DEVELOPMENT OF 3-AXIS TRAVERSE SYSTEM USING ARDUINO

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DEDICATION

To my beloved parents,

Azly Bin Ismail and Norita Binti Ismail

Thank you for all the support, encouragement, enthusiasm, patient and willingness.

To my honoured supervisor,

Puan Fadhilah Binti Shikh Anuar and all UTeM lecturers and staffs.

To my dearest friends

Thank you for always giving me a guidance and persistent help to complete this project thesis.

ABSTRACT

The traverse system is the system that moving the objects in different direction, which can be detremined the axis that want either 1D axis, 2D axis, 3D axis, or 5D axis. A wide range of industries and applications use the traverse system, from robotics to wind tunnel investigations of all sizes and types. The design structural of traverse system determines its stength, speed, workability and weight. One of the application used by traverse system is particle image velocimetry (PIV). The flow measurement accuracy is critical and requires a lot of calibration work. Thus, an automated traversal system is needed to make data collection is more efficient and precise. To build a 3D axis system, an arduino board can be used to run the system on automortion. The traverse system can be made of standard aluminium profile where the camera can be mounted to travel autonomously. The arduino is and open-source electronics platform based on hardware and software that simple to use. With the use of arduino board, the input gain can be turned into an output, signaled the motor to be activated. Result show the speed of X-axis is 32.40mm/s, Y-axis is 27.79mm/s and Z axis is 7.87mm/s and for the vibration on the system which the Z-axis minimum 11.35m/s and maximum 26.90m/s, Y-axis minimum 2.58m/s and maximum 6.77m/s and X-axis minimum 2.44m/s and maximum 6.84m/s. For the stability, the angle of 3-axis which the result is 180 degree for X and Y axis and 90 degree for Z axis which it is great for the 3-axis traverse system.

ABSTRAK

Sistem traverse ialah sistem yang menggerakkan objek-objek dalam arah yang berbeza, yang boleh ditentukan oleh sumbu yang mahu sama ada paksi 1D, paksi 2D, paksi 3D, atau paksi 5D. Pelbagai industri dan aplikasi menggunakan sistem traverse, dari robotik kepada penyelidikan terowongan angin semua saiz dan jenis. Reka bentuk struktural sistem lintasan menentukan ketegangan, kelajuan, kegunaan dan beratnya. Salah satu aplikasi yang digunakan oleh sistem traverse ialah velocimetry gambar partikel (PIV). Ketepatan pengukuran aliran adalah penting dan memerlukan banyak kerja kalibrasi. Oleh itu, sistem laluan automatik diperlukan untuk membuat pengumpulan data lebih berkesan dan tepat. Untuk membina sistem sumbu 3D, papan arduino boleh digunakan untuk menjalankan sistem pada automasi. Sistem traverse boleh diperbuat daripada profil aluminium standard di mana kamera boleh dipasang untuk bergerak secara autonomi. Arduino ialah platform elektronik sumber terbuka yang berasaskan perkakasan dan perisian yang mudah digu nakan. Dengan penggunaan papan arduino, keuntungan input boleh ditukar kepada output, memberi isyarat kepada motor untuk diaktifkan. Hasilnya menunjukkan kelajuan paksi X ialah 32.40mm/s, paksi Y ialah 27.79mm/s dan paksi Z ialah 7.87mm/s dan untuk getaran pada sistem yang paksi Z minimum 11.35m/s dan maksimum 26.90m/s, paksi Y minimum 2.58m/s dan maksimum 6.77m/s dan paksi X Minimum 2.44m/s dan maximum 6.84m/s. Untuk kestabilan pula, sudut 3 paksi dimana hasilnya ialah 180 darjah bagi X dan Y, manakala 90 darjah bagi paksi Z dimana ianya bagus bagi 3 paksi sistem traverse.

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LIST OF SYMBOLS AND ABBREVIATIONS

2D	-	2-Dimension
3D	-	3-Dimension
AM	-	Additive Manufacturing
CAD	-	Computer-Aided-Design
CCD	-	Charge Couple Device
PA66	-	Polyamide 66
mm	-	Length
PIV	-	Particle Image Velocity
m/s	-	Velocity
CTE	-	Charge Transfer Efficiency
QE	-	Quantum Efficiency
CCE	-	Charge Accumulation Efficiency
Hz	-	Frequency
SLA	-	Stereolithography
SLS	-	Selective Laser Sintering
FDM	-	Fused Deposition Modelling
ASTM	-	American Society for Testing and Materials
NPD	-	New Product Development
RP	-	Rapid Prototyping
SFF	-	Solid free Form Fabrication
LM	-	Layered fabrication
DCM	-	Digitalizing the Construction Monitoring

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CHAPTER 1

INTRODUCTION

1.1 Background

Today, the world is facing Industry 4.0, where most industries are changing from human power to machines. One of the machine systems that is variously used in many sectors of industry is the traverse system. The function of this system is to produce the product automatically with high accuracy and a large amount. Most of the big companies, such as Tesla, Apple, and Samsung, have a similar system in place, which is an automatic traverse system, to increase production and reduce labor costs. Traverse systems are functionally defined by the movement of the machine in the X-Y-Z axis, which it simply moves in any direction. That system is applied in many sectors of the industry, such as the crane at the construction site, the CNC machine, robotics, and the survey of the flow.

To determine the accuracy and speed, a non-intrusive optical measurement method called particle image velocimetry (PIV) was used to visualize and quantify fluid flows. High-speed cameras are used to take two images in quick succession of a flow field, and the displacement of particles between the images is measured to determine the velocity field. Numerous fluid dynamics disciplines, including aerospace, automotive, biomedical, and environmental engineering, have made various field use of PIV.

1.2 Problem Statement

Due to the global industry's change to Industry 4.0, robotic and automated machines, such as the automated traverse system, are replacing labor in many sectors. By using the automated traverse system, the rate of production can increase due to the flexibility of this system. This system has high accuracy, which can reduce the defects of the product. It also helps to increase production in the industry because the machine speed system produces the product faster.

1.3 Research Objective

The following are the research objectives:

1. To design a 3-axis traverse system using CAD software.
2. To develop and program the 3-axis traverse system movement.
3. To test the performance of the 3-axis traverse system in terms of stability, movement speed and workability.

1.4 Scope of Research

This study focuses on the design, which will be limited to structural system is 500mm^3. The movement of the traverse system will be travel take around 30 seconds as one cycle to complete one trip, which the length is 400 mm moved to the same position while the stability, speed and workability between each movement is analyzed. The system will consider workable when the position remains accurate after 10 repetitions.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In any research, literature reviews are essential because they provide thorough summaries and evaluations of already published scholarly works that are valid to a given subject or research question. They are an important part of research papers, dissertations, and theses and offer a strong knowledge and comprehension in a particular field of study. A literature review helps to find every information about 3-axis traverse system and Arduino within the existing body of knowledge by discovering key theories, concepts, approaches, and conclusions.

An overview of the research objective will be included in this literature review's framework, which will be followed by a discussion of pertinent ideas and concepts. The important methodologies and approaches used in previous studies will be reviewed for another reviewer, with an emphasis on their advantages and disadvantages. The primary findings and conclusions from the existing literature will then be presented in the review, highlighting the current level of knowledge. The gaps, restrictions, and areas for future research will then be identified, pointing future scholars in the direction of fruitful lines of inquiry.

2.2 Type of Traverse System

A traverse system is a device that allows for the controlled movement of an object along multiple axes. Depending on the quantity of axes of motion involved, there are several types of traverse systems which is 1-axis, 2-axis, 3-axis, and 5-axis systems. A 3-axis system adds a third axis of motion, usually rotational, to the linear motion in a 2-axis traverse system, which typically involves linear motion in two orthogonal directions. With five axes of motion (typically three linear and two rotational) a 5-axis system enables more intricate and precise movements.

A comparison of multiple traverse system design is necessary such as the Cartesian 3-axis traverse system and Scara system to ensure the design chosen are functional and efficient to make the machine operation fast where the production in the industry can be increased.

Figure 2.1: Knee type 3-axis CNC machine (Christopher & Kaleji, 2020)

Figure 2.1 depicts knee-type milling machines with a fixed spindle and a vertically adjustable worktable that is supported by the knee and rests on the saddle. Depending on where the machine tool is positioned, the knee can move up and down on the column. Floor-mounted and bench-style plain horizontal milling machines are a couple of examples of knee-type milling machines

2.2.1 Cartesian 3-axis system

A 3-axis traverse system with a Cartesian structure, also known as a gantry system, enables movement along three perpendicular axes: X, Y, and Z. The Cartesian coordinate system, which uses three axes to determine positions in three dimensions which is also the source of its name.

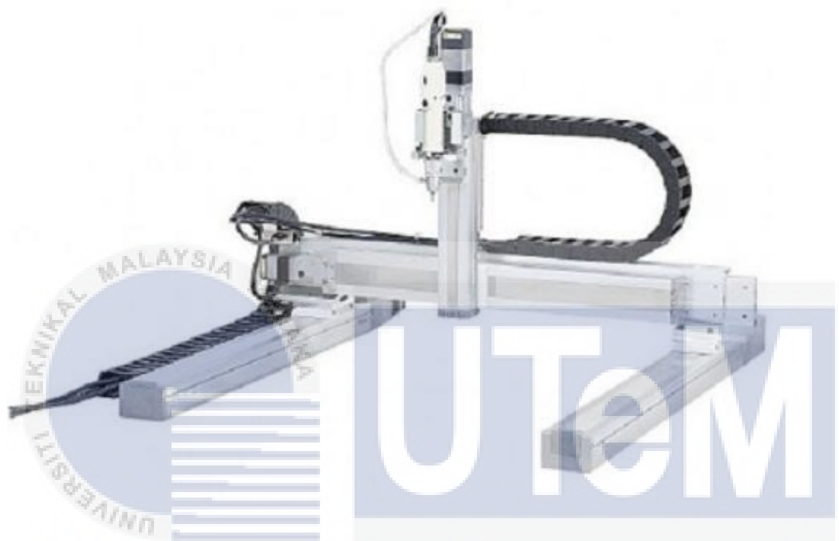


Figure 2.2: Cartesian robot jc-3 series (Janome, 2023)

As shown in Figure 2.2, a Cartesian system has the X and Y axes stand in for movement along the horizontal and vertical axes, respectively, while the Z axis stands in for movement along the depth axis. The X and Y axes constitute the base of the standard rectangular arrangement of these axes, while the Z axis lies perpendicular to the base. The system is made up of drive mechanisms like motors and lead screws or belts as well as linear motion components like linear guides. Each axis is propelled by a motor, enabling fine control and positioning.

Every design has its own strengths and limitations, and precision and accuracy are two of the key advantages of the Cartesian design. With the help of the linear axes, the tool or workpiece can be moved precisely in the X, Y, and Z directions. Cartesian systems are also renowned for their rigidity and stability. Precision must be maintained in a variety of applications; thus, the rectangular design and use of linear guides or rails produce low deflection or vibration during operation (Kurdila, 2020).

The adaptability of Cartesian systems is another benefit. They are appropriate for a variety of applications and workpiece sizes because of their rectangular shape, which enables the use of varied equipment and fixtures. Additionally, these systems frequently come with user-friendly programming interfaces, making it quite simple to run and programmed them. The programming process is made simpler using many systems that use graphical user interfaces or common programming languages (Kampker et al., 2019)

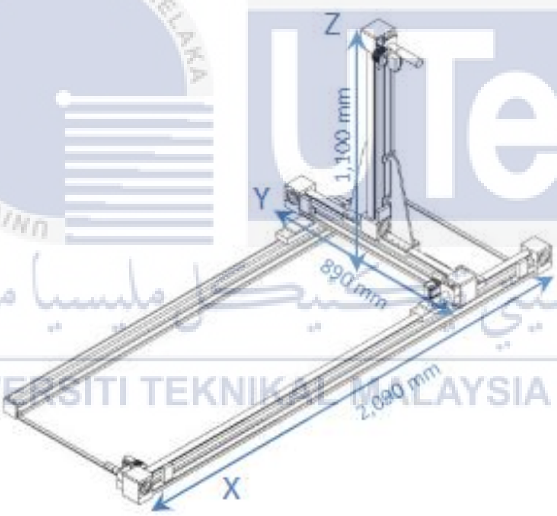


Figure 2.3: The dimention of cartesian robot (Kraiński, 2018)

However, there are some noticeable limitations to Cartesian design as well. First, compared to alternative designs, these systems frequently have a large dimension. Their use may be constrained in applications where space is difficult to come by due to the rectangular configuration's potential need for more workspace as well as shown on figure 2.3 (Kraiński, 2018). Furthermore, unlike designs like articulated robots that give greater flexibility in accessing diverse workplace regions, Cartesian systems are constrained in their path by the linear axes.

A complicated cable management system is another difficulty of Cartesian design. To avoid interference or cable damage throughout operation, good cable management is essential. The mobility of the linear axis can make it difficult to route cables. Since the Cartesian traverse system needs to be built with precise parts like linear guides, it can be more expensive than certain other designs. If extra features or customization choices are required, the price may rise significantly.

The field of micromachining is one area where the Cartesian 3-axis system might be used. The unique technique for micro-milling utilizing a Cartesian 3-axis system is shown by (Sharma et al., 2019). Their use of the Cartesian system allows them to produce microstructures with a high degree of precision and accuracy.

The usage of the Cartesian 3-axis system in additive manufacturing is another instance which is the new method to increase the accuracy of fused deposition modeling (FDM) 3D printing (Alkadi et al., 2020). The accuracy dimensional of the printed parts was significantly improved because the program itself will make the correction from the error due to the system using a closed-loop feedback control system.

Finally, in biomedical engineering, the Cartesian 3-axis system has been used for fabrication of tissue-engineered constructs. The process to fabricate a tissue-engineered construct for bone regeneration by using a Cartesian 3-axis system to place the cells and hydrogel precisely (Ijaz et al., 2018).

2.2.2 SCARA system

A SCARA system which is known as Selective Compliance Assembly Robot Arm or Selective Compliance Articulated Robot Arm, robotic arm used in industrial automation applications. The SCARA system is made up of rigid arms joined together by rotary joints that preserve rigidity in the vertical plane while allowing for compliance in the horizontal plane. The robot can conduct operations inside its designated workspace with a high degree of accuracy and reproducibility thanks to this design. Depending on the model, the SCARA robot often has three or four degrees of freedom.

Figure 2.4: A denso scara robot, (Saeed B. Niku, 2020)

As shown in figure 2.4 A specific configuration of a SCARA robot that makes use of three axes of motion for traversing and positioning is referred to as a SCARA system. Two linear axes (X and Y) and one rotating axis (Z) make up the three axes in most cases. The robot can move in the X, Y, and Z directions horizontally and vertically using this set up. The robot can move in a two-dimensional plane using its X and Y axes, allowing it to access various locations within its workspace. These linear axes make it possible to position the end effector or tooling precisely, making pick-and-place operations, assembling, and packing activities easier to complete (Dinakaran et al., 2023).

The Z axis, which is often rotating, allows for vertical movement or tooling orientation modification. It enables the robot to adjust to different workpiece heights or angles by tilting or moving up and down. The SCARA 3-axis traverse system allows for flexible item positioning and manipulation by combining these three axes. It offers a range of motion that enables the robot to complete tasks in a certain area quickly and accurately. Applications like electronic component assembly, product sorting, and material handling, which call for accurate horizontal and vertical movements, frequently use this arrangement.

SCARA systems are primarily used for assembly and handling operations. They are frequently employed in manufacturing procedures like pick-and-place operations, packaging, sorting, and other jobs requiring exact object manipulation inside of predetermined workspaces. SCARA robots are prized for their quickness, accuracy, and capacity to consistently do repeated jobs (Gautam et al., 2021). The SCARA system is a popular option for a variety of industrial automation applications because it combines precise positioning, quick cycle times, and affordability.

Due to the limitations imposed by the size of their arms and joints, SCARA robots frequently work within a small working area. They are quite effective in settings with little floor space because of their cramped workplace. SCARA systems' small size makes it simple to integrate them into assembly lines or workstations without taking up a lot of room. Although SCARA robots have a smaller range of motion than other robotic systems, they are excellent at jobs that call for accurate horizontal and vertical movements within their assigned workspace. They have some difficulty with dynamic and shifting environments.

SCARA devices often follow pre-programmed routes and are incapable of detecting and avoiding sophisticated obstacles. As a result, individuals could find it difficult to adjust to unforeseen modifications or challenges in their working environment (Andrew S. Nimon et al., 2022).

2.3 Development of Arduino UNO system in robot motor traverse system

The process of creating and implementing instructions that allow a machine to accomplish activities or processes is known as general programming of machines. Through programming, it can be done when you interface with machines like computers, robots, and industrial machinery and give them a set of instructions to follow. Depending on the required functionality of the machine, these instructions can range from straightforward commands to intricate algorithms.

There are often numerous steps in the programming process. First, the work or problem at hand is examined to ascertain the prerequisites and goals. Then, considering the capabilities of the computer, the difficulty of the task, and the resources available, a suitable programming language is selected. C++, Python, Java, and many other programming languages are widely used.

The programmer then creates the logic and algorithms necessary to resolve the issue or conduct the required activities. To do this, divide the issue into smaller, more manageable chunks and create a set of instructions that will lead to the desired result. To regulate the flow of execution, the instructions are frequently written using a combination of control structures, such as loops and conditionals.

Depending on the programming language used, the code is typically compiled or interpreted after being written. While interpretation conducts the code directly without any compilation in between, compilation transforms human-readable code into machine-readable instructions.

Following the programmed instructions, the machine manipulates data, makes judgements, and generates the desired outputs after the code has been executed. Depending on feedback or requirements, the programming code can be improved, changed, or optimized to make sure the machine works as planned.

2.3.1 Manual

An Arduino Uno manual control system utilizes all the Arduino board's features to give users direct control over a variety of components or gadgets. The system's brain, the Arduino Uno, processes input signals and produces output signals based on user inputs. The system often contains input components that let users provide the Arduino input, such as buttons, switches, or sensors. Arduino Uno's digital or analogue input pins are connected to these input devices. Output devices, such as LEDs, motors, or displays, on the other hand, take signals from the Arduino and take specified actions in response to those signals. The necessary digital or analogue output pins of the Arduino Uno are connected to these output devices.

The Arduino Uno needs a program that specifies the system's behavior to implement the manual control mechanism. The Arduino continuously reads the input signals from the connected devices as part of the program. The Arduino conducts instructions to control the output devices in accordance with the state of the input signals. The Arduino, for instance, may start a motor moving or light an LED when a button is pressed. Users can specify the precise actions they want the system to do in response to various input scenarios by updating the program and including the necessary logic (Budiyanto et al, 2020).

Users can engage with the linked devices and exert direct control over their operations with this manual control method. Users can initiate a variety of operations and see how the output devices react by pressing buttons, turning switches, or using sensors to sense their surroundings. The Arduino Uno serves as an intermediary, processing user input and enabling manual and interactive control of the connected devices.

The Arduino Uno can be used for home automation in manual systems, giving users the ability to operate lights, fans, and other appliances through switches or buttons connected to the Arduino. It is also widely used in robotics projects, allowing users to program the Arduino Uno to control motors and sensors, allowing them to manually control the movement and actions of robots. Additionally, users can manually initiate readings of temperature, humidity, or air quality by interacting with the Arduino Uno in environmental monitoring systems (Hasibuan et al., 2021).

2.3.2 Control device

It is necessary to integrate a remote-control device with the Arduino board to enable wireless operation to control an Arduino Uno system using a remote. Users can engage with the Arduino-based system without making physical contact by using a remote control, which allows for remote interaction. A suitable remote control, such as an infrared (IR) or radio frequency (RF) remote, is chosen to configure remote control. To receive the signals sent by the remote control, an appropriate receiver module such as an IR receiver or an RF receiver which is attached to the Arduino Uno.

The receiver module's output pin is wired to an Arduino Uno pin designated for digital input. The "IRremote" library for IR remotes, for example, is installed using the Arduino IDE to enable communication between the receiver module and the Arduino Uno. Then, using the Arduino IDE, a program is created to decode the signals received and translate them into certain instructions or commands. The program configures the remote's button presses or signal patterns to launch specific Arduino system actions. These can involve changing settings, turning on or off components, or starting behaviors within the system (Dewilde & Li, 2021).

Users can operate the system by manipulating the remote-control device after the setup is finished and the program is uploaded to the Arduino Uno. The Arduino Uno receives and decodes signals transmitted in response to the pressing of buttons or the sending of signals, conducting the necessary system functions. The Arduino Uno system may be effortlessly and wirelessly operated from a distance with the help of remote control, giving users freedom and remote interaction with the linked components or devices.

The Arduino Uno develops become a potent tool for wireless control of faraway equipment. It enables users to transmit wireless commands to control their movements or activate functionalities using RF or IR communication modules and can be integrated into remote-controlled vehicles like cars, drones, or robots. For example, the Arduino Uno can receive wireless signals in home security applications, enabling customers to remotely arm or disarm the system via a smartphone app or a dedicated remote control. The Arduino Uno's remote capabilities, which allow it to receive wireless commands to start, stop, or change the parameters of machinery or equipment, are also advantageous for industrial automation (Kondaveeti et al., 2021).

2.3.3 Bluetooth

Using a smartphone app to control an Arduino Uno system offers a simple and practical way to communicate wirelessly with the system. Users can communicate with the Arduino Uno board from their cellphones by creating a specialized mobile application. The software functions as a remote-controlled interface, enabling users to change settings, start processes, or keep an eye on the system's performance. Using a wireless protocol like Bluetooth or Wi-Fi, communication between the smartphone and the Arduino Uno is established. The Arduino Uno may be controlled via the smartphone app since it is equipped with a Bluetooth or Wi-Fi module (Lim et al., 2018).

To control the Arduino Uno system, the mobile app's user interface features buttons, sliders, and other interactive features. The Arduino Uno receives wireless commands from users as they interact with the app, evaluates them, and then executes them, as necessary. The Arduino Uno is running a program that monitors incoming commands, executes the requested operations, and, if necessary, updates the system's status.

This gives consumers the freedom and convenience of remotely controlling the Arduino Uno system. The smartphone app enables users to easily interact with the Arduino Uno system and observe its behaviors in real-time, whether they are controlling lights, motors, sensors, or other components.

Additional options are made possible by the Bluetooth capabilities of the Arduino Uno. Multiple Arduino nodes with Bluetooth modules can build a network in wireless sensor networks where data is gathered and delivered to a central hub. This makes it possible for users to wirelessly monitor and analyze the data from a linked device. The Arduino Uno's Bluetooth connectivity can also be used for smart home systems, enabling users to control many elements of their houses, such as lighting, temperature, and security, through a smartphone app that interacts with the Arduino. Additionally, the Arduino Uno may be included into wearable health monitoring gadgets, where sensors gather health information and Bluetooth-transmit it to the Arduino Uno. The information can then be transferred to a computer or smartphone for analysis and monitoring (Amoran et al., 2021)

2.4 Performance of 3-axis traverse system with PIV camera

A 3-axis traverse system's performance must be assessed considering several crucial factors. To specify the performance parameters that matter for the application, such as precision, repeatability, speed, and load capacity. All these testing is important to consider the 3-axis traverse system that has been built is function and safe to use. Precision measuring tools can be used to calculate the difference between the system's commanded and actual positions to assess accuracy. The reading must be between 1 mm of the position to consider the reading is accurate. In repeatability tests, the system is repeatedly moved to the same position while the divergence between each movement is analyzed. The system will be approved when the position remains accurate after ten repetitions (Schmitt et al., 2017).

Particularly in applications where quick movement is required, speed and acceleration are critical performance aspects. The system's speed can be determined by counting the time it takes to move between various places, while assessing its acceleration capability guarantees that it can reach specified speeds within reasonable timeframes. The movement of the system must within the time estimation to consider speed of traverse is fast. Another crucial factor is loading capacity. The system's capacity to maintain precision, repeatability, and speed under various load circumstances can be evaluated by applying various loads. The performance of the system should be assessed, considering both static and dynamic loads. The traverse system should be able to maintain the precision, repeatability, and speed while certain loads are added to the traverse.

Additionally, the system's operating stability and vibration should be assessed. Excessive vibrations can have a negative impact on performance and accuracy. Any unwelcome vibrations in the system can be measured and examined using vibration analysis tools and procedures. The system's performance under various environmental circumstances, such as temperature changes, humidity, and electromagnetic interference, should also be considered. The temperature test will be run by changing the environment slowly from low temperature to the hot temperature of 3-axis traverse system while monitoring the condition.

For humidity testing, the environment also needs to change under the humidity chamber or using another method which controlling manually by change the humidity content. The simulators and generator can be used to evaluate electromagnetic interference, controlled electromagnetic interference will be tested to the 3-axis traverse system and checked the performance of this system. Evaluating the system under these circumstances can show any potential effects on its performance and show whether more testing or improvements are required (Dewilde & Li, 2021).

The resulting performance results should then be compared to the traverse system's requirement which is the speed, accuracy, repeatability, loading weight, strength and under the circumstances condition which temperature, humidity, and electromagnetic interference. This comparison makes it possible to determine whether the system satisfies the desired performance standards or whether any modifications or changes are needed. These procedures and rigorous testing allow for a thorough assessment of a 3-axis traverse system's performance, allowing for the identification of potential areas for optimization in terms of strength and repeatability to make sure the system have long lifespan in the industry

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology is one of the important chapters for the thesis which explains how this research works. The execution of the thesis starts from designing the 3-axis traverse system by using CAD software until build the prototype. The performance of the prototype also needs to be evaluated by evaluating the stability, movement speed and workability of the prototype.

3.2 Overall Process

The process of making the prototype begins with cumulating the information and the data from past research that people have already done. It can be done by using valid journals, articles, and books. The procedure of making the prototype will be referred to the all the information collected. The procedure for performance test is also included in this section to evaluate the prototypes whether the build's prototype is same performance, better or worse.

3.3 Project Flowchart

The process in the flowchart as shown in Figure 3.1 contaning every step needs to be done. It start by drafting the model of 3-axis traverse system and the selection will be choose by the best design of traverse system. It continue by selection of material use which the material must make the traverse system workable. The programing code to arduino also needed to move the motor that used to move the traverse system. Last, the testing of traverse system in term of the stability, workability and speed.

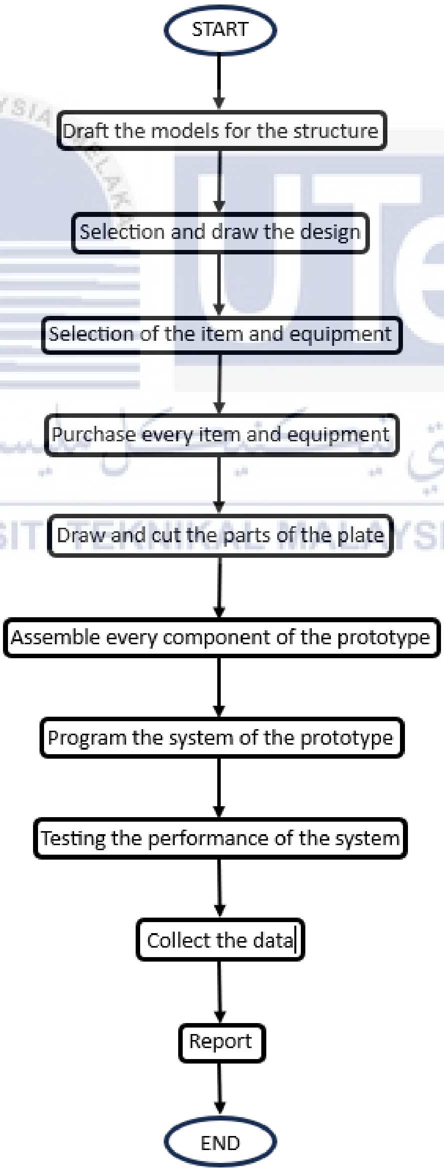


Figure 3.1: Flowchart

3.4 Dimensions

Every related component within the 3-axis traverse in project is measured directly from the object such as TSI Camera Model 630090 and camera holder to consider the dimension needed for the specific traverse system with the size of $500mm^3$.

3.4.1 TSI Camera Model 630090 and camera holder

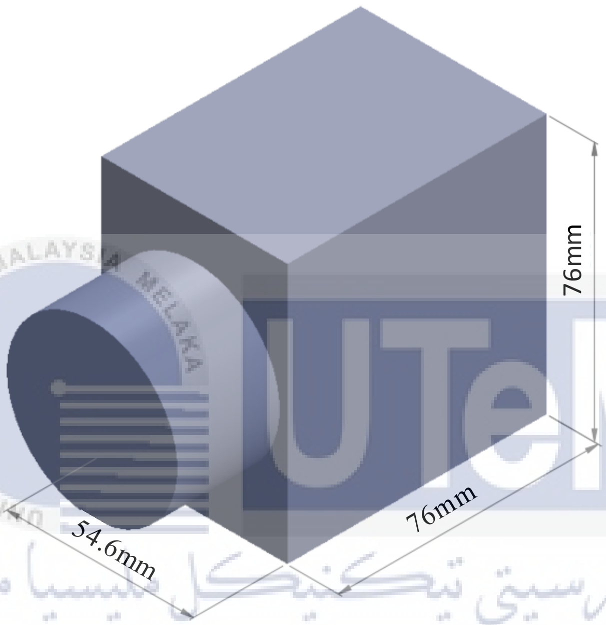


Figure 3.2: Dimension of TSI camera model 630090

Additionally, the length and width of the camera holder are the first things that should be considered to ensure the plate dimension must be more than the bottom area of the camera with the dimension is about 80mm x 80mm which need to focus length of side of camera when using the adjustable camera holder.

3.5 Conceptual design of 3-axis traverse system

Before designing the model of 3-axis traverse system, there are steps that are particularly important to choose the design concept that suitable for the project. Conceptual design is the process where the designs will be evaluated based on many aspects to meet the requirements of design.

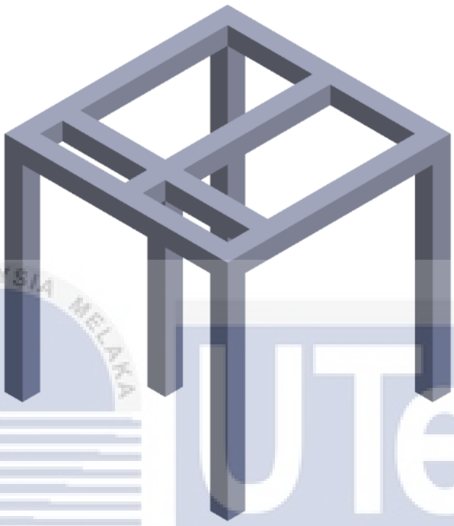


Figure 3.3 Design A

Based on Figure 3.3, Design A is inspired from claw machine which the concept uses are the base or center in higher in the air. The X and Y axis is mainly move at the base and the Z axis will move to ground when the coordinate X and Y already determined. This design also uses 3D printing which the printer will print from the bottom to above.

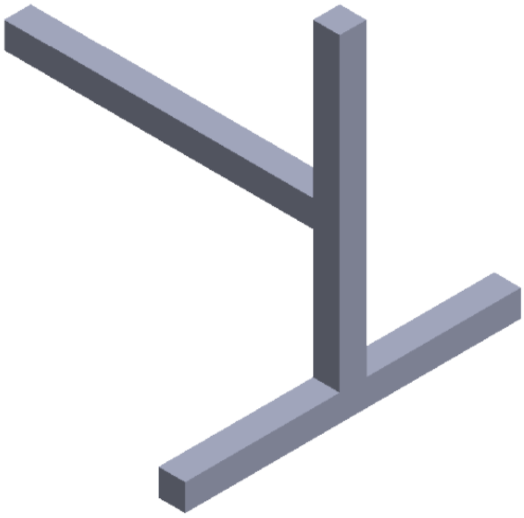


Figure 3.4: Design B

For Figure 3.4, Design B is much simpler than Design A. The design needs only 3 rails for the movement of the system. This system is inspired by the Crane at the building construction where it is used to carry many materials for construction.

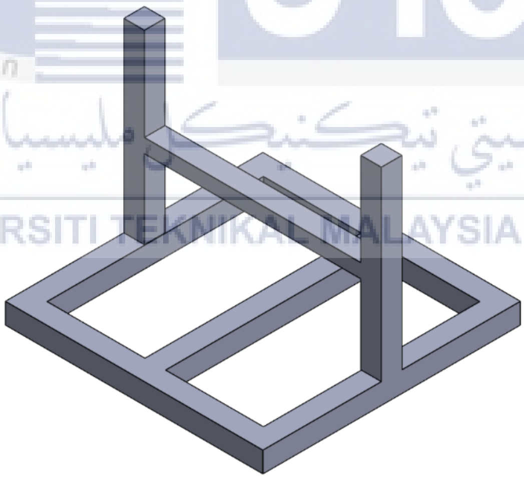


Figure 3.5: Design C

The design in Figure 3.5 is upgraded from Design B where the design has two leg to stand. The Design C concept is to increase the stability of the structure so that there will be no error when using the traverse system.

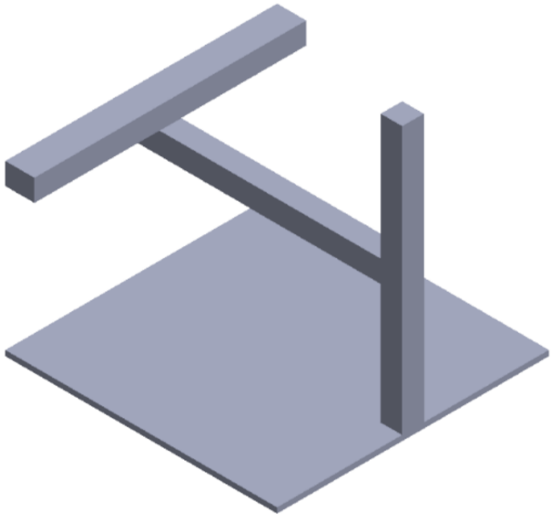


Figure 3.6: Design D

The concept of Design D in Figure 3.6 is same with Design B. The only difference between Design B and D is the base that is used as a trail to move the structure of system in Design B change to higher and Design D has no base but only a pole as the upward movement for the structure. This design is usually used in static places such as at port ships.

Figure 3.7: Design E

The concept of Figure 3.7, which is Design E is upgraded from Design C which it added to increase the stability of structure by joining the two legs with 2 supporters.

3.6 Concept Selection

Concept selection used to consider every vital component needed for design of a 3-axis traverse system. Every design will be evaluated based on the Stability, strength, weight, cost, and difficulty to build. The design that gets the best score will be chosen as a design 3-axis traverse to develop.

3.6.1 Pugh Method

The Pugh method is a methodology for making decisions that is employed in creating the 3-axis traverse system. Its primary purpose is to offer a formal framework for assessing and contrasting various alternatives considering a set of requirements. The Pugh method aids teams in decision-making by defining a reference idea and assessing each alternative using quantitative and qualitative analysis. The procedure entails selecting pertinent criteria, evaluating the performance of the alternatives in comparison to the reference concept, and developing a decision matrix to display the evaluation results. The best idea or solution is then determined by the alternative that received the highest score. Teams may compare options objectively, prevent bias, foster collaboration, and ultimately make better decisions by employing the Pugh approach.

Table 3-1: Pugh method

Criteria Selection	A	B	C	D	E
Stability	S	--	S	-	S
Cost	S	++	+	++	S
Weight	S	++	++	++	+
Durability	S	--	S	--	-
Easy to build	S	++	+	++	S
Total +	0	6	4	6	1
Total -	0	4	0	3	1
Total score	0	2	4	3	0

3.6.2 House of quality, HOQ

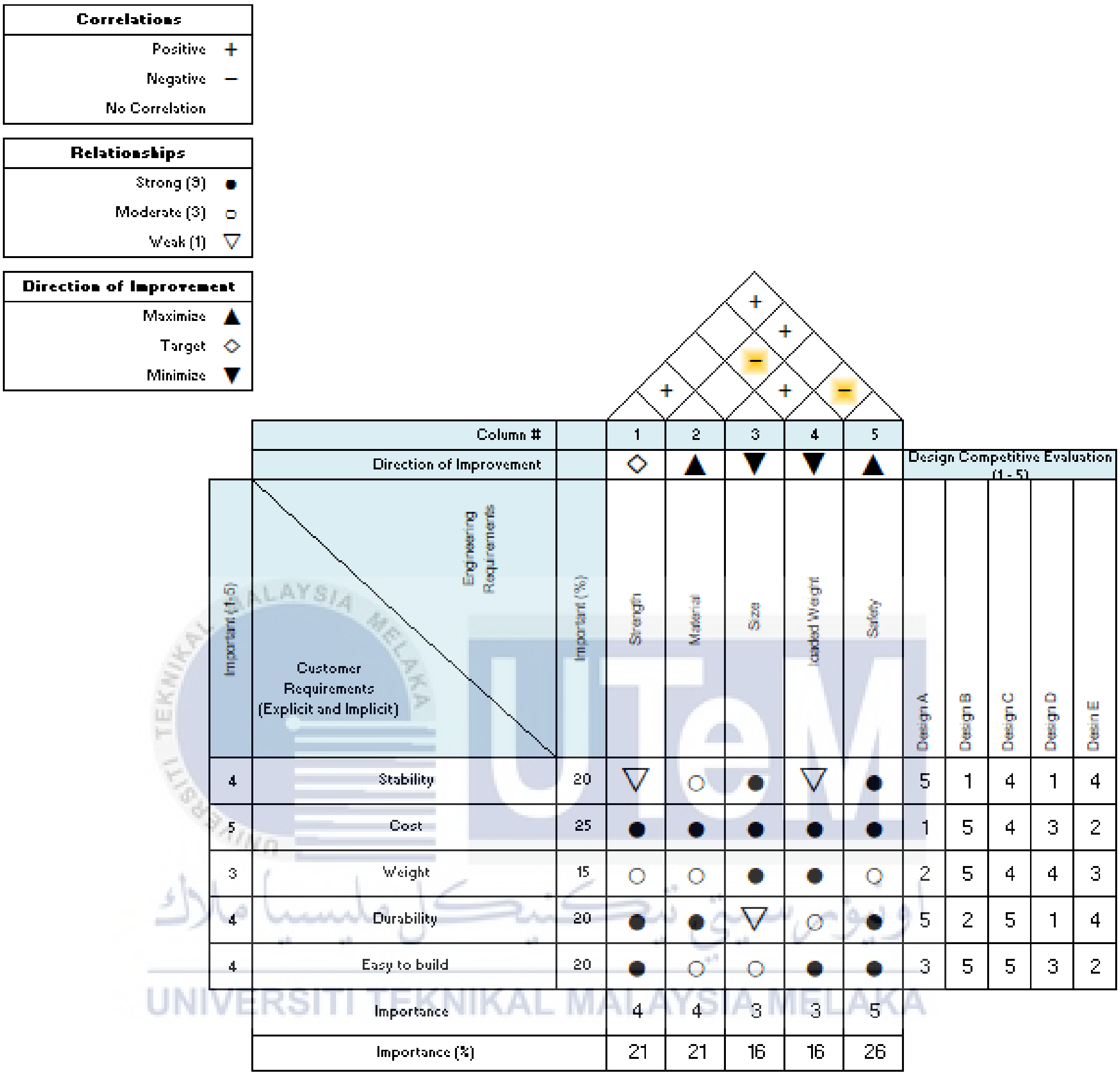
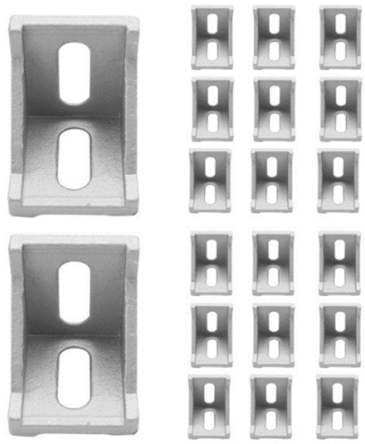


Figure 3.8: House of quality

3.7 Hardware components

Table 3-2: Table of component used in development

Hardware component	Detail	Figure
Aluminium profile 2040	Material: Aluminium 6063-T5 Size: 20mm x 40mm x 500mm Type: European standard 2040 aluminium profile	
Aluminium profile 4040	Material: Aluminium 6063-T5 Size: 40mm x 40mm x 500mm Type: European standard 4040 aluminium profile	
Aluminium plate	Material: Aluminium Thickness: 3mm Characteristics: Strong and hard	

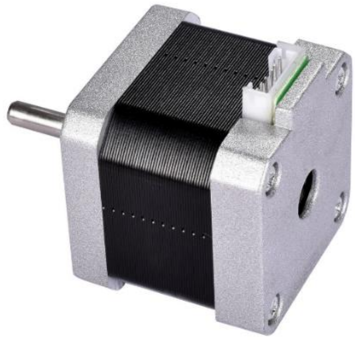
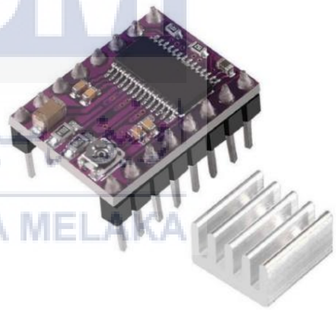
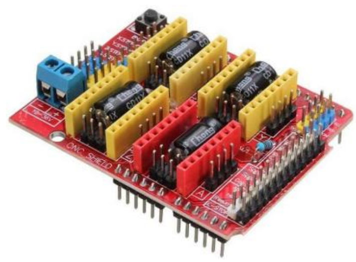
L bracket corner	Material: Die cast aluminium Model no: 1720	
V wheel	Material: Delrin(POM) Thickness: 10.23mm Rockwell Hardness: M80 Compression Strength: 63Mpa	
Open Ended GT2 Timing Belt	Tooth Profile: GT2 Fiberglass Core pitch: 2mm Width: 6mm	

Timing pulley	Material: Aluminium Number of teeth: Bore: 5mm Screw hole: 2xM3	
T8 lead screw thread	Material : 304 Stainless steel Diameter : 8 mm	

3.8 Electronic components

Table 3-3: Electronic component use in development

Electronic component	Detail	Figure
Arduino UNO	Microcontroller: ATmega328 Operating Voltage: 5V Input Voltage (recommended): 7-12V Input Voltage (limits): 6-20V Digital I/O Pins: 14 (of which 6 provide PWM output) Analog Input Pins: 6 DC Current per I/O Pin: 40 mA DC Current for 3.3V Pin: 50 mA Flash Memory: 32 KB of which 0.5 KB used by bootloader SRAM: 2 KB EEPROM: 1 KB Clock Speed: 16 MHz	

NEMA 17 stepper motor	Motor Type: Bipolar Stepper Step Angle: 1.8 deg. Holding Torque: 40N.cm (56oz.in) Rated Current/phase: 1.7A Frame Size: 42 x 42mm Body Length: 40mm Shaft Diameter: 5mm Number of Wire Leads: 4 Wire Length: 400mm Weight: 280g	
DRV8825	A4988: 20*15*11mm(LWH) Heat Sink: 9*9*5mm(LWH) Supply voltage: 45 max. Output current: 2.5A Step resolutions: fullstep, half-step, 1/4-step, 1/8-step, 1/16-step, 1/32-step	
CNC sheild V3 board	Power: 12-35 V DC Colour: Red Compact design 4-axis support	

4 slot battery 3.7V ON OFF switch	Norminal Voltage: 3.7V (fully charged at 4.2V) Minimum discharge voltage: 3.0V	

3.9 Software for CAD design and programming

Table 3-4: Software used in developement

Software	Requirement	Figure
Arduino software (IDE)	Operation system: Window 10, Window 8, Window 7, Windows Vista SP2, Windows Server 2012, Windows Server 2008 R2 SP1. Processor: Pentium 2 266 MHz. Ram: 128 MB. Hard disk: 600 Mb. Java 8 requires. License: non-academic	
Solidworks	Operation system: Windows 10 (64-bit) Processor: Dual core CPU Graphic processor: NVIDIA driver version 451.48 Ram: 8GB - 16GB Hard disk :5GB License: non-academic	

GRBL Controller	Operation system: Windows 10 (64-bit) Processor: Dual core CPU Graphic processor: NVIDIA driver version 451.48 Ram: Below 4GB Hard disk: 5GB License: Free	

3.10 Bill of Material

Bill of material will show the total cost of the equipment and the number of each part needed for this project.

3.10.1 Hardware component

Table 3-5: Bill for hardware component

No.	Name	Quantity	Price
1	Aluminium profile 2040	1	RM 34.00
2	Aluminium profile 4040	6	RM 204.00
3	Aluminium plate	1	RM 32.51
4	L bracket corner	40	RM 25.96

5	**V Wheel**	**15**	**RM 52.50**
6	**Open Ended GT2 Timing Belt**	**2**	**RM 16.00**
7	**Timing pulley**	**3**	**RM 18.30**
8	**Lead screw thread**	**1**	**RM 20.00**
Total cost			**RM 403.27**

3.10.2 Electrical components

Table 3-6: Bill for electronic component

NO.	**Name**	**Quantity**	**Price**
1	**Arduino UNO**	**1**	**RM40.00**
2	**NEMA 17 stepper motor**	**3**	**RM 96.00**
3	**DRV8825**	**4**	**RM 34.80**
4	**CNC Sheild**	**1**	**RM 6.80**
5	**4 slot Battery 3.7V ON OFF switch**	**1**	**RM 3.90**
Total cost			**RM 181.50**

3.11 Assembly parts of traverse system flow.

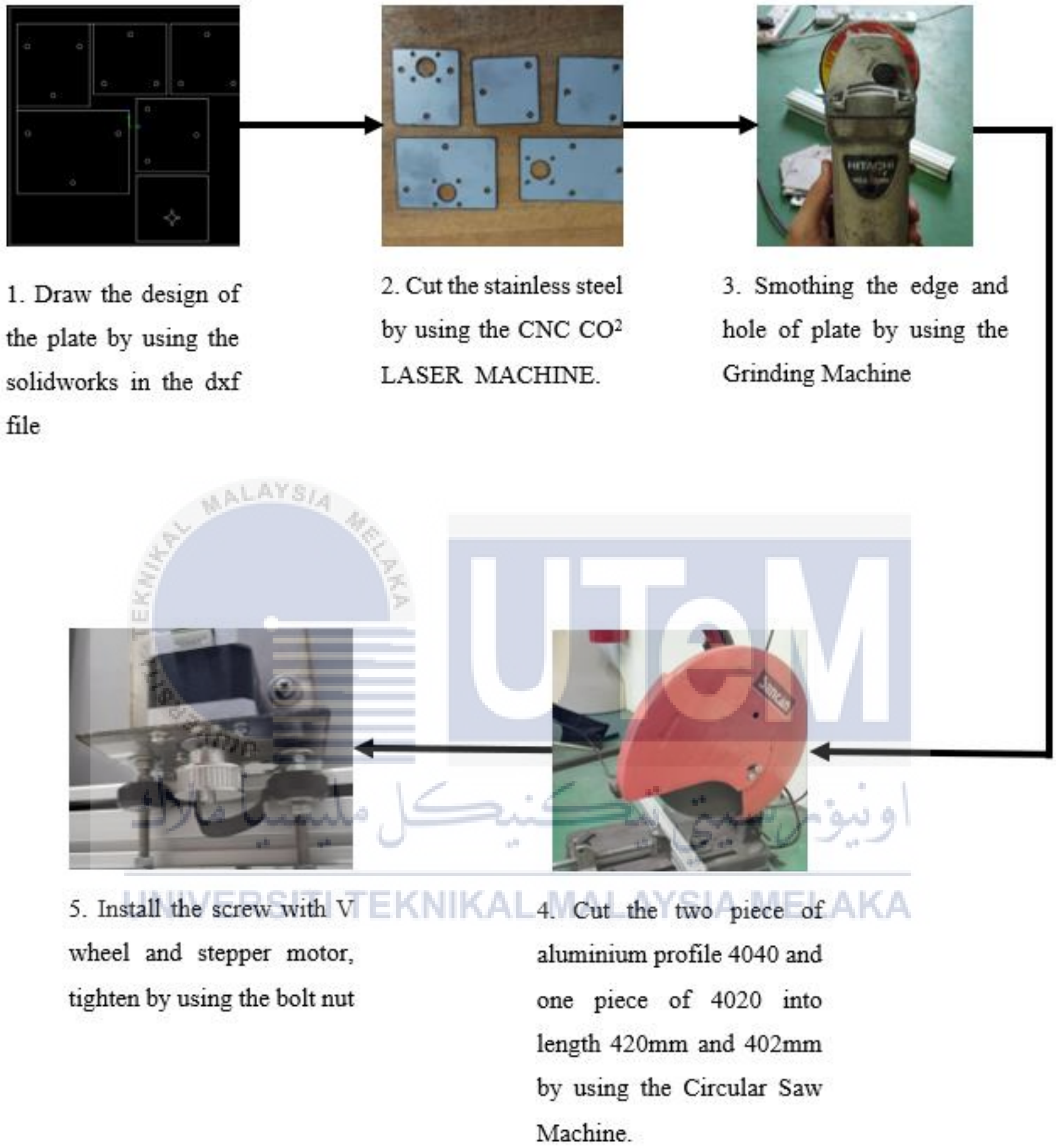


Figure 3.9: Assembly parts of traverse system flow

3.12 Assembly of electronic and electrical component flow.

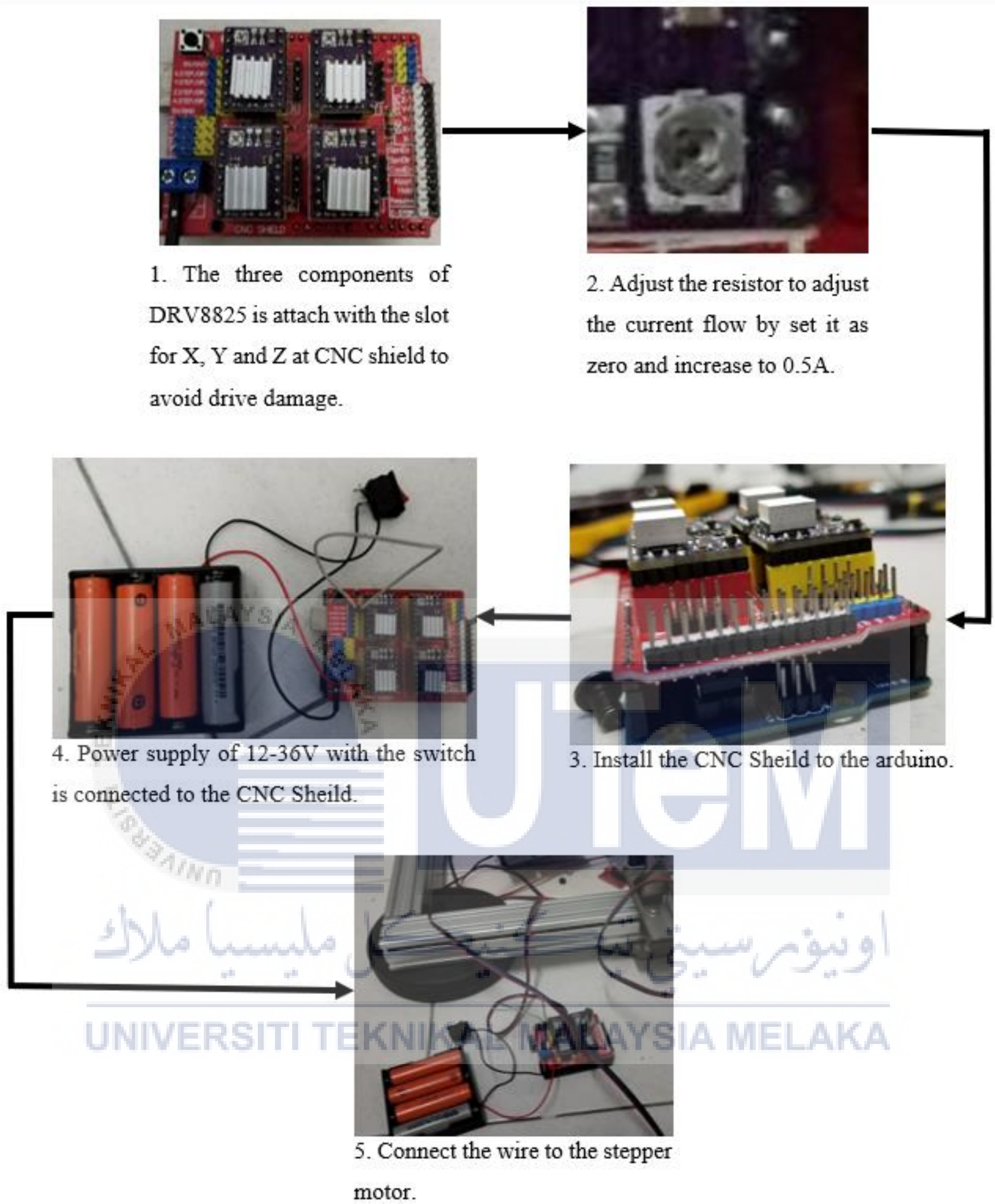


Figure 3.10: Assembly of electronic and electrical component flow

3.13 3-axis programming code.

```
  pinMode(StepY,OUTPUT);
  pinMode(DirY,OUTPUT);
  pinMode(StepZ,OUTPUT);
  pinMode( DirZ,OUTPUT);

}

void loop() {
 digitalWrite(DirX, HIGH); // set direction, HIGH for clockwise, LOW for anticlockwise
 digitalWrite(DirY, HIGH);
 digitalWrite(DirZ, HIGH);

 for(int x = 0; x<200; x++) { // loop for 200 steps
  digitalWrite(StepX,HIGH);
  delayMicroseconds(500);
  digitalWrite(StepX,LOW);
  delayMicroseconds(500);
 }
delay(1000); // delay for 1 second

for(int x = 0; x<200; x++) { // loop for 200 steps
  digitalWrite(StepY,HIGH);
  delayMicroseconds(500);
  digitalWrite(StepY,LOW);
  delayMicroseconds(500);
 }
```

Figure 3.11: 3-axis programing code

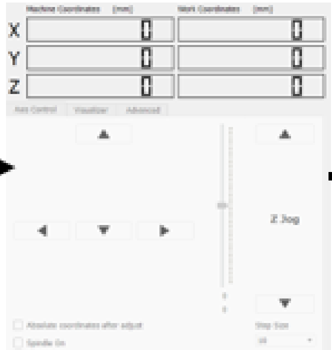
Figure 3.11 show the program code for the system to move in 3-axis which X,Y and Z. This program code allow the system to be controlled by using the GBRL CONTROLLER application the already build and ready to download to the window or play store for controlled by using the phone.

3.14 Procedure of testing

To ensure that the system is functional as needed, it is important to testing the performance. The test of accuracy, speed and stability is required to check the performance of the system.

3.14.1 The flow of movement speed test.

1. Align perpendicularly the A4 paper with any point of the axis and mark the location to the paper.



2. Move the system as it is set and take the time to next location and mark it.

$$s = \frac{d}{t}$$

3. By using formula $\frac{Distance(m)}{Time\ taken(s)}$, calculate the movement speed and repeat the steps for another 2 axis.

Figure 3.12: The flow of movement speed test

3.14.2 The flow of movement stability test.

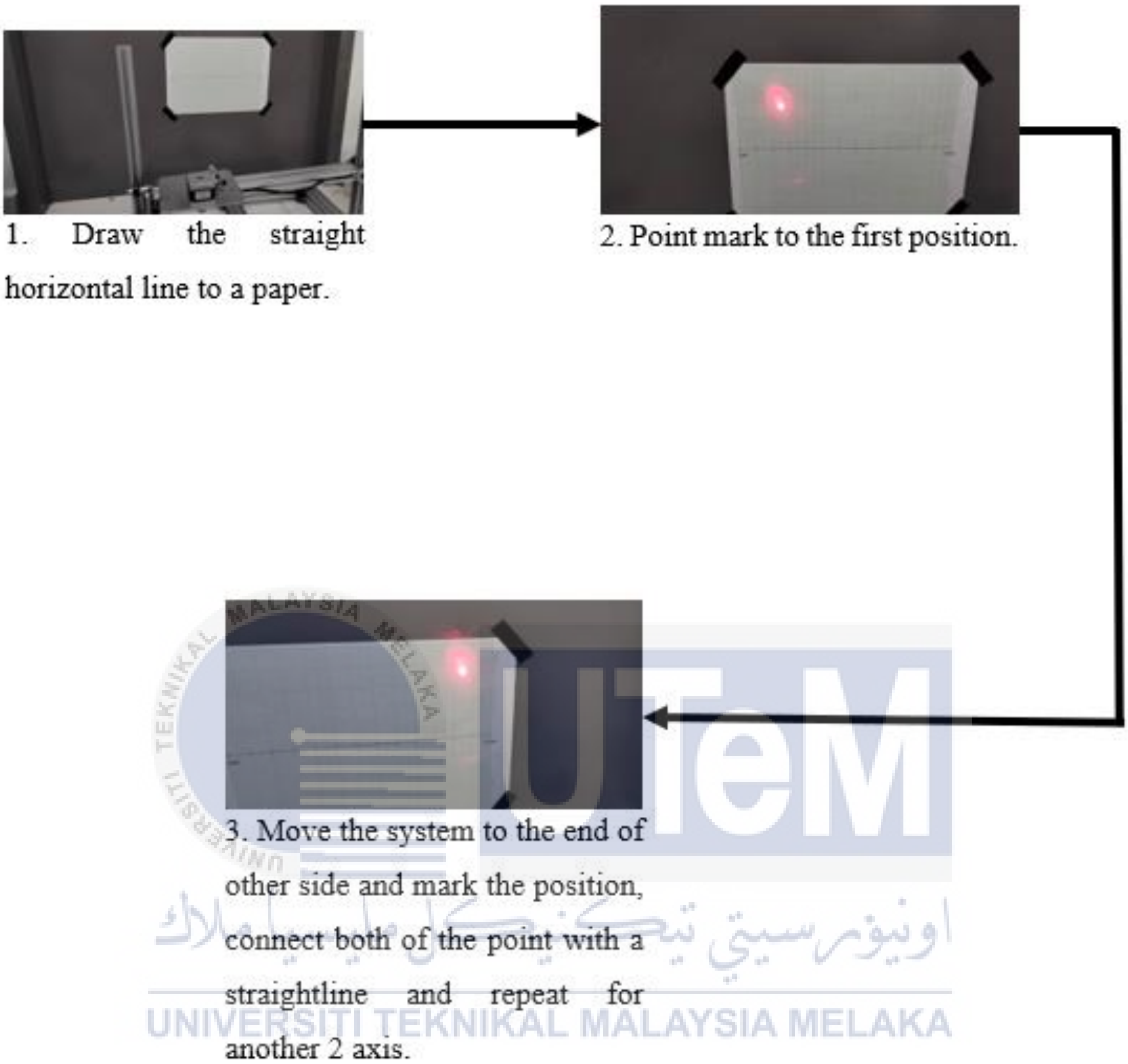


Figure 3.13: The flow of movement stability test

3.14.3 The flow of vibration test.

1. Attach slowly the nozzle of vibration measurement to the X-axis.

2. Record the minimum and maximum value of vibration on the X-axis and repeat the step for Y and Z axis.

Figure 3.14: The flow of vibration test

3.15 Calculation of 3-axis traverse weight

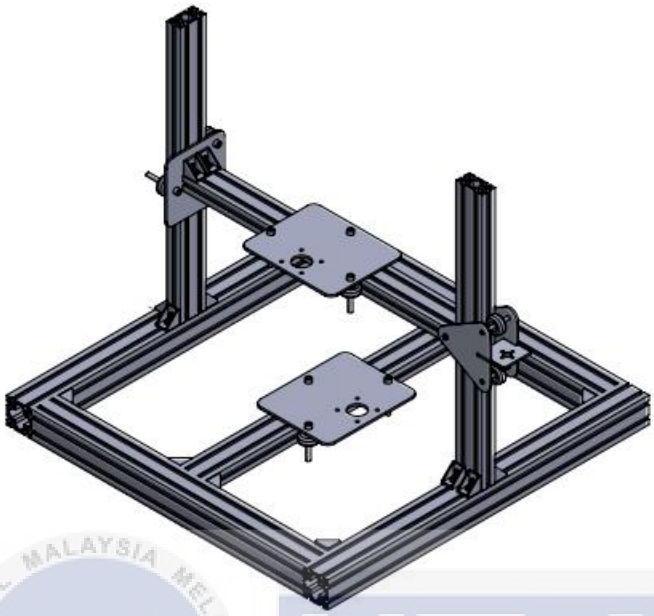


Figure 3.15: 3-axis traverse system

$$\text{Force(N)} = \text{loaded mass (Kg)} \times \text{acceleration} \left(\frac{\text{m}}{\text{s}}\right)$$

The calculation of the 3-axis traverse system is important to determine, especially the part that will be used as the camera holder that will go upward or downward in that system. The weight of that part will determine the torque power that will be used to lift. The weight will be determined total mass of 3-axis traverse system times which in kilogram with the value of gravity which is 9.81m/s.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter describes the result of project base on this thesis objectives. Every data and analysis that collected from the testing process will be determine the performance of this thesis ether that this project is achieve the objectives.

4.2 The traverse system drawing

Every component of 3-axis traverse system design that war selected based on the pugh method and house of quality will be shown in the schematic drawing with the detail of design.

4.2.1 Orthographic drawing

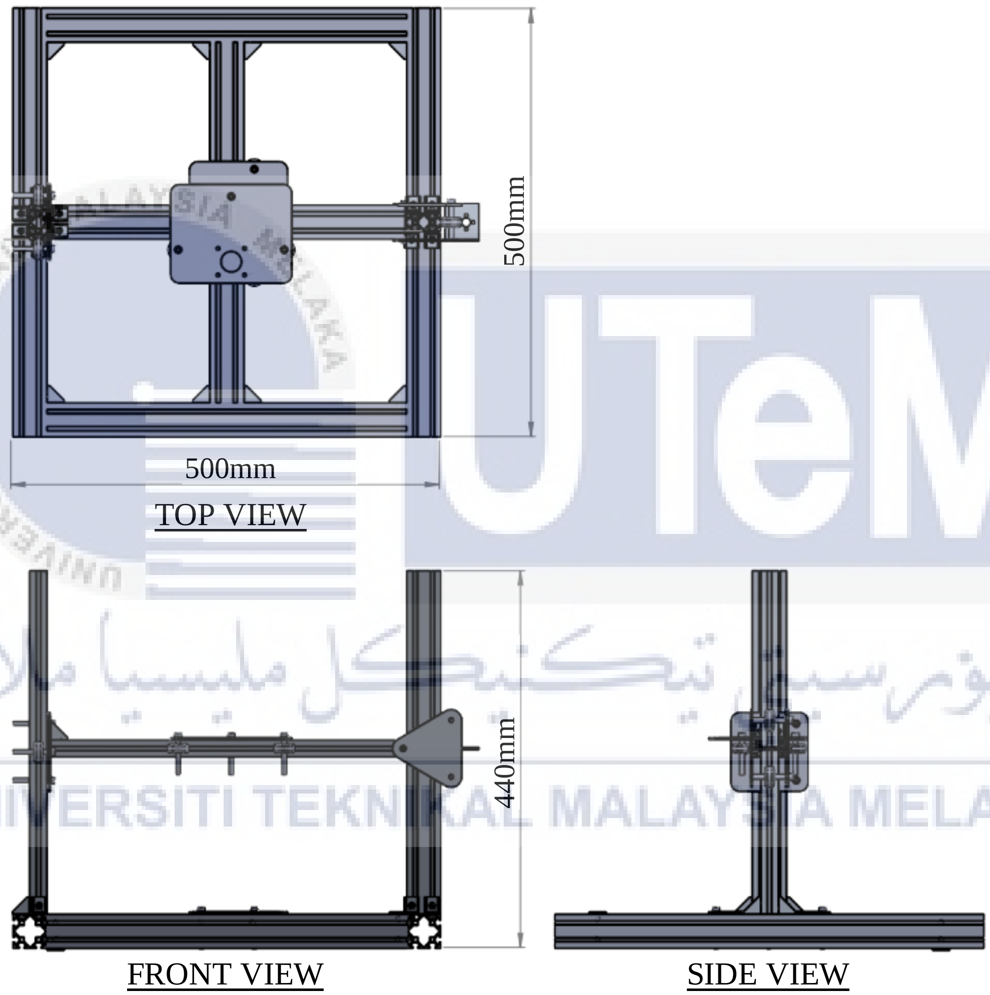


Figure 4.1: Orthographic drawing

4.2.2 Isometric drawing

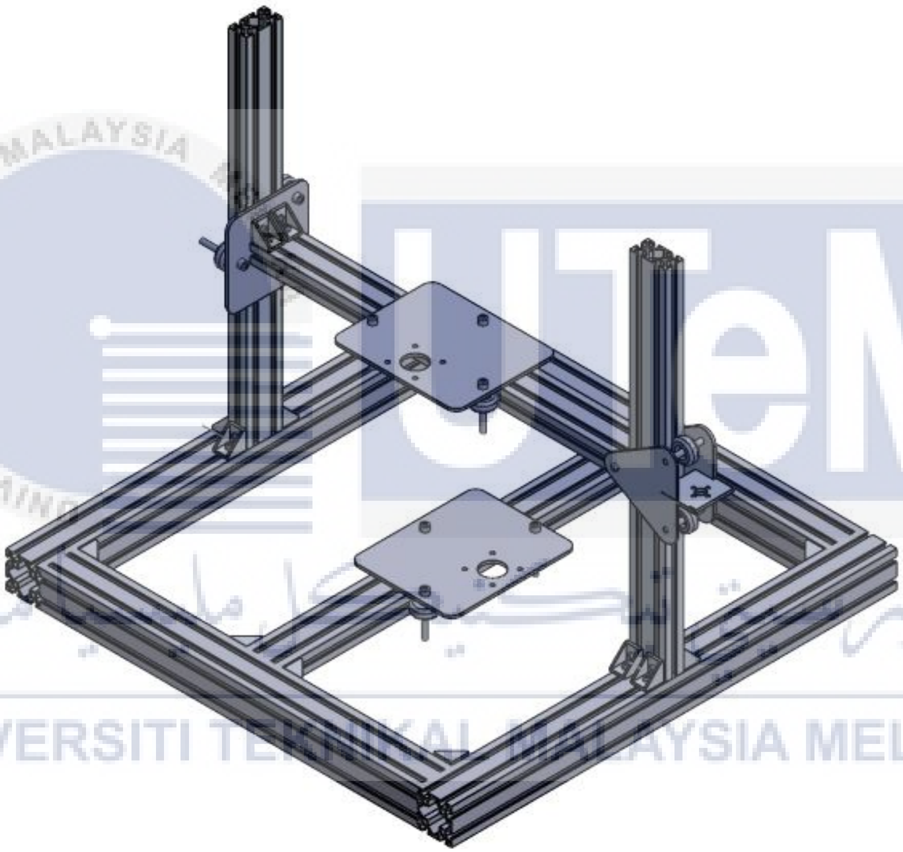


Figure 4.2: Isometric drawing

4.2.3 The exploded drawing

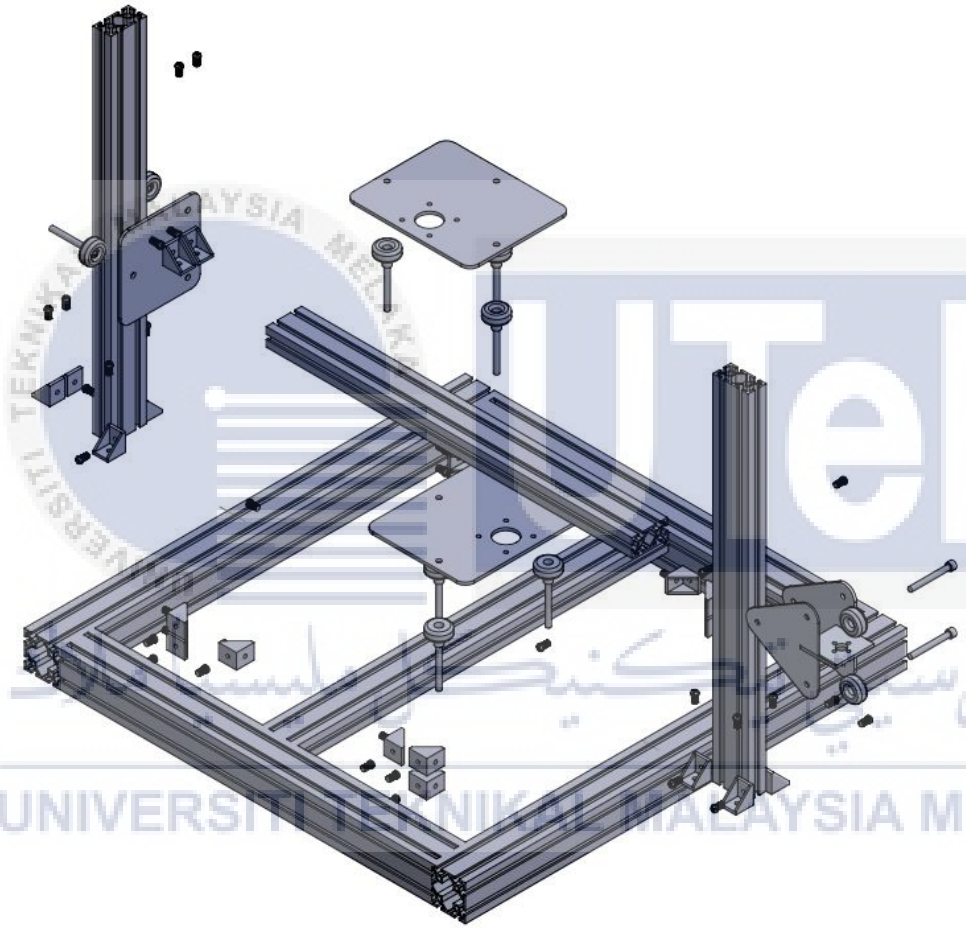
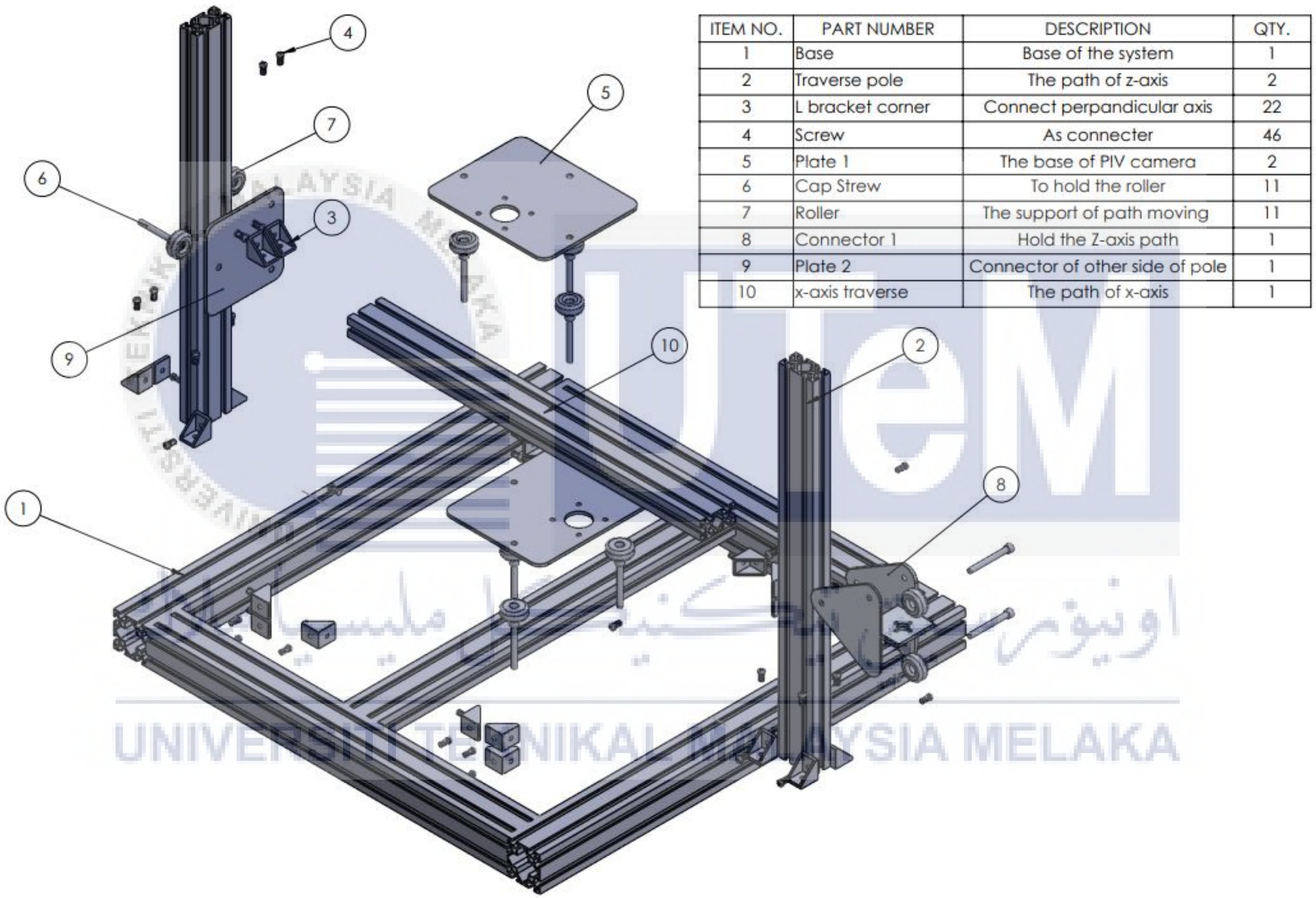


Figure 4.3: The exploded drawing

4.2.4 The bill of material



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Base	Base of the system	1
2	Traverse pole	The path of z-axis	2
3	L bracket corner	Connect perpandicular axis	22
4	Screw	As connecter	46
5	Plate 1	The base of PIV camera	2
6	Cap Strew	To hold the roller	11
7	Roller	The support of path moving	11
8	Connector 1	Hold the Z-axis path	1
9	Plate 2	Connector of other side of pole	1
10	x-axis traverse	The path of x-axis	1

Figure 4.4: The bill of material

4.3 Traverse system prototype

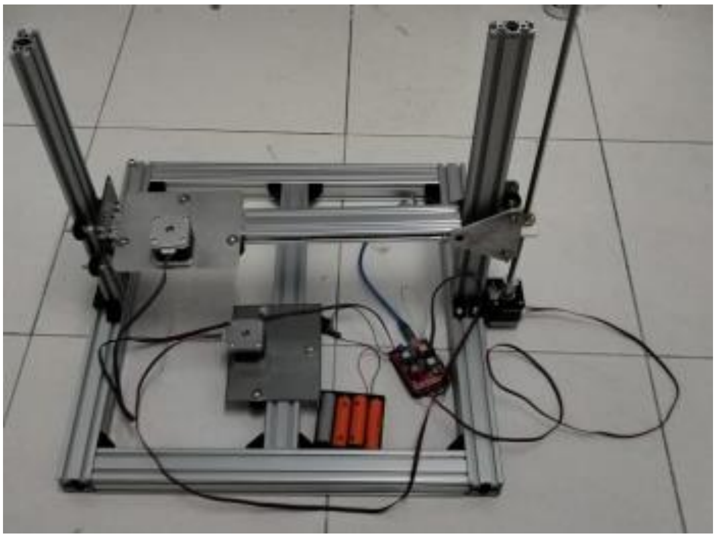


Figure 4.5: The prototype of traverse system

As Figure 4.5 shown the completed prototype of traverse system which have the X-Y-Z axis on the system. The stepper motor used in every axes to control the movement of the traverse system.

4.4 Load distribution

The load that need to carry by the system is important to determine the performance and functinality of the system. It is include the load by the system self carry to make a movement along their own path. As refer Figure 4.6, the load will be place on 3 different place which two of them carry the load from the stepper motor and one will carry the load of the system by it self. The torque of the stepper motor must be higher than the load to make a movement.

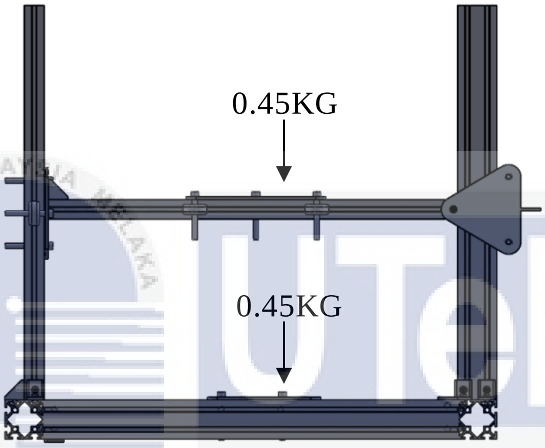


Figure 4.6: The allowable max load

4.5 Result and analysis

The data collected on this section are used to check the fucntionality of the system that meet the require that expected. Utilizing timer, pancil and paper and a vibrometer are the approaches that are used in the process of evaluating the 3-axis traverse system.

4.5.1 Speed of camera holder

The measure of the speed of the system is important to indentify the time taken for the system to travel to another location. The data taken by the targeted position and take the time taken for the system reach the location. The distance from initial to final will be divide by the time taken to get the speed value of the system.

Table 4-1: Movement speed test of traverse system

Axis	Distance set (mm)	Time taken (s)	Movement speed (mm/s)
X	20	0.55	36.36
	40	1.24	32.26
	60	2.10	28.57
Y	20	0.64	31.25
	40	1.51	26.49
	60	2.34	25.64
Z	20	2.34	8.55
	40	5.42	7.38
	60	7.82	7.67

The data as Table 4-1 shown that the average speed of X-axis is 32.40mm/s, Y-axis is 27.79mm/s and Z axis is 7.87mm/s. The X-axis and Y-axis having the small difference of speed to compare with the Z-axis which take much slower to travel. The Z-axis is carrying the system of X-axis which the load is much higher than the X and Y axis.

4.5.2 Stability of traverse system

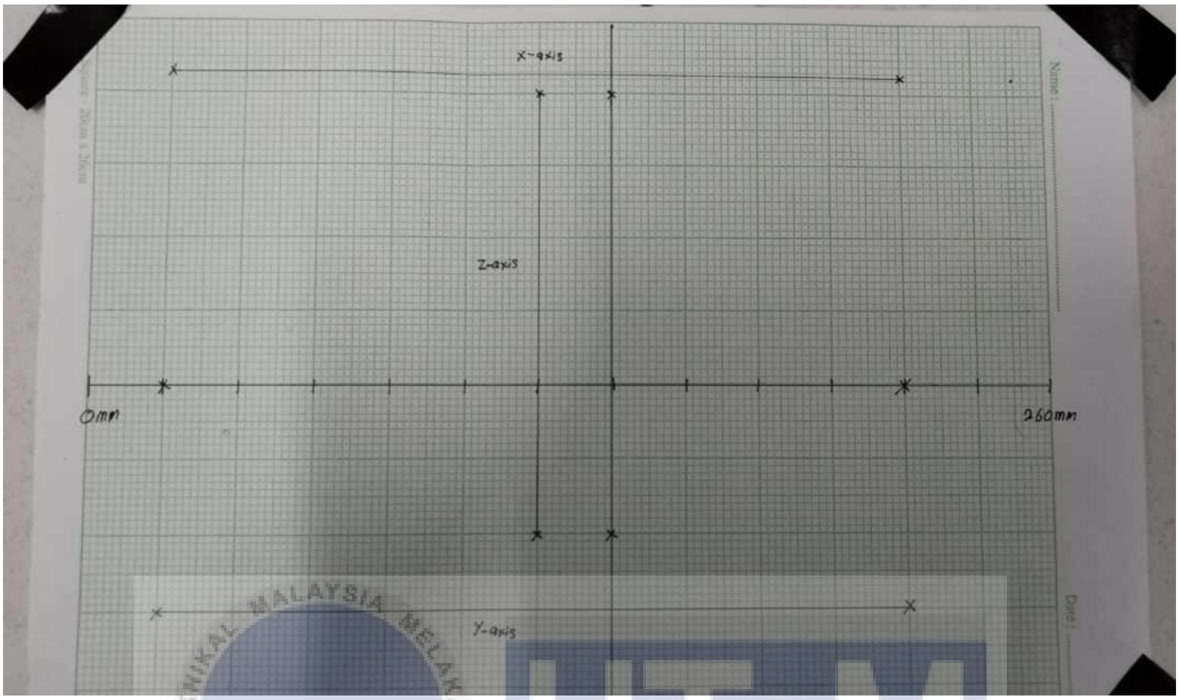


Figure 4.7: Horizontal and vertical line test result

Based on Figure 4.7, every axis in the system is mpving in the straightline which the X and Y axis is the horizontal line and the Z-axis is the vertical line the point is taken with a leser at the initial position and the another point is taken at the last position. From all the information that every axis is moving straight by the route, it can be conclude that the system of 3-axis traverse is stable.

4.5.3 Vibration of traverse system

Table 4-2: Vibration test of traverse system

Axis	Calibrate	Velocity of vibration (m/s)	
		Max	Max
X	1	2.32	7.34
	2	2.53	6.45
	3	2.46	6.82
	Average	2.44	6.84
Y	1	2.48	6.63
	2	2.73	6.84
	3	2.54	6.84
	Average	2.58	6.77
Z	1	11.26	24.64
	2	11.38	27.32
	3	11.42	28.75
	Average	11.35	26.90

Based on Table 4-2, there are 3 difference axes that need to evaluted the vibration which X,Y and Z on the 3-axis traverse system. The vibration on the X and Y axis is quite low to compare with the Z axis due to the load carry. The X and Y can easily travel within their route but the Z axis is struggle to lift the X axis traverse route. It can be concluded that the weight load will determine the vibration and speed of the system.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Based on the research, the main objective is to develop the 3-axis traverse system that can hold a camera holder that can hold a camera such as the Particale Image Velocimetry (PIV) TSI camera model 630090. Overall the objectives of this reasearch are achieved which builded the design of 3-axis traverse system by using the Solidworks software, which it will determine the items that needed to build the prototype of 3-axis traverse system.

The program to the Arduino Uno of the 3-axis traverse system successfully achieved by using the manufactured guidance programming which that can controlled the movement of the stepper motor by using the software application which is called GBRL CONTROLLER that used to control stepper motor.

The testing of 3-axis traverse system also is achived by run the speed test, which the speed of Z-axis is 7.87 mm/s need to be improve another than X and Y axis which is 32.4mm/s and 27.9mm/s. The stability test that used the straightline to determine the angle of 3-axis which the result is 180 degree for X and Y axis and 90 degree for Z axis which it is great for the 3-axis traverse system. The vibration test also taken to check the vibration on the system which the Z-axis minimum 11.35m/s and maximum 26.90m/s the only that have high vibration because of the load that that axis need to carry.

5.2 Recommendation and project future developments

With all the data, this project can always be improved; here are the suggestion that can be use to improve in the future:

- Add double stepper motor for Z-axis to support the load from the both side of the direction.
- Use the stopper of the system to stop the movement of stepper motor when the plate arrive to the end.
- Use a lighter material that can easily lift the system such as the alloy aluminium.

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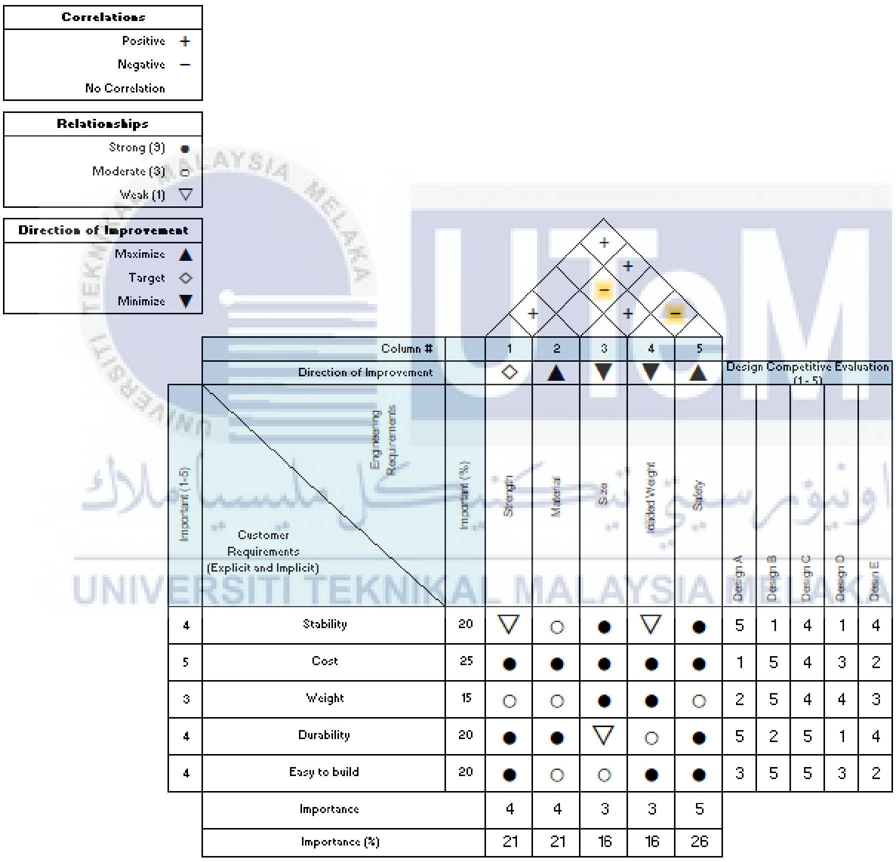
APPENDICES

Criteria Selection	A	B	C	D	E
Stability	S	--	S	-	S
Cost	S	++	+	++	S
Weight	S	++	++	++	+
Durability	S	--	S	--	-
Easy to build	S	++	+	++	S
Total +	0	6	4	6	1
Total -	0	4	0	3	1
Total score	0	2	4	3	0

Appendix A: Pugh method



Appendix B: House of quality