DESIGN OF A MINIATURE AXIAL BLOWER FOR A PORTABLE THERMAL COMFORT SYSTEM

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DESIGN OF A MINIATURE AXIAL BLOWER FOR A PORTABLE THERMAL COMFORT SYSTEM

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Universiti Sains Malaysia

DECLARATION

This paper has never been substantially reviewed for any degree and was not submitted concurrently in a nomination for any degree.

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LIST OF ABBREVIATIONS

CFM	Cubic Feet per Minutes
PPE	Personal Protective Equipment
NPSH	Net Positive Suction Head
PPE	Personal Protective Equipment
PCG	Personal Cooling Gear
BAI	Breathing Apparatus Instruction
SCBA	Self-Contained Breathing Apparatus
LFTE	Live Fire Training Exercise
MFTE	Mock Fire Training Exercise
CPR	Cardiopulmonary Resuscitation
CC	Chest Compressions

ABSTRAK

Pekerja barisan hadapan memakai pakaian Alat Pelindung Diri (PPE) untuk mengelakkan bahaya mendapat COVID-19 akibat daripada masalah pandemik global. Oleh kerana tiada sistem pengudaraan atau penyejukan untuk mengurangkan kesan haba yang dijana, sut ini menyebabkan haba terkumpul di dalamnya. Akibatnya, memakai sut PPE untuk tempoh yang lama boleh menyebabkan seseorang terdedah kepada strok haba. Oleh itu, matlamat projek ini adalah untuk mereka bentuk blower kipas yang boleh menjadi sebahagian daripada sistem penyejukan yang boleh mengurangkan kesan buruk memakai sut PPE.

Konsep untuk membina sistem penyejukan yang boleh digunakan sebagai cara untuk mengurangkan kesan haba yang dijana di dalam sut PPE. Terdapat pelbagai jenis konsep sistem penyejukan yang boleh digunakan untuk mengurangkan kesan negatif apabila memakai sut PPE. Namun, untuk projek ini, pengehebus udara lebih difokuskan sebagai sistem penyejukan kerana medium angin adalah semburan yang tidak akan habis, tidak mempunyai berat dan lebih menjimatkan.

Projek ini bermula dengan mengumpul beberapa data yang diperlukan untuk pembuatan kipas seperti kelajuan kipas, saiz bilah, kedalaman bilah dan bilangan bilah. Daripada data ini, model akan direka bentuk menggunakan perisian solidwork sebelum dicetak melalui pencetak 3D. Seterusnya, menjalankan eksperimen ke atas model dengan menggunakan pelantar ujian dapat memastikan sama ada eksperimen objektif dapat dicapai atau tidak. Daripada kajian yang dibuat, kita boleh menaik taraf model kipas untuk memenuhi sasaran yang dikehendaki. Simulasi yang dijalankan menggunakan perisian ANSYS bertujuan untuk melihat sama ada keputusan yang diperoleh dalam eksperimen memberikan ciri yang sama seperti dalam simulasi.

Hasil kajian ini memberikan hasil yang positif di mana reka bentuk yang dihasilkan dapat memberikan kadar aliran udara yang disasarkan sehingga 10 cfm(0.0047194745 m^3/s) dengan menggunakan persediaan pada 12V, 3600 rpm dan sambungan menggunakan tiub. Keputusan simulasi juga menunjukkan bahawa eksperimen adalah tepat kerana halaju akan meningkat apabila melalui ruang sempit seperti pada tiub venturi.

ABSTRACT

Frontline workers wear Personal Protective Equipment (PPE) clothes to prevent the danger of getting COVID-19 as a result of the global pandemic problems. Since there is no ventilation or cooling system to reduce the effects of the heat generated, this suit causes heat to build up within. As a result, wearing a PPE suit for a long period may cause a person to be prone to heat stroke. Thus, the aim of this project is to design a fan blower that can be part of a cooling system which can reduce the adverse effects of wearing the PPE suit.

The concept to build a cooling system that can be used as a way to reduce the effect of heat generated inside the PPE suit. There are various types of cooling system concepts that can be used to reduce the negative effects when wearing a PPE suit. However, for this project, the fan blower is more focused as a cooling system because the air will not run out, has no weight and is economical.

The project begins by collecting some data required for the manufacture of radial impeller such as specific speed, size of blade, depth of blade and number of blades. From this data, a model will be designed using SOLIDWORK software before being printed through a 3D printer. Next, conducting experiments on the model by using a test rig can ensure whether the objective experiment can be achieved or not. From the study made, we can upgrade the fan model to meet the desired target. Numerical solution conducted using ANSYS software aims to see if the results obtained in the experiment provide similar characteristics as in the simulation.

The results of this study gave a positive result where the design produced can provide a targeted air flow rate of up to 10 cfm (0.0047194745 m^3/s) by using setup at 12V, 3600 rpm and connection using tube. The simulation results also show that the experiment is accurate because the velocity will increase when passing through a narrow space such as on a venturi tube.

CHAPTER 1

INTRODUCTION

1.1 Project Overview

Adequate hygiene, risk management, injection safety, safe waste management, appropriate linens, environmental cleaning and sterilisation are crucial for halting the spread of the COVID-19 infection. A sufficient supply of patient-care equipment, as well as the necessary personnel equipment for protection (PPE)(Tumram, 2020). There are strict rules for donning and doffing PPE, and once it is on, a healthcare worker here will remain in it for at least 6 hours at a stretch. This presents different practical problems as follows:

1. Inability to drink water
2. Inability to eat food
3. Inability to go to toilet
4. High amount of body sweating
5. Increased body temperature

There are several types of cooling systems that can be done, such as auxiliary cooling or personal cooling systems. Here, we focus on the personal cooling system. For example, ice vests, water-cooled garments or wet towels. Wearable personal cooling systems have limitations within a work setting, such as an ice vest cannot withstand the cold temperature for a long time and if worn in freezing conditions causes extreme cold, while the use of water as a cold material gives an additional burden to the user's PPE suit.

Due to that, studies to build a system that uses wind as a cooling medium are being carried out. Air does not require ventilation because it will not run out. The aim of this work is to design a fan or blower that is part of a PPE suit thermal comfort system. The construction of this fan blower requires a study of the appropriate parameter values to minimize the effect of heat generated on the PPE suit. A axial fan blower consists of an impeller with small blades on the circumference, a shroud to direct and control the air flow into the center of the impeller and out at the periphery.

The pressure rises and the flow rate in centrifugal blowers depend on the peripheral speed of the impeller and blade angles. However, the diameter of the fan, size of blade, angle, and number of blades are important parameters that need to be taken into account to achieve the wind generated when the fan rotates to reach a value up to 10 CFM. Finally, to ensure that the target of this project is achieved, the resulting model must go through a test rig process to identify output values such as static pressure and volume flowrate that can be achieved as desired.

1.2 Objectives

The aim of the study is to design a fan blower that can be part of a thermal comfort system that can reduce the adverse effects of wearing the PPE suit.

1.3 Problem Statements

Frontline employees need to wear Personal Protective Equipment (PPE) clothing in order to reduce the risk of contracting COVID-19 as a result of the global pandemic issues. This suit causes heat to build up within since there is no ventilation or cooling system to reduce the effects of the heat generated. As a result, wearing a PPE suit for a long period may cause a person to be prone to heat stroke. Thus, the aim of this project is to design a fan blower that can be part of a thermal comfort system that can reduce the adverse effects of wearing the PPE suit.

1.4 Scope of Work

The concept is to build a thermal comfort system that can be used as a way to reduce the effect of heat generated inside the PPE suit. By studying the parameters for designing a fan blower model using SOLIDWORK software, before fabricating the model using a 3D printer. Next, conducting experiments on the model by using a test rig can ensure whether the objective experiment can be achieved or not. From the study's findings, we can upgrade the fan model to meet the desired target.

The proposed solution the problem that occurs for this project is in terms of creating the design of the impeller. The design of this impeller will be done by cad drawing to get a clear picture before making the actual model using 3D printing. Next, the construction of the test rig is through fabrication because the fabrication design depends on the impeller design as well. This test rig has a diffuser as a place to place the venturi tube. The Venturi tube or venturi meter is an instrument for measuring with accuracy the flow rate of fluids in pipes. A venturi tube is a short pipe with a narrowed inner surface that has been used to measure fluid flow and as a pump. The venturi tube described here is designed to be printed vertically on most common desktop 3D printers, which are frequently limited to 300mm or less. (Hrisko, 2020)The size of the fan and casing design will affect the dimensions required for the venturi tube. This fabrication work involves various processes such as 3D printing, CNC machining, cutting, and assembly.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter will specify the reviews from previous researchers that are related to this final year project. It begins with the coronavirus disease, personal protective equipment (PPE) cooling system, fan blower. Then, an evaluation of suitable air flow rate (CFM) for humans, test rigs, and numerical solutions is discussed. At the end of this chapter, a literature finding, which is the summary of the literature review, is presented.

2.2 Introduction to Corona Virus Disease

First of all, we'll see more about the coronavirus that has hit the rest of the world starting in 2019. The coronavirus disease 19 (COVID-19) is a highly contagious and dangerous viral infection caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which first appeared in Wuhan, China and has since spread throughout the world. Coronaviruses belong to the Coronaviridae family in the Nidovirales order. The virus was given the name coronavirus because of the crown-shaped spikes on its exterior.(Shereen *et al.*, 2020). Coronaviruses are divided into four subgroups alpha (α), beta (β), gamma (γ) and delta (δ) coronavirus.

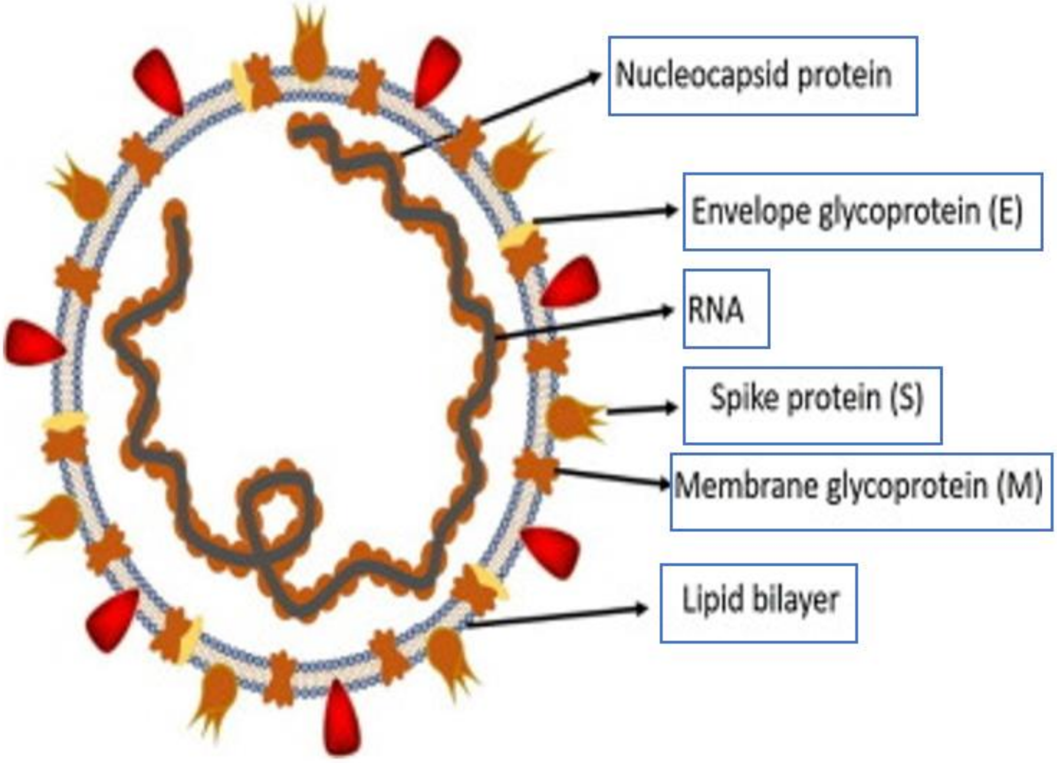

Figure 2.1: Structure Of Respiratory Syndrome Causing Human Coronavirus.((Shereen *et al.*, 2020)

According to a genomic study, bats could be the main reservoir. SARSCoV-2 is phylogenetically related to severe acute respiratory syndrome-like (SARS-like) bat viruses. Although the source of genesis and transmission to humans is unknown, its quick human-to-human transfer has been generally proven. Thousands of people have been impacted by this pandemic, who are either sick or dying as a result of the disease's spread. The most typical signs of this viral illness include a fever, cold, cough, discomfort in the bones, and difficulty breathing, which can progress to pneumonia. Because of the virus, the use of PPE is necessary to reduce cases of infection between patients and outside individuals. Although there are some organizations that have studied and used vaccines as a measure to prevent, the use of PPE is still needed.

Appropriate hygiene, risk management, injection safety, safe waste management, appropriate linens, environmental cleaning, and sterilization are all necessary to prevent the spread of the COVID-19 infection. However, wearing a PPE suit causes some negative effects, such as heat stroke, sweating, discomfort, and can cause the reproduction of germs as a result of the resulting sweat. Here are some references and studies on the effect of PPE, the type of thermal comfort system that is suitable to be used, the design of the fan blower and the study of effectiveness through the test rig experiment process.

2.3 Personal Protective Equipment (PPE)

PPE is a category of protective apparel used to reduce workers' exposure to biological hazards and safeguard their health. PPE includes goggles, face shield, mask, gloves, coveralls or gowns (with or without aprons), head cover, and shoes to prevent contamination, which is likely in the case of droplets generated by an infected person's cough or sneeze, or during aerosol -generating procedures performed in a clinical setting, or during unintentional touching of contaminated areas. According to research, healthcare workers are exposed to many hazards that can adversely affect their health and well-being. These workers are at risk for illness and injury due to dangers such as long hours of work, shifting shifts, physically demanding duties, violence, exposure to infectious diseases and hazardous chemicals.(Tumram, 2020). Due to that, it causes effects such as anxiety and restlessness, headaches, and increased body temperature. The advantages of PCG to improve the comfort, health, and performance of healthcare staff working in hot and humid environments are highlighted in this paper's reference. The personal cooling garment (PCG) is a microclimate assistive device that provides protection from heat stress. It contains the layers forming the garment, the air treatment system, and the distribution channels.(Tumram, 2020). The conclusion of this paper was to alert the administration to the advantages of PCG to improve the comfort and health and performance of healthcare staff working in a hot and humid environment.

Next, for reference on the effect of using PPE suits, the next is from S. S. Bruce-Low. This study focuses more on the effects of wearing personal protective clothing and self-contained breathing apparatus on heart rate, temperature, and oxygen consumption during stepping exercise and live fire training exercises. Firefighter breathing apparatus instructors (BAIs) must possess the ability to respond to both the extrinsic stress of a high-temperature environment and the intrinsic stress from wearing personal protective equipment (PPE) and self-contained breathing apparatus (SCBA), repeatedly and regularly, while training recruits in live fire training exercises (LFTE).(Bruce-Low, Cotterrell and Jones, 2007). Active work in a hot environment on the whole is a more onerous challenge to maintaining a normal body temperature than identical work in a temperate environment. The issue is that the materials necessary for heat loss do not always correlate to those required for fire resistance and environmental waterproofness. This increases the discomfort of wearing the suit for an extended period of time and raises the individual's pulse rate. According to the findings of this study, the minor effort placed on the BAIs by performing the LFTEs causes an increase in heart rate. Heat storage appears to be worsened greatly during the LFTEs compared to the mock fire training exercises (MFTE)s, as evidenced by large increases in RPE, skin, aural, and microclimate temperatures, as well as an increase in HR.

Next, we will comment on the research study on the cooling system that can be done to reduce the effects of heat resulting from the use of PPE suits. According to a study on recommendations to use personal cooling capacity, such as the implementation of a personal cooling capacity in the microclimate between the skin and the innermost clothing layer, has proven to be very effective.(Laprise, 2012). Microclimate Cooling Systems (MCS) have been demonstrated to extend mission length, lower body core temperature increases rates and improve mental clarity. Many technologies, goods, and systems claim to be able to create a microclimate or personal cooling environment.

However, there can be substantial disparities in terms of thermal performance, effectiveness, durability, safety, dependability, and compatibility with personal protective equipment.

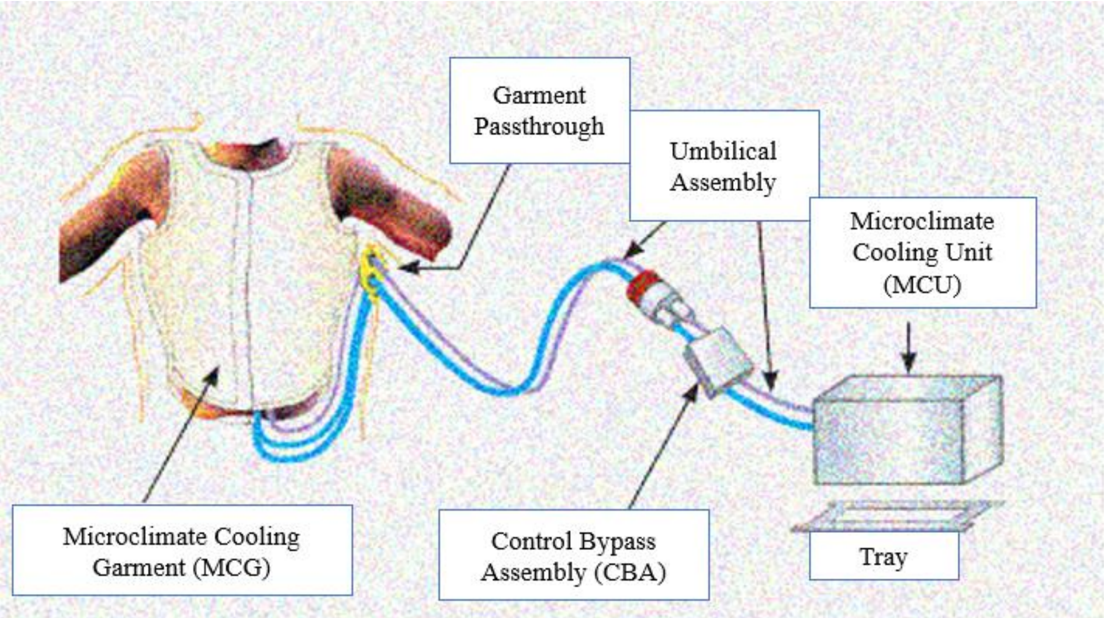

Figure 2.2: Example MCS (Cheuvront, 2005)

In the Journal of Eljon Elezi, he presented a proposal to provide comfort by wearing a PPE suit that is a Single-Circulation Personal Cooling System with Evaporator in a Cooling Suit. This invention utilizes a refrigerator-based cooling system with an evaporator integrated into a cooling suit and an external compressor and condenser. Heat dissipated by the user is absorbed directly from the evaporator, and the heat is then dissipated outside of the cooling system in a condenser.(Elezi *et al.*, 2015).

The idea claims that immediately chilling the user with the evaporator in the suit saves weight and complexity compared to an evaporator-liquid interface where the secondary liquid would then directly cool the person. In addition, this journal also provides recommendations for cooling systems such as body temperature control systems. This invention details a liquid-interface cooling system in which the user wears a vest with cool liquid circulation to remove heat. To cool the liquid circulating through the user's vest, there is a box outside that houses a compressor-refrigerant cooling system and a heat exchanger.(Elezi *et al.*, 2015).

Referring to the journal of Nilesh K Tumran. There are several common methods of cooling that can be done. The cooling vests, cooling neck tie, cooling head gear, cooling body-wears like chill towel, cooling scarf, cooling wrist bands and many more are various components of cooling apparel for personnel working in hot and humid environments(Tumram, 2020) but these things are expensive and not easy to find somewhere. The materials used for the cooling system are of various types such as water, ice and air. On, this project is more focused on the use of air because it is a source that will not run out so it can save costs.

Figure 2.3: Chilling Towel(*Hallie Gould,2022*)

2.4 Design of The Fan Blower

To know more about creating or designing blowers, we will refer to some research papers. The first research paper is an investigation of a miniature centrifugal fan. The first thing when they fan blowers is to know the specifications and size to be designed. A centrifugal fan has been adopted for this study. The specifications are 100 mm 90 mm 20 mm in dimension with an 8 cfm flow rate. (Tsai and Wu, 2007). The process is divided into three parts. Firstly, design and analysis: We have designed a fan according to our design experience of the P-60 miniature turbojet engine compressor. The following design parameters were obtained by the aforementioned design rules:(Tsai and Wu, 2007). Secondly, make a prototype manufacturing impeller or centrifugal fan by using a CNC 5 axis type machine so that the prototype can undergo the next test to obtain data so that it reaches the desired target. The results obtained show that the target flowrate that is set can be achieved by the fan blower design by using a more powerful motor that is at 4000 rpm.

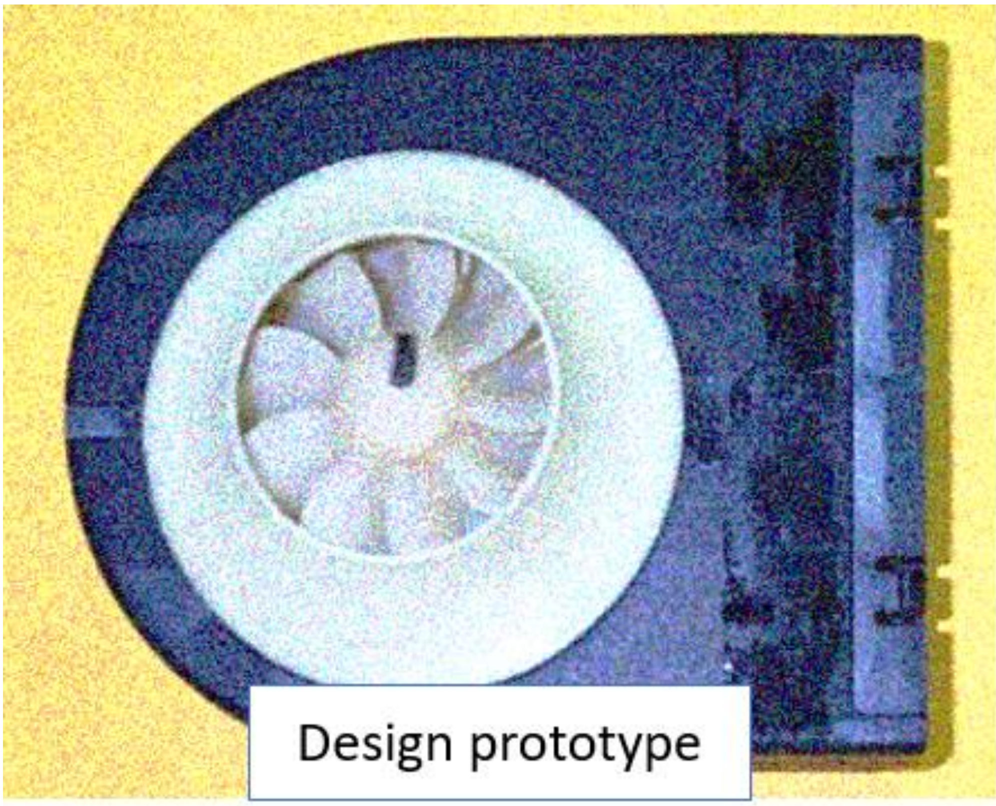

Figure 2.4: Design Prototype of Fan Impeller ((Tsai and Wu, 2007))

The concepts involved in the design of a blower are similar to those involved in the design of a centrifugal pump, with the exception that the name "centrifugal pump" is frequently associated with liquid as its working fluid, whereas the blower is designed to work with water. As a result, the blower can be defined as a device that converts "driver" energy to kinetic energy in a fluid by accelerating it to the outer rim of a revolving device known as an impeller. According to this study, the most important concerns for blower designs are air flow and static pressure, as well as available power, because these three address the fundamental questions of how much air is required and how much it will cost in system power to gain it.

The blower provides the necessary airflow that is needed for the gasification of biomass. Blowers are usually available in AC or DC. The blower to be used should be capable of overcoming the pressure exerted by the biomass and, subsequently, by the char. (Abubakar A. Bukar, 2018). Blowers are commonly associated with difficulties such as vibration, lack of performance, excessive noise, and premature component failure as a result of this architecture. The blower's speed is limited by these. It is likely that there is an uneven surface on the blade. This can be controlled by making the fan design using a 3D printer.

2.5 An Evaluation of Suitable Air Flow Rate (CFM) For Human

The air flow rate in CFM is a matter that is highly emphasized in this project study. There are several studies that show the most appropriate value for cooling the body while using a PPE suit is at a rate of up to 10 CFM. According to a study from a research paper that uses lightweight ambient air-cooling units for hazardous environments, Previously, the U.S. Armed Forces used a microclimate liquid and air cooling system as a personal cooling approach by accelerating the removal of stored heat.(Chen, Constable and Bomalaski, 1997) The device is powered by a battery weighing 3.9 kg. The device also produces 12.07 CFM of wind for the suit worn by the U.S. Army. 9.95 CFM to the body and 2.11 CFM to the face. The disadvantages of this tool are the excessive weight, which causes the movement of the army to be limited and slow.

Next, an air flow rate of 10 CFM and above is also recommended as an appropriate value for the use of the suit specified in the physiological safety of the airfed suit. An aired suit is a type of personal protective equipment used to protect the wearer from inhalation of hazardous substances and from skin contamination. During the testing, measurements of the AFS wearer's heart rate, sweat loss, and rectal temperature were taken. The results are used to develop a series of charts that can be used to manage the use of suits to reduce the effects of heat on the wearer. From this study, he found that the air supply flow rate could be varied in response to ambient conditions and work rate in order to aid the prevention of thermal stress. However, he found that increasing the air-flow rate above 10 CFM (270 l/min) had little additional benefit.(Frost, S; Mogridge, 2008) From the findings of this research, it can be concluded that the appropriate airflow rate of the cooling system for a PPE suit is up to 10 CFM, which is the target objective of this project being carried out.

A venturi tube is a short pipe with a narrowed inner surface that has been used to measure fluid flow and as a pump. The venturi tube presented here is meant to fit within the vertical printing capabilities of many typical desktop 3D printers, which are often limited to 300mm or less.(Hrisko, 2020). The size of the fan and casing design will affect the dimensions required for the venturi tube. The incompressible flow equations derived in the theoretical section of this research and the ASME performance test code are compared using computational fluid dynamics (CFD) simulation. The CFD model will show that the ASME venturi tube approximations are accurate, as well as the inaccuracy related with the 3D printed venturi tube.(Hrisko, 2020) The alignment of pressure tap locations and velocity ranges allowed for direct comparison between the flow rate calculated from the venturi tube and the flow rate simulated and recorded by the CFD simulation. Allowing for direct comparison between the flow rate calculated from the venturi tube and the flow rate simulated and recorded by the CFD simulation. The parameters specified in the ASME performance test code on flow measurement were used to design a 3D printed venturi tube. The goal was to build a low-cost system for measuring flow rates across many operational modes using the dimensions of a standard DC cooling fan.

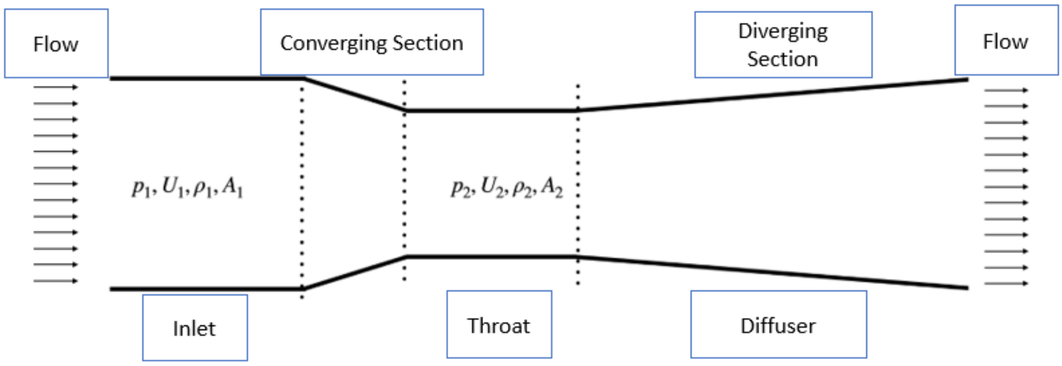

Figure 2.5:Differential Pressure Meter Diagram Showing The Inlet And Throat As The Test Points For The Variables Used For Quantifying Velocities And Flow Rates. (Hrisko, 2020)

To test the fan design, we need to use a test rig. According to research, there are extremely few specifics on fan and blower test rigs in the literature. One possible explanation is that test rigs are utilized by the fan and blower industry, which, in general, does not disclose in order to safeguard its knowledge.(Epple *et al.*, 2017). The required data is that the main performance characteristic of the fan is supplied by the increase of the total-to-static pressure t sΔ p-against the volume flow rate Q at a constant rotational speed n. A test rig is a device that measures the pressure and flow rate of the test rig itself, rather than the fan. The test rig has a system characteristic, and pressure and flow rate are measured at appropriate test rig locations. The pressure and suction side numerical simulations of the test rigs were carried out using the commercial code ANSYS CFX 14.0, which solved the Navier-Stokes and continuity equations.

The finite volume approach is used by ANSYS CFX to solve these equations(Epple *et al.*, 2017). It's also worth noting that modelling the fans explicitly isn't required to imitate the test rigs. Because the focus is on the test rig rather than the fans, simulating the flow through the test rig at the appropriate flow rates is sufficient. In order to achieve an optimal and compact test rig design, the instructions from the standards, analytical computations, and CFD computations were merged in this study.

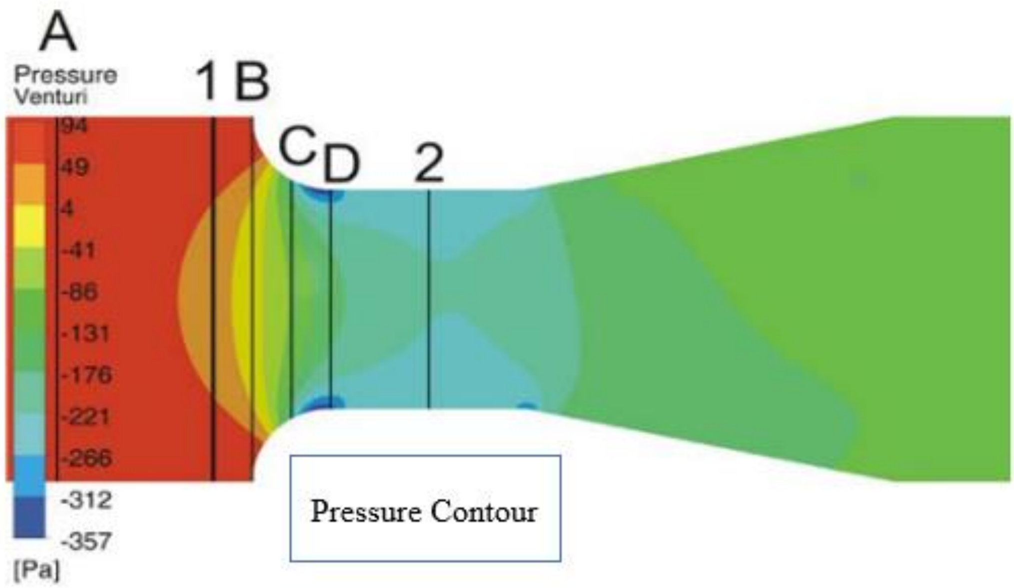

Figure 2.6:Curved Pressure Distribution in The Venturi Nozzle (Epple *et al.*, 2017)

2.6 Literature Findings

Based on the literature review discussed, the coronavirus is a disease that is dangerous to the health of the world community. Therefore, the use of PPE is important when handling patients to control the rate of infection.

This PPE will cause heat stroke, sweating and discomfort when applied over a long period of time. The air that traps inside the PPE, the heat generated by the body and the lack of a cooling system cause this to happen. The research also identified various types of cooling systems that can be used, such as PCG, SCBA, MCS, cooling vest and chill tower. The materials used for the cooling system are of various types, such as water, ice and wind. On the other hand, this project is more focused on the use of water because it is a source that will not run out, so it can save costs and the cooling system can be mitigated. From research that has been carried out, the design of the impeller is linked to the air flow rate produced. The weight, type of impeller, number of blades and depth of blade will have an impact on the production of air flow.

From the literature review conducted, it can be concluded that the model must undergo a process of analysis (experiment) so that the objective project can be achieved through experiments using test rigs and numerical solutions by using ANSYS Thus, this project will focus on designing the impeller for the PPE cooling system to achieve the wind generated when the fan rotates to reach a value of 10 cfm.

CHAPTER 3

METHODOLOGY

3.1 Overview

This chapter will present the data collector, cad drawing, model making, simulation and experiment used in this project. The experimental design is divided into two types of control study, where the difference is on the tube connection. All processes were completed with the help of supervisors, technicians and their own work carried out in workshops, CNC and automotive lab at Mechanical School of Universiti Sains Malaysia (USM).

3.2 Impeller Data Collector.

The data required for the manufacture of the size of the impeller model and its type depends on the type of motor that will move the fan in terms of power and rpm. The target air flow rate to be achieved or the minimum air flow rate that can be generated by the impeller so that it can be classified as a cooling system. Specific speed is also an important parameter in the selection of impeller type because specific speed is a metric that can be used to forecast how well a pump or turbine will work. It predicts the general shape of a pump's impeller. The "form" of this impeller indicates its flow and head characteristics, allowing the design to choose the best pump or turbine for a given application. Basic dimensions of the unit's components can be simply computed if the desired specific speed was established.

$$N_s = \frac{NQ^{0.5}}{gH^{0.75}} \quad \text{(Eq 3-1)}$$

$$D_s = \frac{DH^{0.25}}{Q^{0.5}} \quad \text{(Eq 3-2)}$$

Where,

N_s: Specific Speed (Dimensionless)

N: Pump Rotational Speed (Rpm)

Q: Flowrate (L/S) At the Point of Best Efficiency

H: Total Head (M) Per Stage at The Point of Best Efficiency

D_s: Specific Speed Diameter

From these calculations, we estimate that the specific speed diameter is equal to 1 by using a diagram from the Cordier diagram. Designers have the option of choosing a precise speed and diameter. Identify the other stage parameters such as flow coefficient and work coefficient based on the stated requirements of flow rate, discharge pressure, and rotation speed. Designers can quickly generate the initial size of the fan geometry based on certain suggestions and assumptions.

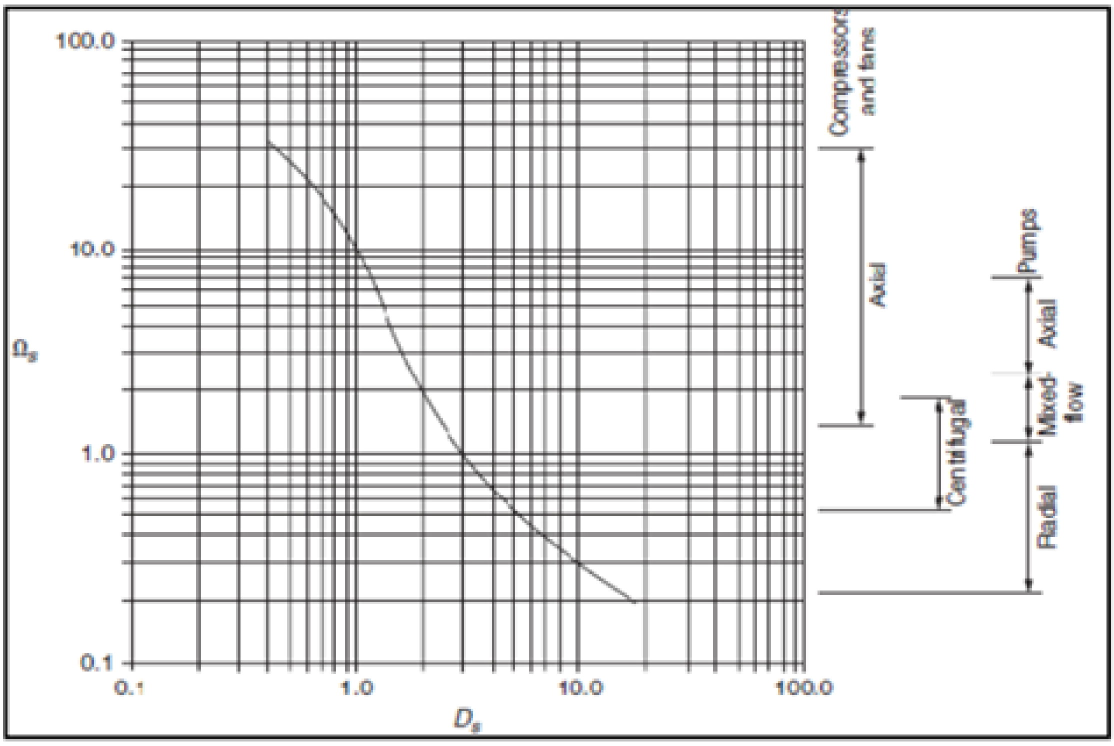

Figure 3.1:Cordier Diagrams Correlating Specific Speed Ns and Specific Diameter for Pump and Fan Selection. (Initial Sizing of Centrifugal Fans | Turbomachinery blog, 2020)

Next, we need to calculate and identify the loading stage. because it is a measure of the load on a turbomachinery stage, whether it is a part of a compressor, fan or turbine. We allow that it is calculated as a fan or blower. After that, we calculate the number of blades that are targeted at around 30 blades. by using a slip factor of around (0.85-0.9). The calculation is as below. We assumed a value for calculation.

Table 3.1:Data for calculation

Factor	Value
Blade inclined angle◦	90
Depth of Blade (m)	0.017
Diameter (m)	0.1
Rotation (RPM), N	3000
Flow rate, Q ($\frac{m^3}{s}$)	0.004719
Slip Factor, σ_s	0.9

By using the formula for stadola slip factor, we need to calculate the number of blades that are needed.

$$\sigma_s = 1 - \frac{\pi \sin(30)}{Z\left(1 - \left(\frac{C_{r2}}{U_2}\right)\cot(30)\right)} \quad \text{(Eq 3-3)}$$

Where,

σ_s: Slip factor

Z: Number of blades

c_{r2}: Flow velocity

U_2: Tip Speed

We already calculated that we get the value of Z=34.80, so we approximated the value as 30. For the next step, the ratio of radial velocity to tip speed and calculating the blade depth have been calculated, which is 0.006008 and 19.12 mm, approximately 2 cm. The ratio for inner diameter and outer diameter is by referring to the impeller model available on the internet as a reference. After all the data is successfully taken, we can proceed to the manufacture of the cad model using SOLIDWORK. The steps of this data collection are according to the order of the flow chart shown in appendix A (Table A.1) and data calculation in the appendix (Figure A.1).

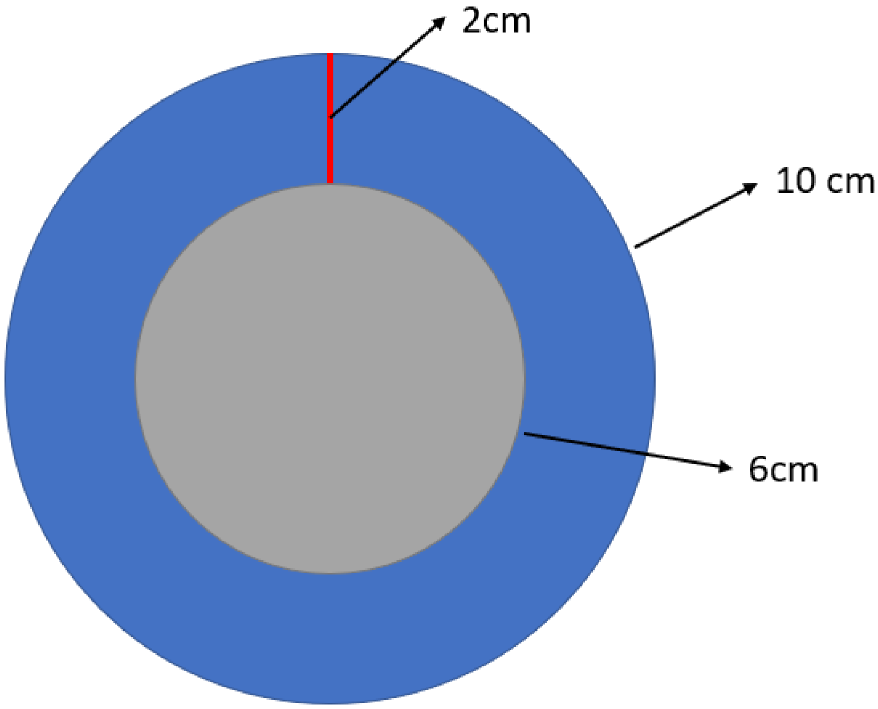

Figure 3.2:Ratio of Inner and Outer Diameter of Impeller Blade

3.3 Cad Drawing

SOLIDWORKS is used to develop mechatronic systems from beginning to end. At the initial stage, the software is used for planning, visual ideation, modelling, feasibility assessment, prototyping and project management. The software is then used for the design and construction of mechanical, electrical, and software elements. This drawing is divided into three parts, namely: impeller design, casing and test rig.

Radial impeller design is according to figure 3.2. The given dimensions we will draw and we need to remember that this model cad will be used to do the model realistically so we need to take into account safety features and factors that cause the model to function properly.

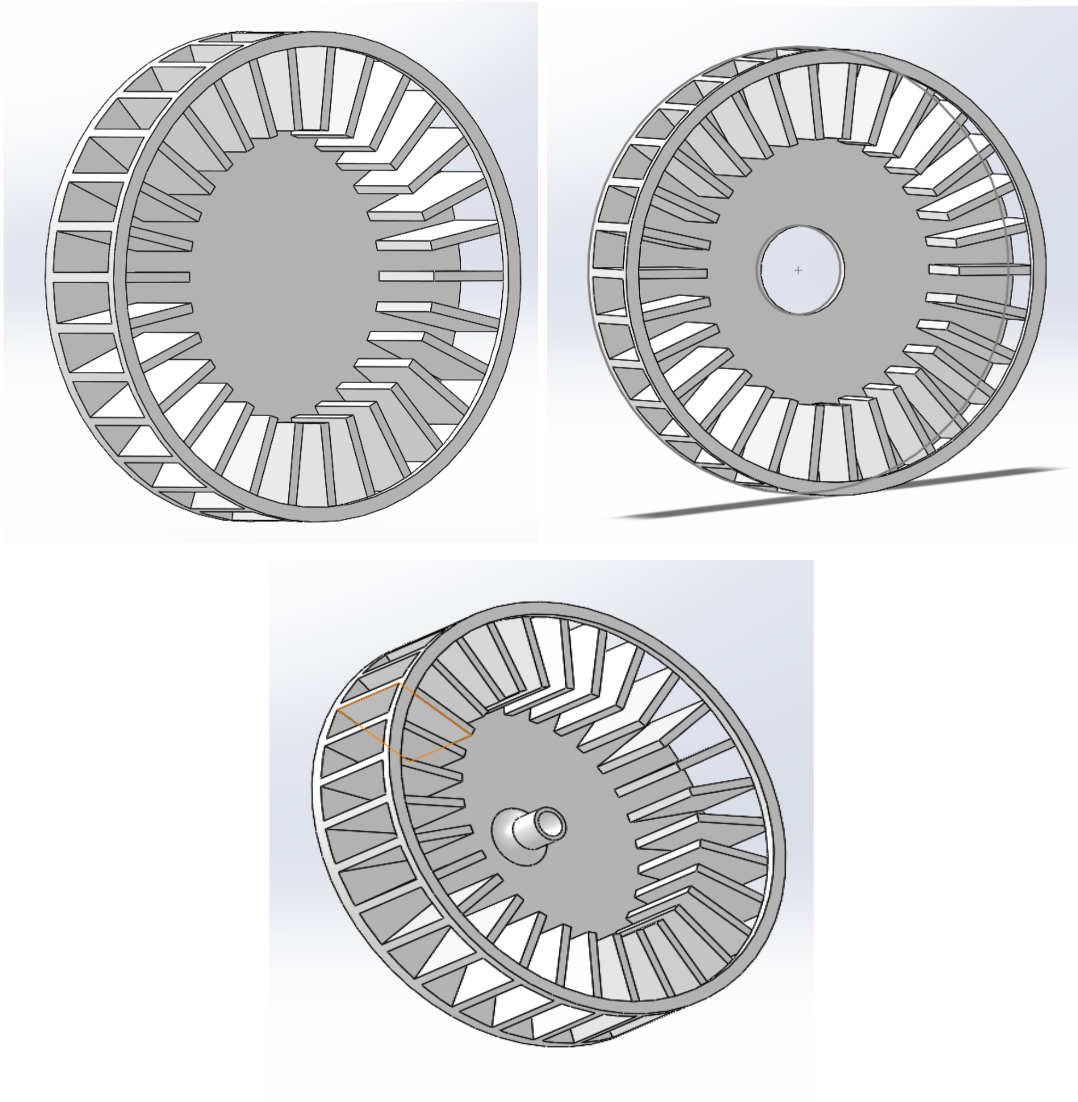

Figure 3.3:Three Types of Radial Impeller Cad Design

Figure 3.3 shows that the impeller design was improved from time to time when this project was carried out. The picture on the right is the final design chosen because it is suitable to be connected to the M6 shaft.

Casing design is also drawn based on a book 'How to design and build centrifugal fans for the home shop'. The radial blower model that is ready for assembly will be seen in the figure below.

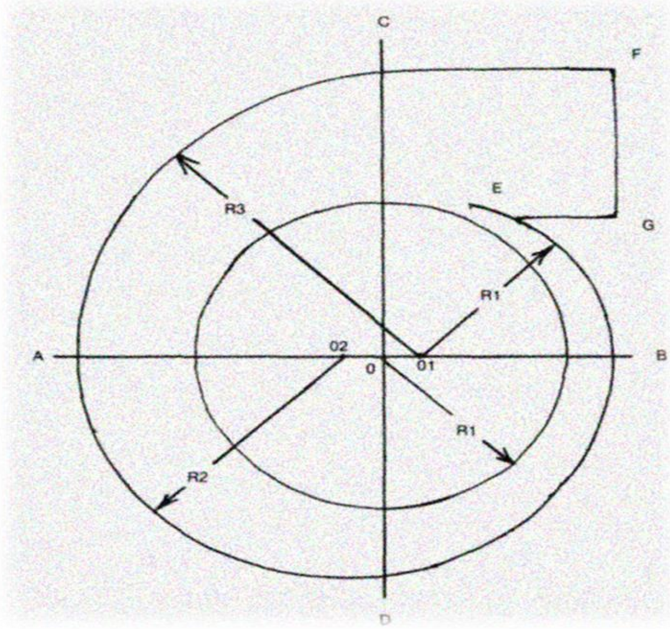

Figure 3.4: Casing Sketch of The Impeller. (David J. Gingery, 1987)

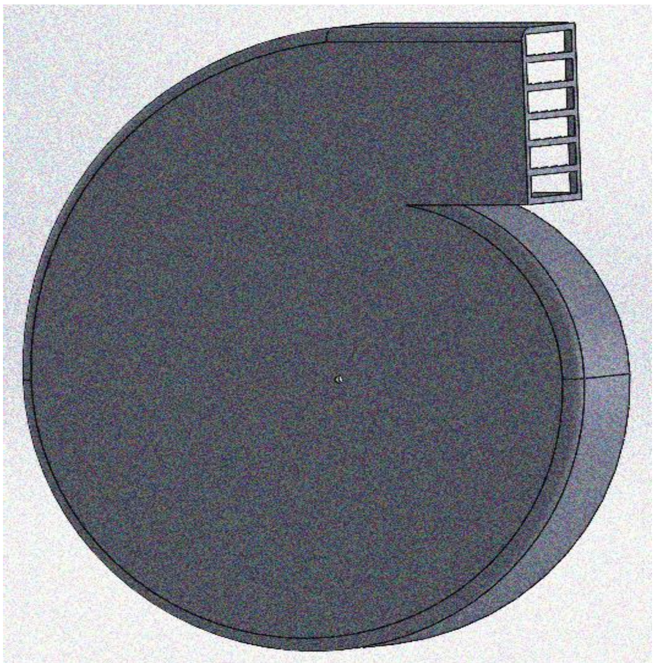

Figure 3.5:Cad Model for Casing

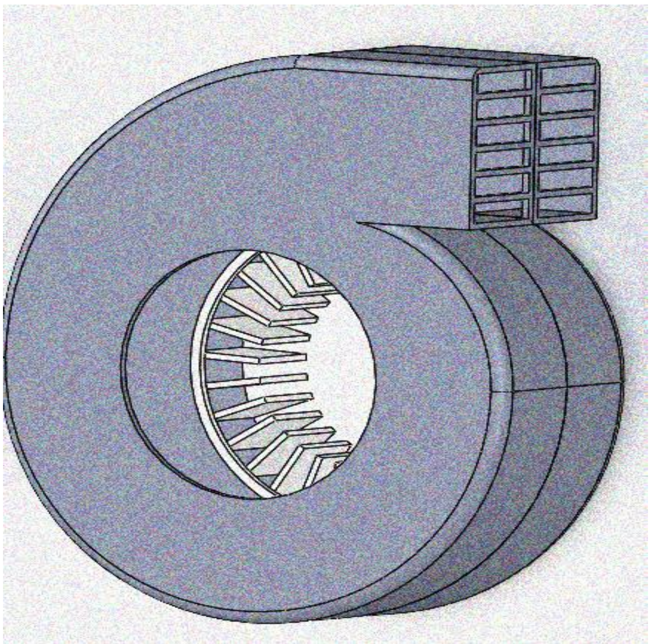

Figure 3.6: Assembly Drawing for Casing and Impeller

To test the fan design, we need to use a test rig. A test rig is a device that measures the pressure and flow rate of the test rig itself, rather than the fan. The test rig has a system characteristic and pressure and flow rate are measured at appropriate test rig locations.

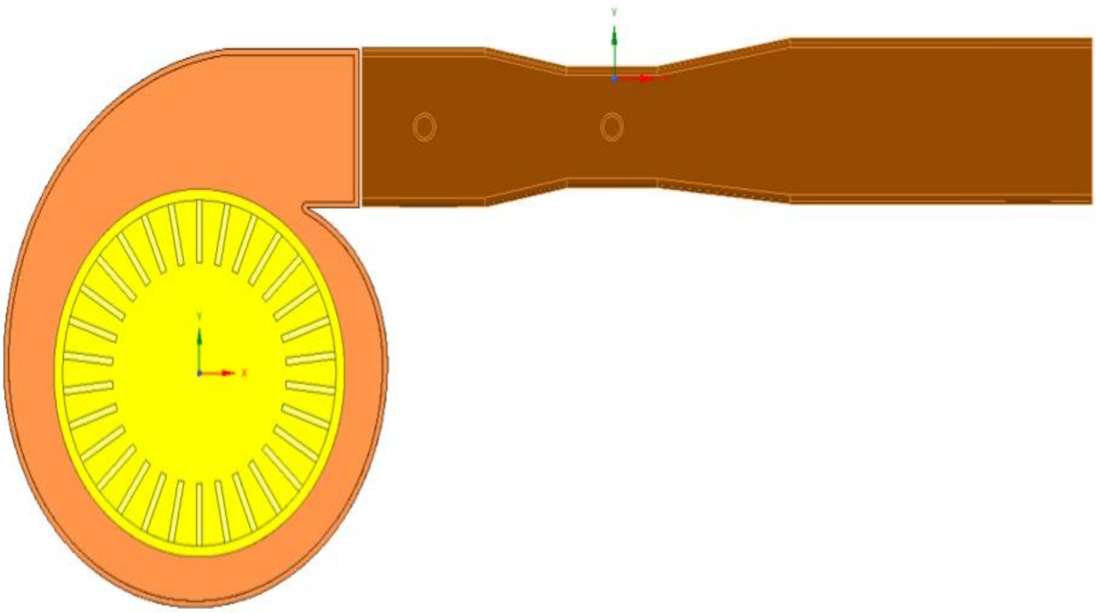

Figure 3.7: Initial concept of test rig

`Originally, the test rig was a combination of a full fan blower and a venturi tube, so it is like the figure above. However, if we want to build a model, we need to consider a simpler way of doing it. Because of that, the model changed by removing the inside from having to be cut and made the shape of the fan blower.

The dimensions used in this final design are according to the actual measurements of the model that will be made so that the manufacturing process will run smoothly. From the final design of this test rig, there are some drawings that need to be made as listed below.

1. Radial impeller
2. Back cover
3. Glass acrylic
4. Dc motor
5. Shaft
6. Motor base
7. Base
8. Wood Panel

The final concept of test rig design is as shown in figure 3.8. From the entire design of this cad, the dimension details will be shown in the appendix. After the concept design is ready, we will proceed to the part for model making. Most of this making process has been done by myself.

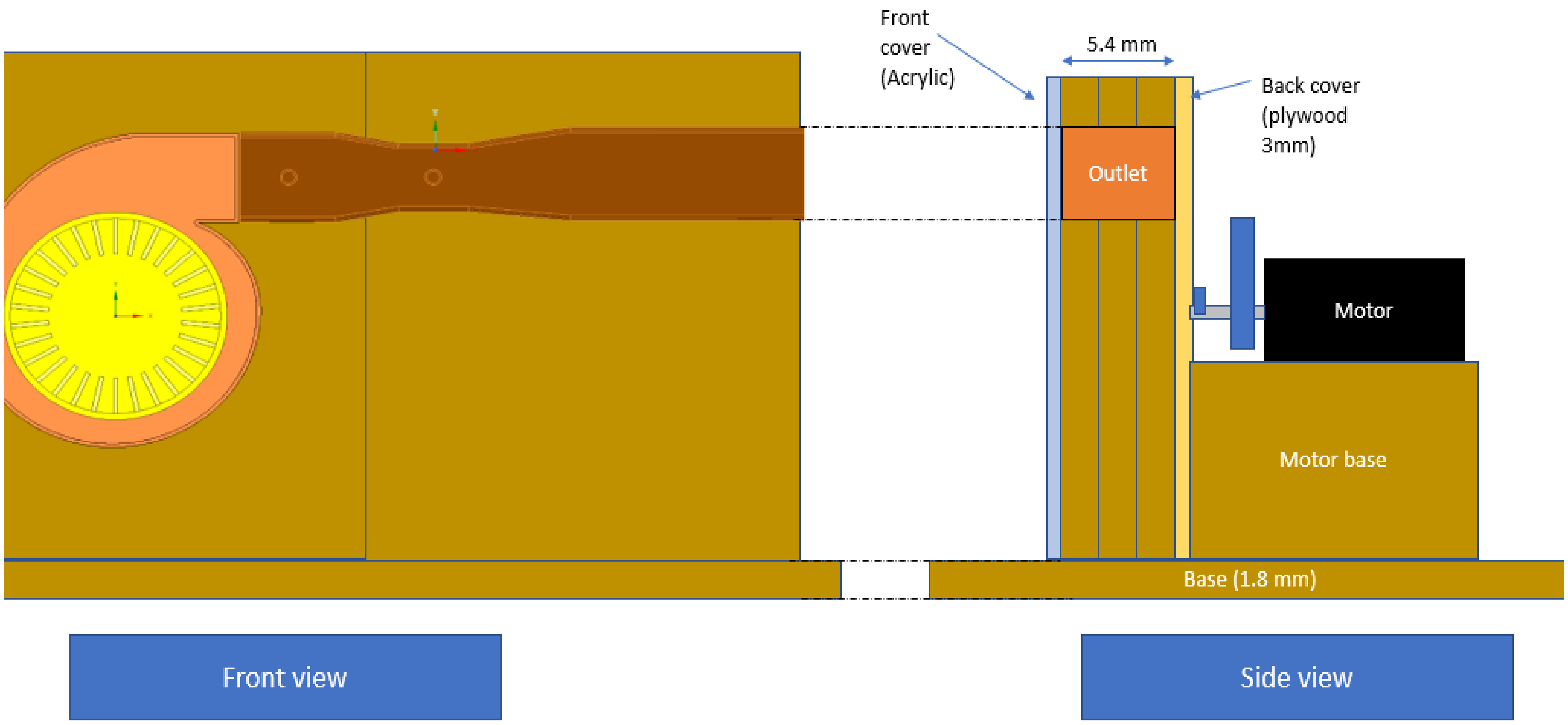

Figure 3.8: Final concept design of the test rig

3.4 Model Making

During the process of model making, the list of materials required is the initial thing that needs to be made so that we can estimate the cost and how much value is needed for the construction of a test rig model.

Table 3.2: Bill of Materials

Bill of materials		
Materials	**Value**	**Price**
Plywood(A3)	6	RM 76.50
Acrylic sheet	1	RM 25.00
Brushed Motor	1	RM 72.00
Manometer	2	RM 107.00
PLA Filament	1	RM 89.00
Sand paper	3	RM 5.70
Screw	10	RM 3.00
Glue	1	RM 9.80
Jigsaw Machine	1	RM 59.90
Shaft M6(1meter)	1	RM 15.00
Bearing	2	RM 2.20
Tap and Die set	1	RM 35.00
Measuring tape	1	RM 2.00
Nut	1	RM 0.30
Shaft Coupling	3	RM 15.00
Glove	1	RM 2.00
Wood Filler	1	RM 11.50
Tube	2	RM 2.50
Wood Rasp File Half Round	1	RM 7.50
Splitter	2	RM 1.00
Banana pin wire	1	RM 2.90

The process can be done after purchasing all the necessary equipment. The process begins by cutting wood according to the shape of the test rig that has been drawn on the drawing cad. I use a jig saw machine for the wood cutting process because it is automatic and faster than using a traditional saw manually.