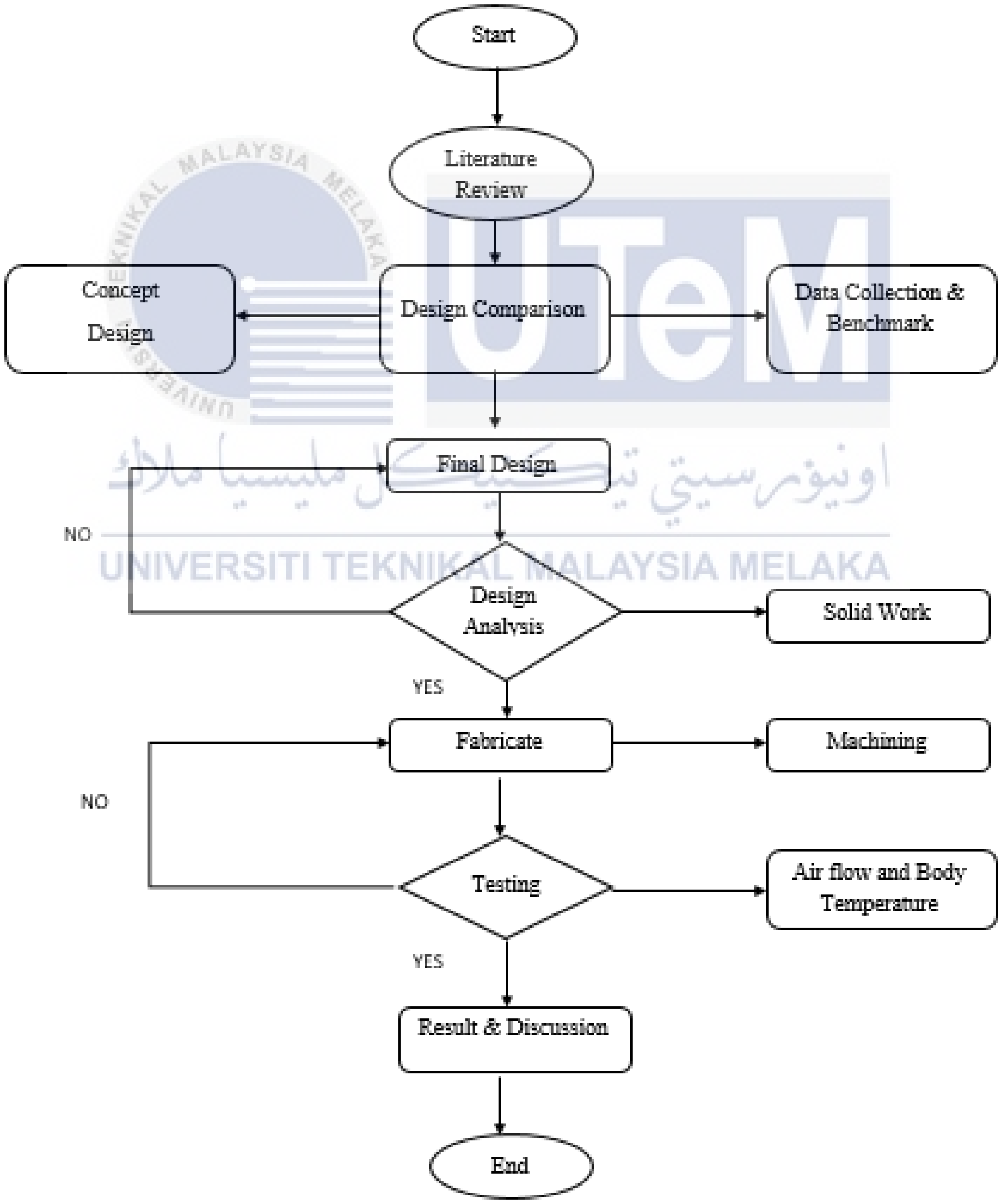
Next, this chapter will consider material selection, design analysis, and finally, the finished product. Finally, this chapter will be clarified in detail step by step to analyze election and how to fabricate the product. These several steps will be used to design and manufacture the Fabric Duct Fan Belt.

3.2 Process Flow Chart

This process flow chart below shows the sequential phases of a process and the decisions that must be made to function. A form represents every step in the chart below. To indicate the flow and direction of the process, lines and arrows link these forms. The flow chart below describes all the methods to design and find the final design of the Fabric Duct Fan Belt from the beginning until the end. First, we'll go through the steps to create the last fabricating fan belt.



3.3 Design Comparison

The design comparison is where the fabric duct design has been chosen to improve the study. This improvement includes a better suitable design, more ergonomics, and more effectiveness than the actual design highlighted for the project. This stage would compare the existing design of the mini waist fan using a conceptual design that was a study by criteria selected and the problem statement of the project.

3.4 Benchmark

To select the benchmark, a few analyses must be made to gain a piece of knowledge about the design problem and design freedom. The first step is to analyze the problem statement. The problem statement is to fix and improve the existing product of a Mini Hanging Waist Fan. A few questions about enhancing an existing mini hanging waist fan are listed. For example like:-

- How fast must the fan airflow rate come out?
- What is the expected maximum airflow rate could be?
- Is battery performance is essential for outdoor workers?
- Does the hanging fan is portable and comfortable while doing works?
- What if the customer's cloth flies out when the fan is on?

After listing the problem statement, a design problem must come out. To solve the design problem, first thing first must formulate. Process of decision making and activities have to be listed in other to come out with the solution. The steps in developing a design

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problem are to obtain a detailed understanding of the design problem. A clear understanding can be obtained by seeking info from the literature review, surveys, market studies, benchmark studies, and observation studies in other to interpret summarized data.

3.4.1 Data Collection

Data collection is the next step after a complete understanding of the design has been obtained from the info. A few characteristics have been concluded to design the Fabric Duct that achieves customer satisfaction to collect data. To gather the data analysis, a survey about the effect of using a waist fan while working was taken from five random workers. The data collection is taken based on a subjective comfort rating questionnaire.

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Criteria of waist fan that must be followed:-

- Comforts
- Durability
- Reliability
- Sustainability

Table 3. 1 Subjective comfort rating questionnaire

Date: ______________________ Age: ______________

Time: ______________________ Weight: ______________

Name: ______________________ Cloth Type: ______________

QUESTION	Bad	Poor	Acceptable	Good	Excellent
Able to do work	1	2	3	4	5
Is it functional	1	2	3	4	5
Is easy to use	1	2	3	4	5
Fits at the waist	1	2	3	4	5

Sweating	1	2	3	4	5
Get enough airflow	1	2	3	4	5
Feeling Dehydrated	1	2	3	4	5
Feeling fatigued	1	2	3	4	5
Has a nice feeling	1	2	3	4	5
Can offer a high task performance	1	2	3	4	5

3.5 Concept Design

Definition of a concept is the means of providing functions. In this stage, the design idea is represented by sketches and drawing software. The concept design can also fulfil the primary functional objectives and performance criteria identified via market research. The illustrations will be explained via textual descriptions to get a better view of understanding the overall project. This segment also would describe the alternative design concept. For example:-

1. For distributing the air to the worker bodies?

Table 3. 2 Shows the idea of alternative design

Alternative	Physical principle	Abstract Embodiment
1	Laminar Flow	Fabric duct
2	Fan mechanics	Fan

After feasibility studies and alternative concept design have been completed, a project brief has been developed, and the concept design will occur. A few sketches have been made at the concept design to achieve this project's requirement and objective. The process related to the Fabric Fan Duct Belt is considered by weight, length, the material used, and frame designs.

3.5.1 Sketching of Design Concept

3.5.1.1 First Design

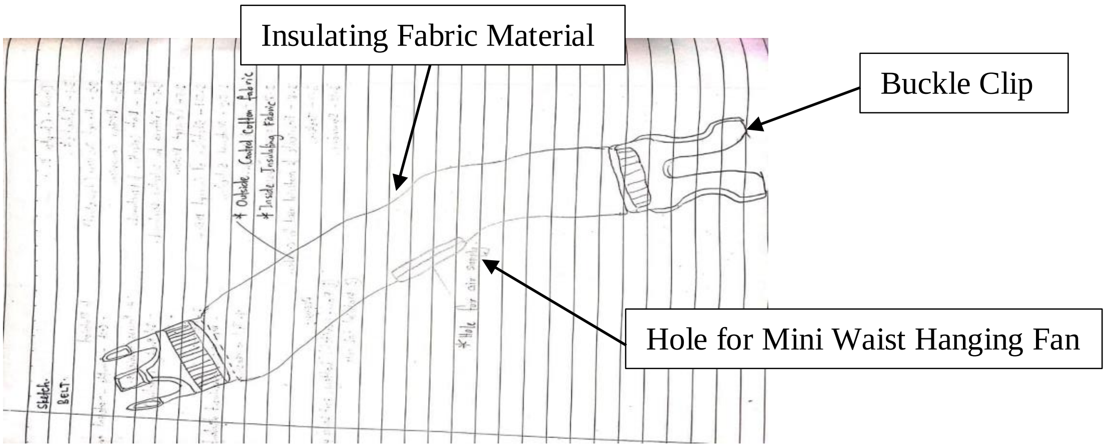

Figure 3. 1 Sketching for the first concept

Figure 3.1 shows the first concept of the Fabric Duct Fan Belt, where it will use coated cotton fabric on the outside and insulating fabric on the inside. The idea of the material is the same as the cooling bag. A plastic buckle clip will be used to tighten the Fabric Duct Fan Belt at the waist. Because the ready-made mini hanging waist fan already has the clip, the Fabric Duct Fan Belt will be added a hole for the supply fan. For distribution of the air, will be added 20 mini holes at the top with a diameter of 2 mm.

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3.5.1.2 Second Design

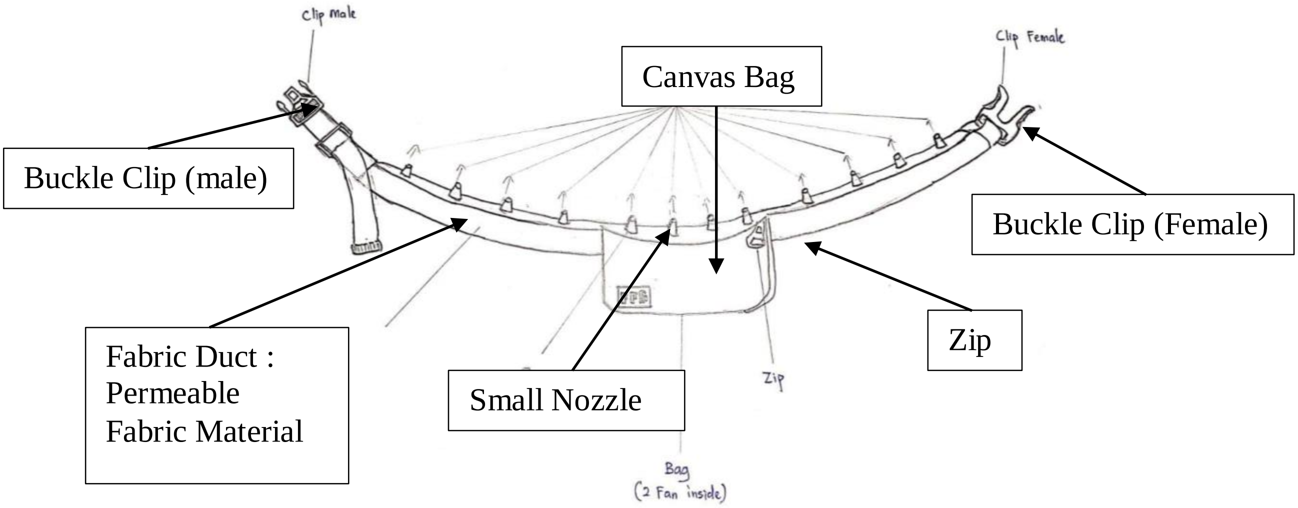

Figure 3. 2 Sketching for the second concept

Figure 3.2 shows the second concept of the Fabric Duct Fan Belt. A little bit of improvement is added to this design. For the material will be used permeable fabric material. It will take the actual material like an industry fabric duct. The bag's material will be used canvas to hold the mini hanging waist fan, and it will be added a zip same as a bag. The air distribution will add up a small nozzle with a diameter size of 4 mm and a height of 5 mm. To hold the Fabric Duct Fan belt firmly at the waist will use an adjustable plastic buckle clip type.

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3.5.1.3 Third Design

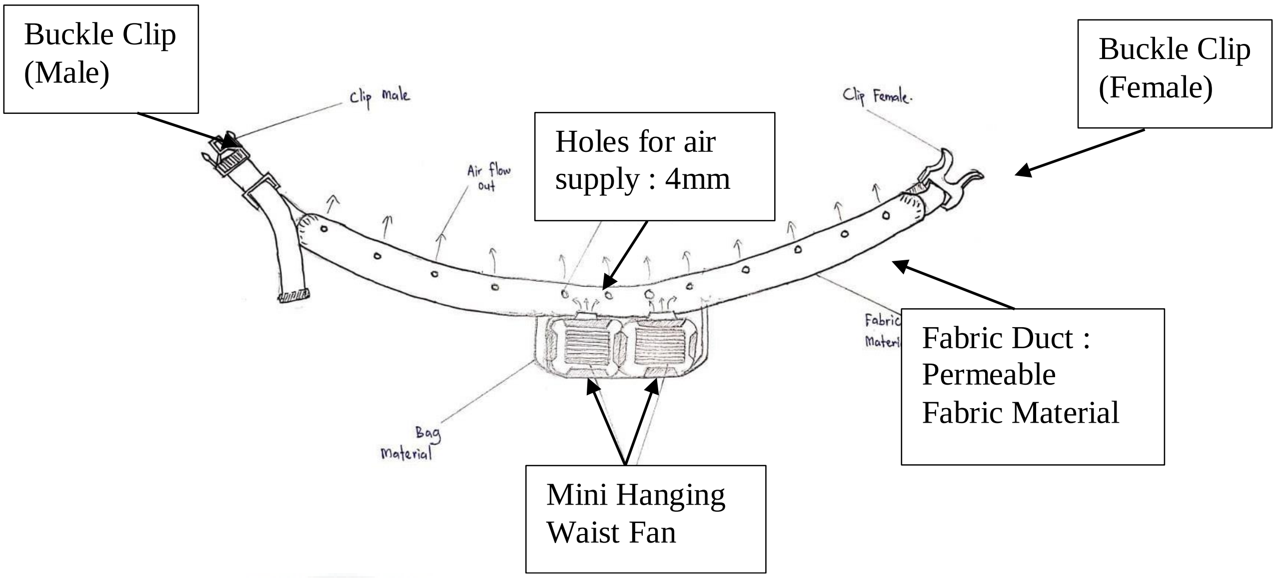

Figure 3. 3 Sketching for the Third Concept

Figure 3.3 shows the third concept of the Fabric Duct Fan Belt. The idea is almost similar to the second concept with a difference in the hole distribution type. The hole distribution type will be using a 4mm diameter hole without a nozzle. 10 number of hole distribution is added to distribute the air into the body. Material for Fabric Duct and bag will be using permeable fabric material, and the fan of the mini hanging waist fan will not be closed. Instead, it will be left open to increase the fan's performance. An adjustable plastic buckle clip will be used to hold the Fabric Duct Fan belt firmly.

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3.5.1.4 Illustration of The Design

Figure 3.4 below shows the illustration conceptual design for the Fabric Duct Fan Belt. The software that is used for editing the figure below is Canva. Since PSM 1 has not yet done an actual project, this method enhances making the Fabric Duct Fan Belt. The Mini Hanging Waist Fan will be purchased at the Shopee online shop for RM 36.80. To ensure the Fabric Duct Fan Belt gets enough air supply, two Mini Hanging Waist Fan quantities are purchased. Table 3.3 below shows the estimation cost for the product's material and the wage cost.

Table 3. 3 Shows the estimation cost for Fabric Fan Duct

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BORANG TUNTUTAN PERBELANJAAN PSM 2

Nota:
1. Sila isi Borang Tuntutan Perbelanjaan PSM dalam SATU (1) salinan sahaja.
*2. Borang ini mesti **ditaip** kemas. Borang tulisan tangan atau yang tidak lengkap akan dipulangkan.*
3. Untuk bayaran secara tunai:
a. Hanya resit asal diterima (cap syarikat dan tandatangan).
b. Resit tidak boleh ditulis sendiri untuk penambahan item atau amaun.
c. Tidak boleh ada pembetulan/perubahan pada resit.
d. Sekiranya inbois, perlu nyatakan CASH/TUNAI.
4. Untuk bayaran secara Online Transfer:
a. Lampirkan 'order detail' yang dicetak dari pembelian online.
b. Lampirkan bukti bayaran transaksi online terdapat nama pembayar.
5. Semua resit pembelian hendaklah ditampal di atas kertas A4 dan dilampirkan bersama borang ini sebagai bukti pembelian.
6. Tuntutan yang dibenarkan hanyalah untuk pembelian komponen PSM.

Nama Pelajar:	MOHAMAD ZAHIM BIN MOHAMAD SUKAIRI		
No. Matrik:	B091810344	No Telefon:	0137360424
Jabatan:	JTKM	Program:	BMMH
Nama Penyelia:	TS. AZMAN BIN IBRAHIM		
			44
Bayaran kepada:	Pelajar		
Nama Bank:	Maybank	No Akaun:	154129149424

BIL	DESKRIPSI	NO RESIT	JUMLAH (RM)
1	Duct Tape	POS/07655	5.9
2	Waist fan with USB Rechargebale Battery	2110065X2UN4PM	53.59
3	WAIST FAN WITH USB RECHARGEABLE BATTERY	2106028G427W3N	77.63
4	DUCT TAPE	B16-1808-23000122	14
5	TACTICAL WIDE BLACKHAWK BELT	2109123QTE22C2	13.9
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
JUMLAH TUNTUTAN			165.02

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MOHAMAD ZAHIM BIN MOHAMAD SUKAIRI
Tandatangan Pelajar Tarikh : 08/11/2021

Disokong Oleh: Diluluskan oleh:

Tandatangan dan Cop Penyelia PSM
Tarikh:

Tandatangan dan Cop Dekan
Tarikh:

Figure 3. 4 Illustration of Fabric Duct Fan Belt (Final design)

3.5.2 Material Selection

The material selection that has been decided to fabricate the product is permeable fabric. This material is a Thermoplastic Polyurethane film (TPU), which belongs to the pore-free hydrophilic film family. The waterproof effect is natural and good since the film itself has no pores, and it also makes the fabric duct windproof and warm. Its hydrophilic properties are primarily responsible for its moisture permeability. This film is laminated with the fabric's good qualities and high-tech microporous film products, resulting in a functional material with various good features.

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Fabrics that are permeable to vapour are frequently more flexible. Vapour permeable fabrics have a more significant experience and may conform to the user's body form. The weight distribution is more comfortable because they're woven. Moreover, less pressure is exerted on the user's body because of the yielding fabric, resulting in a more pleasant experience.

Next, permeable fabrics are fantastic for flexibility and breathability. This material is also easy to keep clean. Dartex, one of the renowned providers of permeable materials, suggests washing the material first, then wiping it down with authorized cleaning agents.

Then, rinse it with clean water and adequately dry it. These materials are completely waterproof.

Last but not least is pressure care. Permeable materials are better for pressure care. The fabric’s elasticity helps diffuse pressure and avoids putting additional strain on vulnerable places. Airflow and breathability are further advantages of permeable materials, which is it can reduce the chance of sweating and help retain the skin’s integrity.

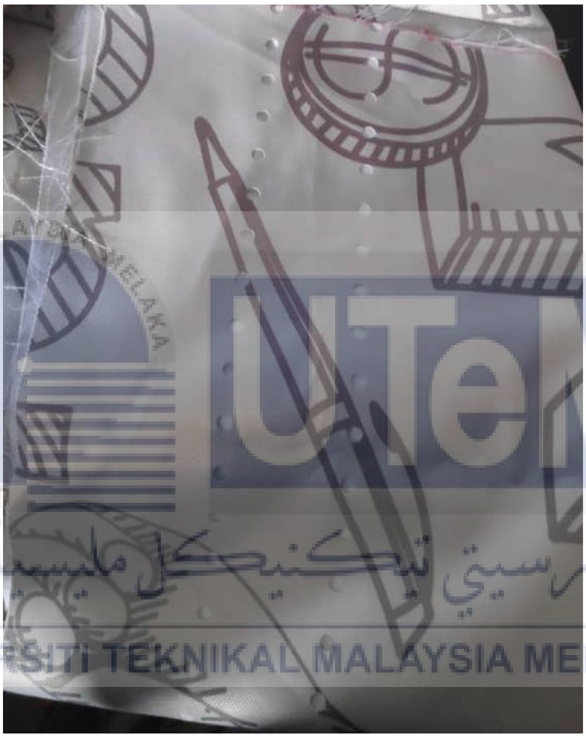

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Figure 3. 5 Shows the material of the permeable fabric

3.6 Final Design

The final design step is when only one of the best three concept designs will be chosen. The final conceptual design is derived from 3 abstract designs. The final design, material, data analysis, and assembly with parts will be complete. Final designs will be shown in Chapter 4.

3.7 Prototype

The prototype must have been made to develop various design options to experimentally realize the fabric duct fan belt. A prototype for each option shows a distinct perspective "look and feel" for how the system may be put together. Users may then turn to these prototypes for a concrete illustration of what is achievable. The prototype's material choice and fabrication method will use duct tape because of its durability. Duct tape has a lot of advantages, one of which is its durability. Compared to practically any other type of tape on the market, duct tape is strong and long-lasting. It is regarded as a necessary component in many households and businesses. Duct tape is commonly used to seal air ducts and may endure for years before being renewed.

In addition, duct tape lasts a long time and has many strengths. It can be used for jobs where you wouldn't be able to use any other kind of tape. You will not be able to rip duct tape easily because of its inherent strength. Because of its power, duct tape might theoretically sustain a significant amount of weight or force without being destroyed.

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3.7.1 First Prototype

The prototype aims to create a new Fabric Duct Fan Belt application. This allows the users to cool down the body temperature effect due to long heat exposure to direct sunlight. Firstly, take the duct tape and pull out a piece long enough that it would wrap around your waist. Next, take a second piece of tape the same length. Then, take one piece of tape and put it from the sticky side to the sticky side. Repeat this step by combining it with a three-layer. Then flip the other part to another to get the diameter. Take another piece of tape the same length, and stick it together. Figure 1 below shows the red duct tape is a piece of duct tape combined. The blue and yellow ones are duct tape connected to get the diameter.

Figure 3. 6 Shows the prototype is in progress

Next, take a piece of plastic bag, wrap it at the edge of the duct tape, and sellotape it. To ensure no air loss while the system was operating, stick the hot glue gun to increase the durability. Then, repeat this step to another edge.

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Figure 3. 7 Shows prototype has been wrapped

Then, cut the duct tape according to the measurement of the tip of the mini hanging waist fan. Next, glue the fan and the duct tape together using a hot glue gun. Then, take another duct tape and stick it to ensure no air leakage during the operating system.

Figure 3. 8 Shows the attached mini hanging waist fan and duct tape

The part will use the same prototype for the holes, which means that students started with five holes and tested. Repeat the process with ten holes, fifteen holes, twenty holes and twenty-five holes. Using the plastic holes puncher plier, punch the prototype. Students need to use the fold and punch method because of the limitation to hitting straight forward. Last but not least, attach the prototype with the belt using a hot glue gun.

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Figure 3. 9 Shows punching the prototype

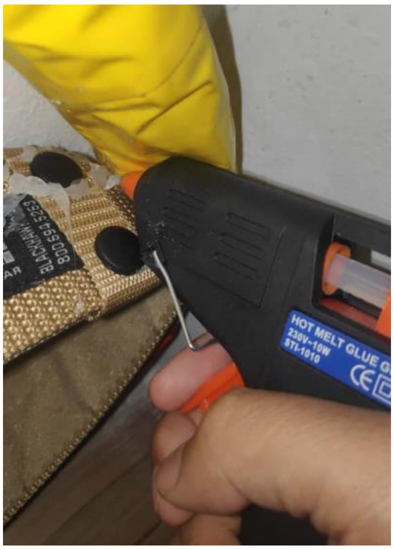

Figure 3. 10 Shows attached the prototype with belt

3.7.2 Second Prototype

The second prototype will be using a balloon as the base to mould the prototype. Firstly, blow the balloon using a pump (see Figure 3.11). Next, tie the edge of the balloon to simulate the waist. Then, take a piece of duct tape and tape it with sticky on the top side. The reason is to make sure that the inner part is sticky and the air can flow smoothly. Next, take another piece of duct tape and stick it on top of the duct tape (refer to figure 3.12). Repeat this step until all the balloons are covered with duct tape.

Figure 3. 11 Shows the balloon is being pumped

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Figure 3. 12 Shows the duct tape is sticking

After tapping all the balloons, now it's time to blow up the balloon. Take sharp objects like scissors or a pin, and poke the balloons in the duct tape. Now we have the base of the Fabric Duct Fan Belt. Take the scissors and trim the edges of the prototype. Then, take a plastic bag, wrap it at the edge of the duct tape and tape it. Repeat this step at the other trims. Next, cut the prototype according to the measurement of the tip of the mini hanging waist fans. Glue the duct tape with a mini hanging waist fan using a hot glue gun. Take another duct tape and stick it to ensure no air leakage. Using the plastic hole puncher plier, punch the prototype to five holes, ten holes, fifteen holes etc.

Figure 3. 13 Shows the final product of the second prototype

3.7.3 Third Prototype

The third prototype will be using permeable fabric found from the Prihoda Malaysia Sdn. Bhd. First of all, cut the fabric into rectangular. Then flip the other part to another to get the diameter. Pin the fabric so that the material does not move and sew it along the way. The fabric must be upside down before sewing it. Next, cut another piece of fabric into a circle. Before cutting, make sure to mark the diameter using a protector. Then pin the circle fabric at the edge of the material (refer to Figure 3.15). After that, sew the fabric along the way. Just send it to the tailor for the waist hanging fans holder to sew it.

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Figure 3. 14 Shows the fabric was being sewed to get the diameter

Figure 3. 15 Shows the edge of the fabric that has been sewing

Figure 3. 16 Shows the front and back of the 3rd design prototype

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Figure 3. 17 Shows the finished product for 3rd design

3.8 Equipments/ Experiment Apparatus/ Consumable Materials

- 1 unit of Fabric Duct Fan Belt
- Thermocouple Type-K
- Data Logger
- Infrared Thermometer
- Mini Hanging Waist Fan

3.9 Protocol of the Experiment

After producing the product, it should be tested to observe whether the product achieved the project's objective. Next, to measure whether the product is functioning or not. One male participated in six random experiments, i.e., conventional (without any equipment), two mini hanging waist fans, and two mini hanging waist fans (including the fabric duct belt). The participant who participates in this experiment will test all of these experiments.

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Before the experiment began, the investigation was conducted in an opening condition in a warm environment. The temperature of 37ºC, 60% of relative humidity, 0.3 m/s air velocity, and 450 W/m² of solar radiation to simulate a model of the typical summer working environment on Malaysian Construction sites (Yi et al., 2017). To simulate the outdoor workers that work in hot ambient temperatures, the subject would be sunbathing for 3-5 minutes so that the body temperature will remain constant. Figure 3.6 below shows the layout setting of the experiment. Two temperature sensors were placed in front and back of the subject body to measure temperature. An infrared thermometer is used to measure the ambient temperature. Start the experiment with a timer and record data every 30 seconds for 20 minutes. Record all the data in the table below.

Figure 3. 18 Shows T1 and T2 (front body)

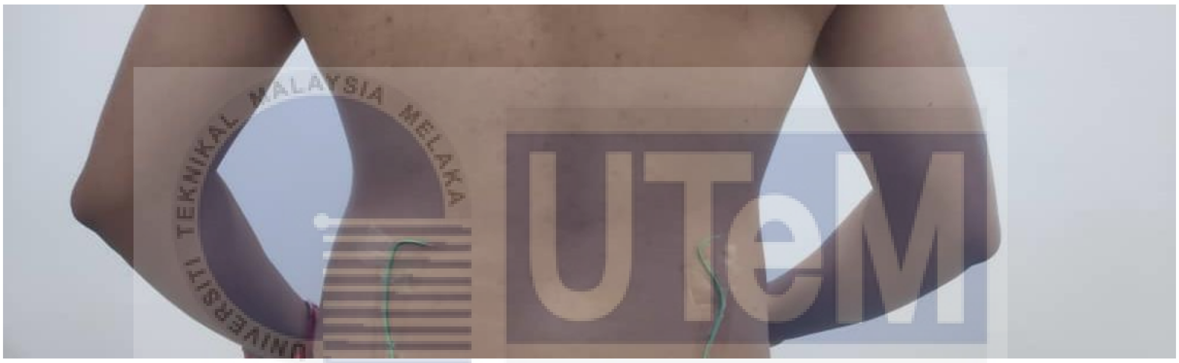

Figure 3. 19 Shows T3 and T4 (back body)

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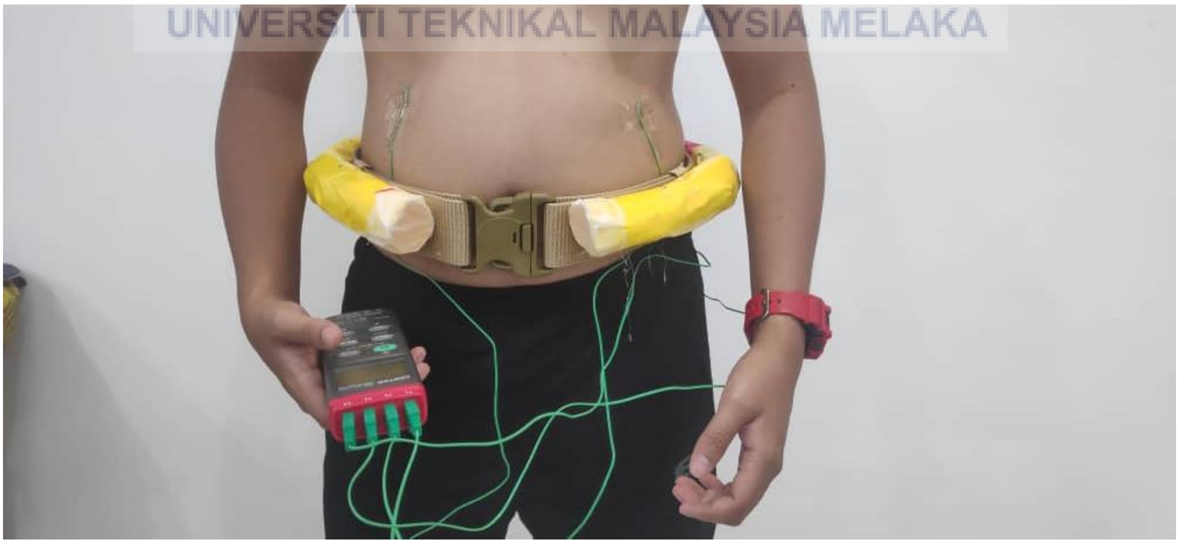

Figure 3. 20 Shows view from in front

Figure 3. 21 Shows a view from behind

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Figure 3. 22 Shows experiment is in progress

3.10 Summary of Methodology

This chapter described the progress of the Fabric Duct Fan Belt and showed the initial description from the design comparison until the experiment of the product. For design comparison, the fabric duct was chosen for improvement includes a better design, more ergonomics, and more effectiveness. For benchmarking, an analysis has been made to gain new knowledge about product improvement. The problem statement of the project has been analyzed, and a few questions have been presented in this project. The purpose of the problem statement is to improve the airflow rate at the existing product, Mini Hanging Waist Fan, and decrease the temperature on the front and back body. Next on this chapter will describe the three conceptual designs and the attached sketching. There is no difference between these three designs: they take a belt concept. An illustration of the design and the cost of the project also has been attached in this chapter. The software used to illustrate the method is Canva, and the cost of the project mostly is a survey using the application Shopee Online Shop. For the material selection, research has been done, and the best material to produce Fabric Duct Fan Belt is Permeable Fabric material. Permeable fabric is chosen because it is waterproof, windproof, has good flexibility, is easy to wash, and has high-pressure care. For fabrication, it may wage a tailor. After the product is completely fabricated, an experiment has been held to ensure the effectiveness and to achieve the main objective of the Fabric Duct Fan Belt. An open area environment is chosen to simulate the workers that work in a hot environment. Temperature, relative humidity, air velocity, ambient temperature and solar radiation must be considered before the experiment.

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CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter will present the analysis result for concept design and benchmark of the Fabric Duct Fan Belt. Also, it will show the design problem that has been faced while fabricating and optimizing the Prototype. This chapter also discusses selecting the Fabric Duct Fan Belt method from three concept designs. After that, the results will be studied on the quantity of the holes towards the body's temperature. Then in this chapter also makes the design comparison between the best selecting design and no fans in terms of body temperature. Finally, the survey will be conducted using a radar chart by comparing the value of 10 respondents towards experience using Fabric Duct Fan Belt. Every result will attach in a photo, diagram and table will be shown.

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4.2 Design Problem

Based on the objective of this research precisely is to fabricate and optimize the fabric duct fan belt. There are a few issues faced while building this prototype. First, the air cannot be passed to the front of the body due to the crumbs on the side of the body (refer to figure 4.2). The problems happen attributable during the fabricating process. There are a few mistakes while attaching the prototype to the belt. Firstly, the approach to fabricate the prototype where the duct tape is pasted straight forward. To overcome this is by used the balloon to make it as a base to get inner diameter and outer diameter.

The second is while attaching the duct tape and belt, the belt is not clipped, and the glueing process is straightforward. The solution to tackle this problem is by glueing the prototype with the belt while the belt is on the clip (refer to figure 4.2), which means that the prototype's inner diameter is lesser than the prototype's outer diameter.

Figure 4. 1 Shows the view from the side where the crumbs have happened while wearing the belt

Figure 4. 2 Shows the view from the top where the hot glue gun was placed

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The third issue faced while fabricating the prototype is the air losses at the supply between fan and prototype. Observations have been made while the fabric duct fan belt is operating. Through the sense of taste and hearing, students have detected a leaking at the air source between fan and prototype (refer to figure 4.3). To overcome this, add more glue and increase the reliability by making a bag using duct tape (refer to figure 4.4). Last but not least, the holes that have been punched are so small that the air that comes out is not enough for the first punch, which is five holes. This is because the air at the back of the body is more than the air in front of the body. To overcome this is by punching it with the 3.5mm diameter holes.

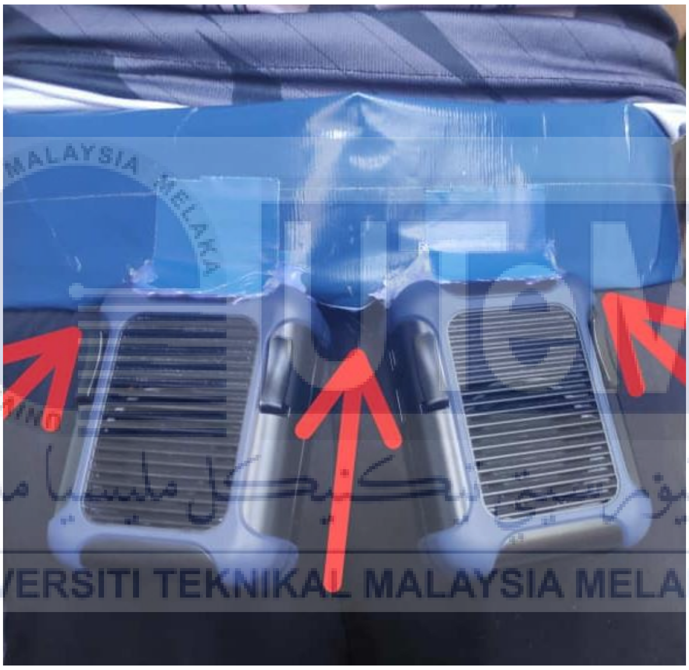

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Figure 4. 3 Shows the places that leaking air

Figure 4. 4 Shows an improvised design

Figure 4. 5 Shows the prototype being punched with a 3.5mm diameter

4.3 Core Body Temperature

This section presents the result for the Fabric Duct Fan Belt. The experiment was conducted in an open area with an ambient temperature of 30ºC to 31 ºC from 12 PM until 1 PM. For the first experiment, the subject is placed under the Sun for 20 minutes without using any cooling device. The temperature at the front and the back of the body is taken every 30 seconds for 20 minutes. The result is displayed in table 4.1. In the second experiment, the Fabric Duct Fan Belt uses a quantity of 5 holes with a diameter of 3.5mm each and again repeat the steps to measure the temperature of the body every 30 seconds for 20 minutes duration. The results are shown in Table 4.2.

In the third experiment, the Fabric Duct Fan Belt uses 10 holes with a diameter of 3.5mm each. The results are shown in Table 4.3. For the fourth experiment, the Fabric Duct Fan Belt uses 15 holes with a diameter of 3.5mm each. The results are shown in Table 4.4. In the fifth experiment, the Fabric Duct Fan Belt uses 20 holes of 3.5mm each. The results are shown in Table 4.5. Finally, the Fabric Duct Fan Belt used 25 holes with 3.5 each for the last experiment. Again repeat the steps to measure the temperature of the body every 30 seconds for 20 minutes duration. The clothes that the volunteer is wearing are fabric material. The volunteer is age 24 with a weight of 65kg, and before the experiment and during experiments were given 350ml water. The main findings of Mini Hanging Waist Fan testing were improved cooling air distribution towards the front, back, and side of the body while covering the lower cloth.

Table 4. 1 The result before using Fabric Duct Fan Belt

Date:	6/1/2022		Age:	25
Time:	1231		Weight:	65KG
Name:	ZAHIM		Cloth Type:	COTTON
Body Temp before:	T1:34.2 ºC ,	T2:32.9 ºC,	T3: 31.8 ºC,	T4: 30.8 ºC
Diameter:	0mm		Ambient Temperature:	31 ºC

Minute	Hole Quantity 5 hole			
	Front Body		Back Body	
	T1	T2	T3	T4
0.5	35.1	32	31.2	30.5
1.0	34	32.8	31.2	30.5
1.5	34.6	34.3	31	30.5
2.0	35.7	33.8	31.6	30.9
2.5	34.8	33.6	32.1	31.5
3.0	33.5	33.6	32.1	32.1
3.5	34.1	33.8	32.8	32.7
4.0	34.1	34.4	33.5	33.3
4.5	36.7	34.4	34.1	35.3
5.0	36.8	34.1	33.8	34.4
5.5	35.7	35.3	34.1	34.3
6.0	35.4	35	35	35.1
6.5	36.4	36.3	35.5	35.6
7.0	36.8	36.7	35.9	36.3
7.5	36.9	37.1	35.9	36.2
8.0	37	36.5	36.4	36.8
8.5	37.1	37.8	36.7	37.3
9.0	37.9	38	37	37.5

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9.5	38.3	37.2	36.7	37.2
10.0	37	37.3	36.3	37
10.5	37.1	37.1	36.4	36.7
11.0	37.4	37.9	36.3	36.5
11.5	37.5	37.7	36.7	36.8
12.0	37.8	38.3	36.6	36.9
12.5	37.2	37.1	36.5	36.9
13.0	37.9	37.8	36.6	36.8
13.5	37.8	37.4	36.4	36.6
14.0	37.8	38.1	36.1	36.7
14.5	38.1	37.4	35.8	36
15.0	37	37	35.8	35.8
15.5	37.7	36.1	35.9	36.3
16.0	38.1	37.7	36.4	36.3
16.5	37.2	37.2	36	35.9
17.0	37.3	37.4	35.9	35.9
17.5	38.2	37.8	35.7	35.8
18.0	38.5	37.1	35.9	35.8
18.5	38.3	37.4	36.1	36.5
19.0	38.1	37.9	36.7	37.2
19.5	37.7	37.8	37.7	38.2
20.0	37.8	38.4	38.5	39

Table 4. 2 The result for 5 holes Fabric Duct Fan Belt

Date: 12/12/2021 Age: 24
Time: 1330 Weight: 65KG
Name: ZAHIM Cloth Type: COTTON
Body Temp before: T1:35 ºC , T2:36 ºC, T3: 34.8 ºC, T4: 34.4 ºC
Diameter: 3.5mm Ambient Temperature: 31 ºC

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	Hole Quantity			
Minute	5 hole			
	Front Body		Back Body	
	T1	T2	T3	T4
0.5	35	36	34.8	34.4
1.0	34.6	36.1	34.2	34.1
1.5	34.3	35.5	33.8	33.8
2.0	33.8	35.2	33.9	33.8
2.5	34.3	35.3	34.1	33.7
3.0	34.2	35.3	34.3	33.6
3.5	34.4	35.5	33.8	33.8
4.0	34.7	34.5	33.7	33.8

4.5	35.3	35.2	34.1	33.8
5.0	35	35.1	33.7	33.8
5.5	35.1	35	33.9	34.1
6.0	34.9	35	35	35.4
6.5	34.9	35.4	35.4	37
7.0	35.1	35.8	36.4	37.8
7.5	35.3	36	37.3	40.4
8.0	35.3	36.5	37.4	40.4
8.5	36	36.8	37.2	40.3
9.0	36.2	36.6	36.7	37.7
9.5	36.2	37.7	36.6	37.2
10.0	36.3	36.9	36.4	36.7
10.5	36.6	37.3	36.8	37.4
11.0	36.1	37.1	36.6	37.1
11.5	36.3	37	36.8	36.8
12.0	36.4	37.3	36.9	37.1
12.5	36.9	37.5	37.2	37.3
13.0	37	37.9	37.2	37.3
13.5	37.8	37.4	37.1	37
14.0	36.7	37	37.1	37
14.5	36.9	37.3	37.3	37.1
15.0	36.5	37.4	37	36.8
15.5	36.6	37.9	36.8	36.6
16.0	37.2	37.7	36.8	36.6
16.5	37.3	38	37.4	37.3
17.0	37.4	38.6	37.4	37.3
17.5	38	38.8	37.7	37.5
18.0	37.4	38.8	37.4	37.3
18.5	38	38.5	37.2	37.5
19.0	38	38	37.3	37.7
19.5	37.2	38.6	37.7	37.9
20.0	38.7	38.8	37.7	37.7

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Table 4. 3 The result for 10 holes Fabric Duct Fan Belt

Date:	13/12/2021		Age:	24
Time:	1240		Weight:	65KG
Name:	ZAHIM		Cloth Type:	COTTON
Body Temp before:	T1:32.1 ºC ,	T2:33.6 ºC,	T3: 34.3 ºC,	T4: 31.6 ºC
Diameter:	3.5mm		Ambient Temperature:	31 ºC

	Hole Quantity
Minute	10 hole

	Front Body		Back Body	
	T1	T2	T3	T4
0.5	31.4	32.5	33.1	31.8
1.0	31.6	32.7	33.3	32.4
1.5	31.7	32.7	33.5	32.3
2.0	31.9	32.9	33.6	32.8
2.5	32.7	33.1	34.3	32.9
3.0	33	33.2	34.7	33.2
3.5	33	34.2	34.4	32.8
4.0	33.2	34.2	33.8	32.6
4.5	33	33.8	33.8	32.9
5.0	34.1	34.9	33.9	33.4
5.5	34.7	35.2	34.7	34.2
6.0	34.9	36.1	35.5	34.7
6.5	35.6	36.3	35.7	34.7
7.0	35.3	36.2	35.9	35
7.5	35.2	36.8	36	35.1
8.0	35.8	37.1	35.9	35.6
8.5	36	37.3	35.8	35.8
9.0	36.3	36.7	36.3	37.5
9.5	36.6	36.7	36.4	36
10.0	36.8	36.8	36.3	36
10.5	36.9	36.3	35.8	35.9
11.0	37.2	36.4	36.1	36.4
11.5	37.7	36.7	37	37
12.0	37.7	36.8	37.5	37.3
12.5	37.8	37.7	37.7	37.3
13.0	37.2	37.4	38	37.1
13.5	37.3	37.8	38.5	37.9
14.0	37.3	38	37.8	37.3
14.5	38	37.9	38.5	38.1
15.0	38	38	38.4	38.1
15.5	38.5	38.7	38.3	38
16.0	38.1	38.2	37.9	38.1
16.5	38.2	38	38.6	38.3
17.0	38.4	37.9	38.3	37.9
17.5	38.3	38.1	38.4	37.9
18.0	38.4	38.4	38.1	37.8
18.5	38.3	38.4	38.2	38.2
19.0	38.2	38.4	38.7	38.7
19.5	38	38.4	38.8	38.8
20.0	38.2	38.3	39	38.9

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Table 4. 4 The result for 15 holes Fabric Duct Fan Belt

Date:	13/12/2021		Age:	24
Time:	1454		Weight:	65KG
Name:	ZAHIM		Cloth Type:	COTTON
Body Temp before:	T1:32.6 ºC ,	T2:34.2 ºC,	T3: 33.9 ºC,	T4: 30.9 ºC
Diameter:	3.5mm		Ambient Temperature:	31 ºC

Minute	Hole Quantity			
	15 hole			
	Front Body		Back Body	
	T1	T2	T3	T4
0.5	32.1	33	32.2	30.3
1.0	32.3	33.6	32.3	30.5
1.5	32.7	33.2	32.8	31.1
2.0	33.3	33.9	33.1	30.9
2.5	34.6	35.4	33.2	31.1
3.0	34.1	34.1	34.5	31.3
3.5	33.8	33.8	33.2	30.9
4.0	34.3	34.5	33.8	31.8
4.5	34.5	35.2	34.6	32.8
5.0	36	36.1	35.3	34
5.5	36.4	36.7	36.5	34.8
6.0	36.7	36.9	36.6	35.1
6.5	36.7	37.1	36.9	35.2
7.0	36.8	37.5	36.7	35.5
7.5	36.9	37.9	36.9	35.3
8.0	37.4	38.4	37.7	35.4
8.5	37	37.3	36.8	34.2
9.0	36.8	37.4	37	35.2
9.5	37.4	37.4	36.8	35
10.0	37.5	38	37.3	34.9
10.5	37.8	37.9	37.2	35.5
11.0	37	36.4	36.6	35.5
11.5	37.9	37.7	37.3	36
12.0	38.1	38	37.8	36.2
12.5	38	37.8	37.2	36.1
13.0	38	38	37.2	35.9
13.5	37.9	37.7	37.4	36.1
14.0	37.7	37.5	37.5	35.9
14.5	37.8	37.5	37	36
15.0	37.7	37.8	37.5	35.8
15.5	37.1	37.5	37.4	35.7

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16.0	37.5	37.5	37.2	35.9
16.5	37.5	38	37.4	35.6
17.0	38.3	37.9	36.9	35.1
17.5	37.2	37.3	36.5	35
18.0	37.2	37.5	36.7	35.1
18.5	37.3	37.4	36.8	35.3
19.0	37.2	37.7	36.7	35.5
19.5	37	37.4	36.8	35.9
20.0	37.2	37.3	37.1	35.7

Table 4. 5 The result for 20 holes Fabric Duct Fan Belt

Date:	20/12/2021		Age:	24
Time:	1422		Weight:	65KG
Name:	ZAHIM		Cloth Type:	COTTON
Body Temp before:	T1:33.8 ºC ,	T2:33.2 ºC,	T3: 34.9 ºC,	T4: 33.1 ºC
Diameter:	3.5mm		Ambient Temperature:	31 ºC

Minute	Hole Quantity			
	20 hole			
	Front Body		Back Body	
	T1	T2	T3	T4
0.5	32.8	33	33.7	32.9
1.0	33.2	33.4	33.3	32.8
1.5	33.1	33.5	34.5	33.6
2.0	33.6	34	34.6	33.6
2.5	34	34.2	33.8	33.3
3.0	33.9	34.4	33.6	33.3
3.5	34.4	35	34.6	33.6
4.0	34.7	35.2	34.8	34.1
4.5	35.2	35.4	35.8	35.2
5.0	35.2	35.7	35.9	35.1
5.5	35.2	35.7	35.9	35
6.0	35.2	36.1	37	35.5
6.5	35	36.2	36	35.2
7.0	35	36.4	35.9	35.1
7.5	35.7	36.9	36.4	35.9
8.0	35.8	36.7	36.3	36.1
8.5	35.9	36.8	36.6	36.6
9.0	36.4	37.4	37.9	37.5
9.5	36.6	37.5	37.4	37.2

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10.0	36.5	37.2	36.9	36.9
10.5	36.6	37.1	37.7	37.1
11.0	37.1	37.3	37.8	37.2
11.5	37.5	37.7	37.5	37
12.0	37.7	38.1	37.8	36.9
12.5	37	38	37.4	36.5
13.0	37.3	38.3	38.1	36.9
13.5	37.4	38.4	37.9	36.9
14.0	37.4	37.7	36.9	36
14.5	37.1	37.2	36.3	36
15.0	37.2	37.1	36.6	36.2
15.5	37.7	37.3	36.8	36.2
16.0	37.8	37.2	37	36.3
16.5	37.9	37.4	36.9	36.9
17.0	37.7	37.5	36.8	36.6
17.5	37.9	38	37.1	36.4
18.0	37.7	37.8	37.9	37.2
18.5	37.8	37.8	38	38.2
19.0	37.8	37.5	37.8	37.7
19.5	37.9	37.9	37	37.7
20.0	37.8	37.7	37.2	36.8

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Table 4. 6 The result for 25 holes Fabric Duct Fan Belt

Date:	20/12/2021		Age:	24
Time:	1422		Weight:	65KG
Name:	ZAHIM		Cloth Type:	COTTON
Body Temp before:	T1:33.8 ºC ,	T2:33.2 ºC,	T3: 34.9 ºC,	T4: 33.1 ºC
Diameter:	3.5mm		Ambient Temperature:	31 ºC

Minute	Hole Quantity			
	20 hole			
	Front Body		Back Body	
	T1	T2	T3	T4
0.5	32.7	33.5	33.4	32.2
1.0	32.3	33.4	33.1	32.4
1.5	32.3	33.7	33.5	32.1
2.0	32.3	33.8	33.4	32.2
2.5	32.6	33.8	33.2	32.1
3.0	32.8	33.9	33	32.2
3.5	32.4	34.3	33.5	32.7
4.0	32.9	34.3	33.5	32.9
4.5	33.5	34.4	33.5	32.7

5.0	33.4	34.1	33.6	33
5.5	33.7	34.3	33.9	32.9
6.0	33.9	34	33.9	33.2
6.5	34.4	34.4	34.2	33.7
7.0	34.8	35.3	34.6	33.9
7.5	34.8	35.1	34.9	34.3
8.0	35.2	35.2	35.1	34.3
8.5	35.2	35.4	35.3	34.6
9.0	35.3	35.9	35.8	34.7
9.5	35.3	35.9	35.6	35.1
10.0	35.2	36.1	35.8	35.2
10.5	35.5	36.5	36.1	35.4
11.0	35.2	36.2	36	35.6
11.5	35.1	35.9	36.1	35.8
12.0	35.3	35.9	36	36
12.5	35.4	35.9	36	36.3
13.0	35.6	36	36.1	36.3
13.5	36.2	36.2	36	36.4
14.0	36.3	36.4	36.4	36.7
14.5	36.8	36.5	36.4	36.4
15.0	36.8	36.5	36.6	36.4
15.5	36.9	36.7	36.6	36.7
16.0	36.7	36.7	37	36.8
16.5	37	37	37.4	37.1
17.0	37.5	37.3	37.4	37.1
17.5	37.9	37.3	37.2	37
18.0	38	37.3	37.4	37.2
18.5	37.8	37.3	37.1	36.9
19.0	37.5	37.3	37.1	36.7
19.5	37.2	37.5	37.5	37.1
20.0	37.1	37.5	37.8	37.4

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4.3.1 Selecting The Best Design

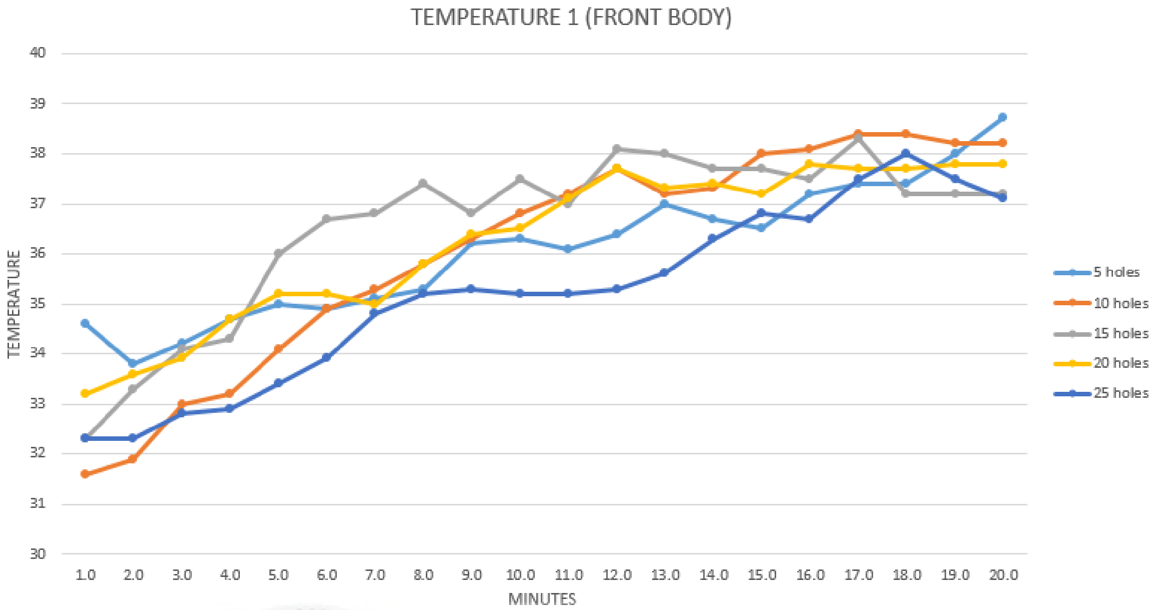

Figure 4. 6 Fabric Duct Fan Belt for Temperature 1 (5holes: Blue, 10holes: Red, 15holes: Grey, 20holes: Yellow, 25holes: Purple)

Figure 4.6 shows the line graph for body temperature 1. Temperature 1 was placed at the front of the body on the right side. As we can see, 1 until 2 minutes, 5 holes and 25 holes experiencing a decline, while 10 holes, 15 holes, and 20 holes experiencing an increase. For the past 3 minutes, all holes were experiencing growth until minute 6. Then, the 20 holes body temperature started to decrease to 0.2ºC. After that, all trends of line graph back to increase again. In minute 8, 25 holes began to decrease the body temperature. And this temperature remains constant to the average temperature of 35.2ºC until minute 12. At the same time, the other holes started to decrease the temperature in minute 14 except for holes 10, where they kept increasing until minute 17. To conclude, the trend pattern of the line graph for 25 holes is the most constant than the other 4 holes.

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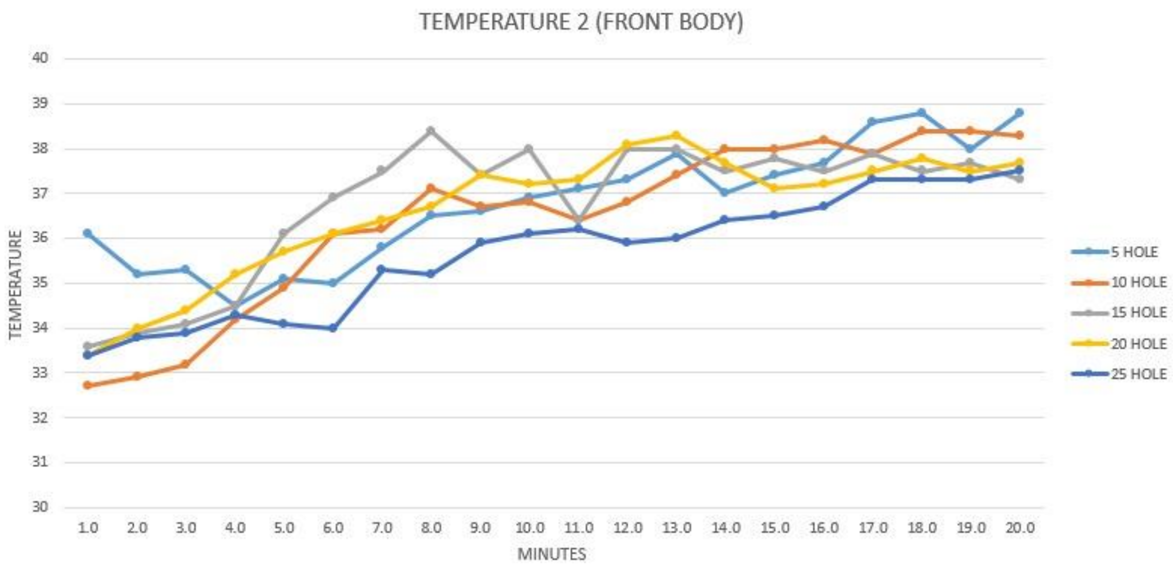

Figure 4. 7 Fabric Duct Fan Belt for Temperature 2 (5holes: Blue, 10holes: Red, 15holes: Grey, 20holes: Yellow, 25holes: Purple)

Figure 4.7 shows the line graph for body temperature 2. The temperature was placed at the front of the body on the left side. As we can see, minutes 1 until minutes 2, all holes except holes 5 experienced increased. This happens due to the body temperature that adapts to the ambient temperature. Holes 5 is still decreasing until minute 4. In minute 4, all the holes are still rising except holes 25. We can see that holes 15 rose sharply until the peak at minutes 8. The increase was from 34.5ºC until 38.4ºC. For holes 25, the temperature began to be constant from minute 9 until minute 16. The temperature is between 35.9ºC to 36.7 ºC. Then it rises sharply until minutes 17. Then it goes back to constant until the end of the experiment. We see that the movement is messed up from this graph trend except for 25 holes. This indicates the unbalance of the airflow to temperature 2. Holes 25 is the most constant because the body gets enough airflow rate.

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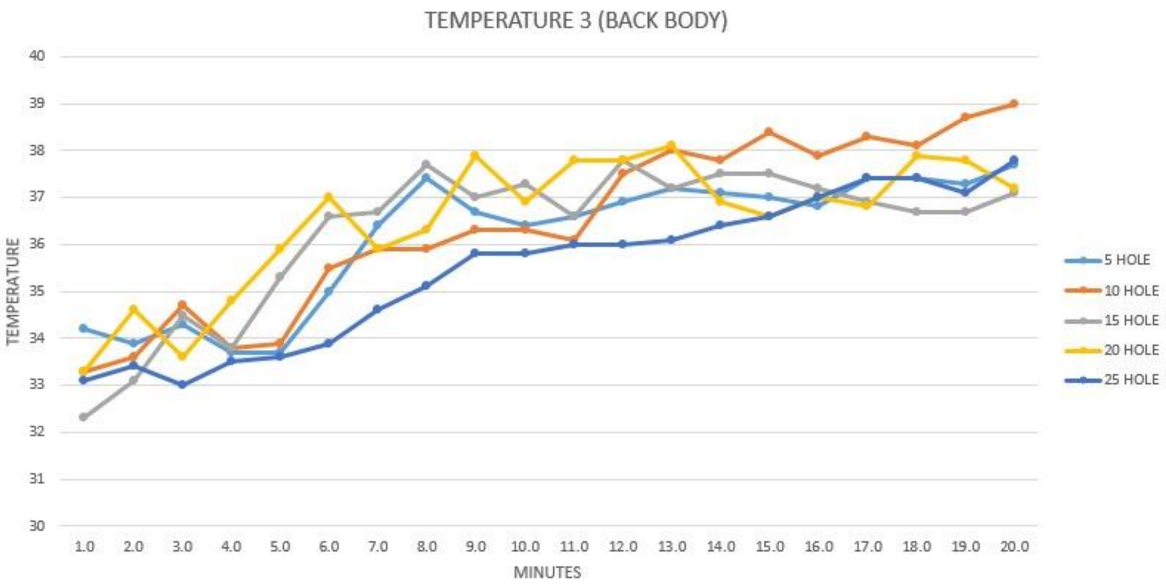

Figure 4. 8 Fabric Duct Fan Belt for Temperature 3 (5holes: Blue, 10holes: Red, 15holes: Grey, 20holes: Yellow, 25holes: Purple)

Figure 4.8 shows the results for body temperature 3 using a line graph. The temperature was placed at the back of the body on the left side. As we can see, the temperature was increased for the first 1 minute until 2 minutes. This temperature keeps rising sharply from minutes 1 to 8 minutes except for holes 25. Holes 25 are still growing, but they rise in the control condition. After minutes 8 until the end of the experiment, the temperature is kept constant between average temperature 35.1ºC until 38.8ºC. In this trend of the graph, we can see that holes 25 are getting the most consistent in a control condition for the average body temperature.

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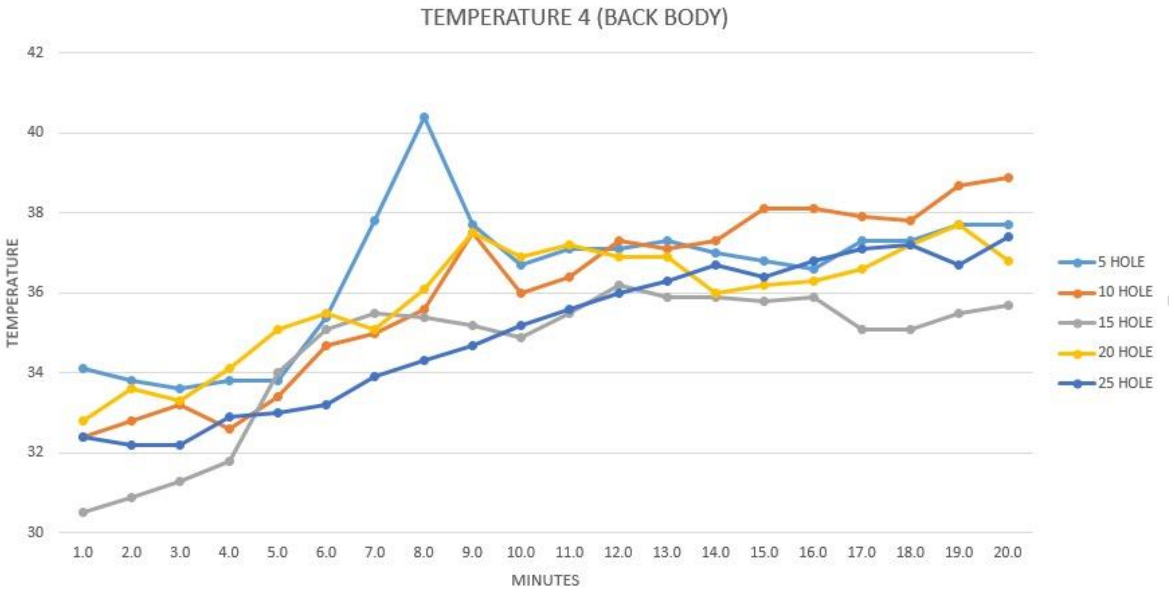

Figure 4. 9 Fabric Duct Fan Belt for Temperature 4 (5holes: Blue, 10holes: Red, 15holes: Grey, 20holes: Yellow, 25holes: Purple)

Figure 4.9 shows the line graph for body temperature 4. The temperature was placed at the back of the body on the right side. As we can see, the temperature for holes 5 and holes 25 were decreased. On the other side, holes 10, 15 and 20 were increased. For the holes 5, the peak temperature is at minutes 8, where the temperature is 40.4ºC. This happened because, during the experiment, one of the fans were shut out of the blue. We can see that the trend of the graph for holes 5, holes 10, holes 15, and holes 20 is unstable. The direction of the chart for holes 25 was the most constant and in the control condition.

The Fabric Duct Fan Belt variations during the 20 minutes exercise are shown in Figures 4.6 until 4.9, respectively, for the different cases. It can be noticed that in the first 5 minutes, the body temperature increased dramatically from their initial thermo-neutral state. However, after 10 minutes, the body temperature remains constant until the experiment's end. It can be seen obviously that the 25 holes get the lowest body temperature. This is due to the more significant airflow that the body receives. This result shows that the more the hole quantity, the lower the body's average temperature. This is because the airflow in 25 holes is more extensive than in 5 holes, 10 holes, 15 holes, and 20 holes.

4.4 Comparison

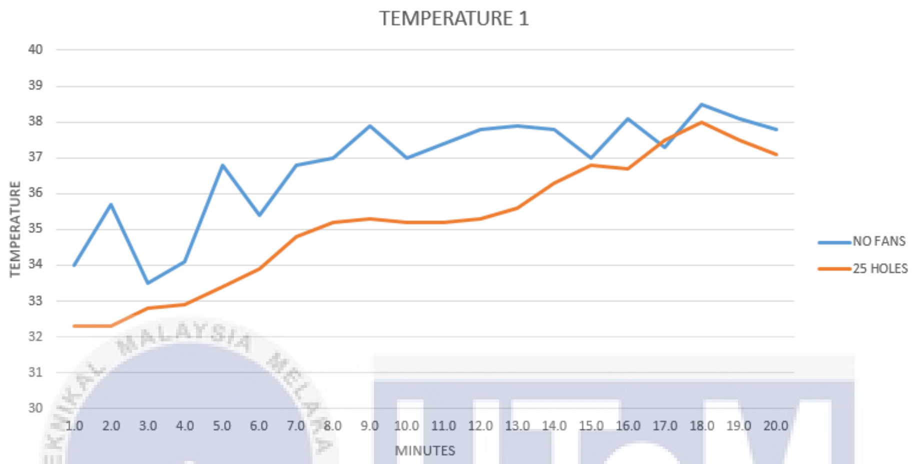

Figure 4. 10 Comparison Temperature 1 front body between no fans and 25 holes (Blue represent no fans and red represent using 25 holes Fabric Duct Fan Belt)

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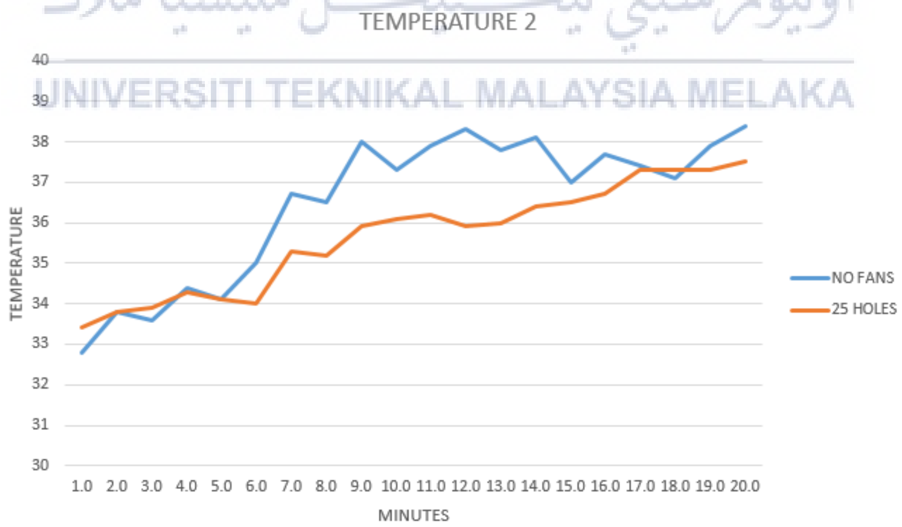

Figure 4. 11 Comparison Temperature 2 front body between no fans and 25 holes (Blue represent no fans and red represent using 25 holes Fabric Duct Fan Belt)

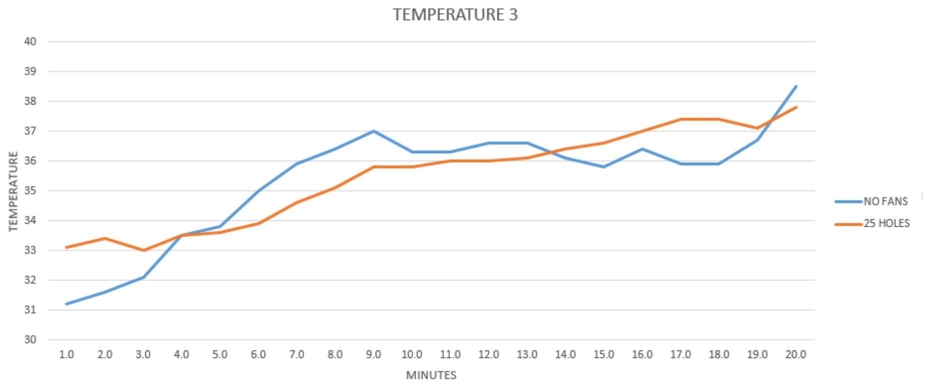

Figure 4. 12 Comparison Temperature 3 front body between no fans and 25 holes (Blue represent no fans and red represent using 25 holes Fabric Duct Fan Belt)

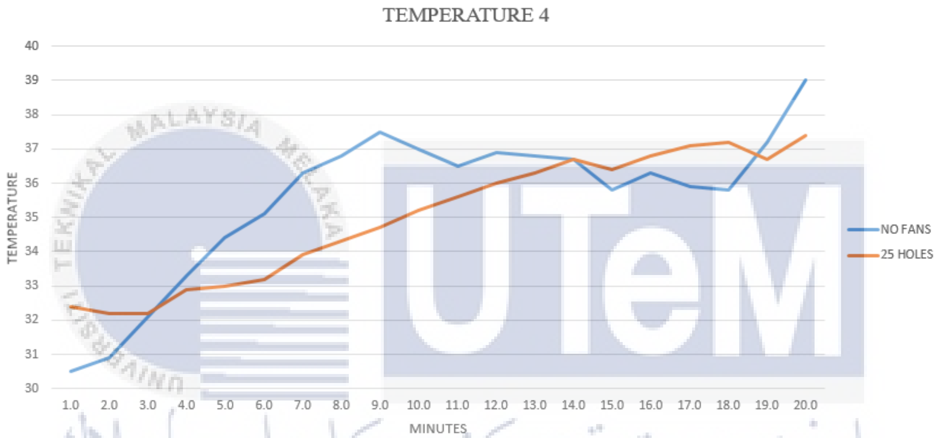

Figure 4. 13 Comparison Temperature 4 front body between no fans and 25 holes (Blue represent no fans and red represent using 25 holes Fabric Duct Fan Belt)

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The Fabric Duct Fan Belt variations during the 20 minutes exercise are shown in Figures 4.11 until 4.14, respectively, for the different cases. The figure above represents the comparison without Fabric Duct Fan Belt and Fabric Duct Fan Belt (25 holes). It can be noticed that before using Fabric Duct Fan Belt, the body temperature of T1, T2, T3, and T4 are slightly higher from their initial thermo-neutral state till their final forms, respectively, at the end of the experiments. In the first 5 minutes, the temperature will keep increasing drastically. After that, the temperature will increase dramatically because of the hot environment. This is because the body's internal "thermostat" maintains a consistent interior body temperature by pumping more blood to the skin and boosting sweating production. Between five minutes until fifteen minutes, the body raises the rate of heat escape to balance the heat burden. When the “heat acquisition” rate exceeds the “heat loss” rate in a hot environment, the body temperature increases. After 5 minutes, the body started to maintain the temperature. At this time, the Fabric Duct Fan Belt plays the role of preserving the body temperature.

Figures 4.10 and 4.11 show that the front's body temperature is slightly different. Notice that the body temperature at the front is higher and uneven before using Fabric Duct Fan Belt. After using Fabric Duct Fan Belt, the temperature decreased drastically. This shows that the front body temperature gets enough airflow after using the Fabric Duct Fan Belt. Figures 4.12 and 4.13, the temperature for both is consistent. But notice that before is higher than after using fabric duct fan belt. When subjected to situations that disrupt thermal homeostasis, the human thermoregulatory system keeps the core body temperature stable (Aryal et al., 2017). Vasoconstriction and vasodilation are the two main processes that alter blood flow to the cutaneous vasculature by constricting or dilating blood vessels. As a result, the skin blood flow and hence the skin temperature rises during physical activity to efficiently transmit the metabolic heat generated. However, the rise in skin temperature during thermoregulation is not uniform. It is dependent on various factors, including external temperature, mode of activity, and activity intensity which influence the body’s overall heat debt.

4.5 Survey

The survey from students UTeM or workers who work in a hot environment on using Fabric Duct Fan Belt and their feedback. The feedback survey required to fill the rating of comfortable by the surveyors based on their experience. The rating will be served from 1 until 5, 1 represents terrible, and 5 illustrates excellent.

Table 4. 7 Subjective comfort rating questionnaire

QUESTION	Terrible	Poor	Acceptable	Good	Excellent
Fits at the waist	1	2	3	4	5
Sweating	1	2	3	4	5
Get enough airflow	1	2	3	4	5
Is it comfortable?	1	2	3	4	5
Has a nice feeling	1	2	3	4	5
Overall performance	1	2	3	4	5

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Table 4. 8 Survey from UTeM student's

Bil.	Name	Weight	It fits at the waist	Sweating	Get enough airflow	Is it comfortable?	Has a nice feeling	Overall performance
1.	Afiq Hamizan	65kg	5	5	5	5	5	5
2.	Saiful Syahmi	50kg	0	3	4	3	5	5
3.	Iqmal Zaiddie	90kg	0	2	4	4	4	4
4.	Mohd Nazrin	55kg	0	4	3	5	5	5
5.	Mohd Amir	65kg	5	3	4	5	5	5
6.	Mohd sayyidi	63kg	4	5	5	5	5	5
7.	Mohd Uzair	58kg	1	2	3	3	4	4
8.	Ahmad Asyraf	65kg	5	4	5	4	4	5
9.	Ahmad Syahir	50kg	0	4	3	5	5	4
10.	Luqman Haqim	65kg	5	4	5	4	4	4
AVERAGE			2.5	3.6	4.1	4.3	4.6	4.6

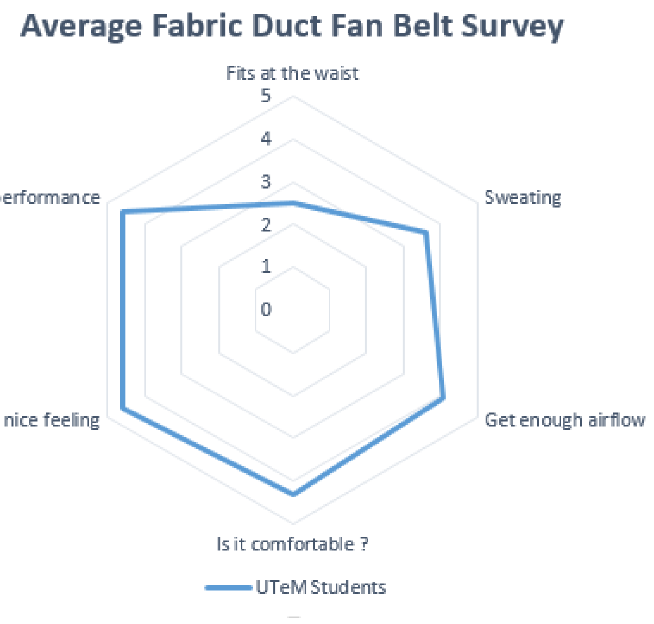

Figure 4. 14 Average Fabric Duct Fan Belt Survey

Figure 4.14 shows the result for the Average Fabric Duct Fan Belt where it has been tested on 10 students' UTeM. The result shows that the rating from 1 to 5 which is 1, represents bad until 5 represent excellently. The radar chart shows that the fits at the waist get the lowest average, which is 2.5. This is because Fabric Duct Fan Belt has no adjustment and is permanent. The limitation is for people who weighted 65kg until 68kg. The sweating rating got an average of 3.6, which is the second-lowest. More significant people create more heat due to having to move greater body mass, which results in more heat being generated and, as a result, more sweat. A more significant body requires more sweat to cool off since it has a larger surface area. In terms of getting enough airflow, comfortable, nice feeling, and overall performance got a high rating. It shows that the Fabric Duct Fan Belt is functional goodly.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 Conclusion

This section will conclude overall of the research. Overall, this research has achieved the objective. First, the effect of prolonged exposure to direct sunlight on body temperature has been investigated. The body temperature will be increased along with time. Heat can be lost if the skin temperature is higher than the ambient temperature, and it can be added if the skin is directly exposed to sunlight. Next, the results from the analyses prove that continuous air flows circulating the body can reduce and maintain the body temperature. Sweat transfer as water on the skin into water vapour gas is evaporation. At rest, this mechanism accounts for about 25% of heat loss, but it becomes the primary source of heat loss during the experiment.

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Finally, this research proposed developing and modifying electric fans as the main supply. The concept of this design is by using Fabric Duct as the primary air distribution for cooling the body temperature. Three prototypes were built during the process. For the material, we will be using permeable fabric. However, duct tape is used as the proven concept, but there is still room for improvement. It is essential to use a material that cannot be passed to reduce the total air loss. In terms of shape, this research used a C shape to balance the airflow to the body. However, the shape cannot be straight. The minimum number of holes for the Fabric Duct Fan Belt is 25. If less than 25 holes, the temperature will rise and does not in the control condition.

5.2 Recommendation

A few recommendations should be implemented and conducted in a future project.

1. The design can be improved to make it more efficient and easy to use. For example, the holes can be added for more than 25 holes because the more the number of holes, the lower the temperature.

2. The adjustment of the belt also can be improved. By improving the adjustment of the belt, workers with various weights can wear the Fabric Duct Fan Belt.

3. Lastly, the design of the Fabric Duct Fan Belt. For future study, the creation of the Fans bag can be improved. The Fans must be supported so that it can work much more efficiently

4. The research can be further by measured heart rate, local skin temperatures, thermal comfort and sensation, and wetness skin.

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APPENDICES 1

Project Title:	Study On Body Temperature Effect Towards Workers That Works In Hot Ambient By Using Cooling Fan	PSM 1		PSM 2
Student Name:	MOHAMAD ZAHIM BIN MOHAMAD SUKAIRI	Course:	BMMH S1/2	

APPENDIX A Effective Gantt Chart for PSM 1

W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Literature Review					Methodology			Introduction		Draft/Finalised			Presentation	QnA session
Date					Date			Date		Date	Date	Date	Date	Date
17/3	24/3	31/3	7/4	14/4	21/4	28/4	5/5	12/5	26/5	2/6	9/6	16/6	28/6	2/7

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APPENDIX BEffective Gantt Chart for PSM 2

Result and Discussion										Conclusion and Recommendations			e-logbook	Report & 4 pages summary	Presentation	QnA session
Date					Date			Date		Date	Date	Date	Date	Date	Date	Date
6/10	13/10	20/10	27/10	3/11	10/11	17/11	24/11	1/12	8/12	15/12	22/12	29/12	9/1	18/1	18/1	21/1

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APPENDIX C Thesis Status Verification Form

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BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA

TAJUK: **STUDY ON BODY TEMPERATURE EFFECT TOWARDS WORKERS THAT WORKS ON HOT AMBIENT BY USING COOLING FAN**

SESI PENGAJIAN: **2020/21 Semester 1**

Saya **MOHAMAD ZAHIM BIN MOHAMAD SUKAIRI**

mengaku membenarkan tesis ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

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☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☑ TIDAK TERHAD

Zahim

Disahkan oleh:

Alamat Tetap:
Rumah No 6, Lorong 3
Kg. Sungai Kajang Lama, 45500
Tanjung Karang, Selangor

Tarikh: 16/1/2022

Cop Rasmi: AZMAN BIN IBRAHIM
Jurutera Pengajar
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APPENDIX D Turnitin Report

Report PSM 2

ORIGINALITY REPORT

7%	5%	3%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.dosh.gov.my Internet Source	3%
2	Wen Yi, Yijie Zhao, Albert P.C. Chan, Edmond W.M. Lam. "Optimal cooling intervention for construction workers in a hot and humid environment", Building and Environment, 2017 Publication	1%
3	bianet.org Internet Source	1%
4	thermalscience.vinca.rs Internet Source	1%
5	Payel Acharya, Bethany Boggess, Kai Zhang. "Assessing Heat Stress and Health among Construction Workers in a Changing Climate: A Review", International Journal of Environmental Research and Public Health, 2018 Publication	1%
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