FABRICATION OF A TEST BED FOR PERFORMANCE TESTING OF UNMANNED AERIAL VEHICLE (UAV) PROPULSION SYSTEM

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JUDUL: FABRICATION OF A TEST BED FOR PERFORMANCE TESTING OF UNMANNED AERIAL VEHICLE (UAV) PROPULSION SYSTEM

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DEDICATION

I specially dedicate to my beloved parents

(Azmi bin Mohd; Zain & Zaiton binti Zakaria), my siblings,

My supervisor and those who have guided

And motivated me for this project

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This project was conducted under the supervision of Ahmad Basirul Subha Bin Alias in University Malaysia Pahang (UMP). I am very grateful to him for his patience and his constructive comments that enriched this research project. His time and efforts have been a great contribution during the preparation of this thesis that cannot be forgotten forever. I would also like to acknowledge with much appreciation the crucial role of the staff in Mechanical Laboratory, for their valuable comments, sharing their time and knowledge on this research project during the project was carried out and giving a permission to use all the necessary tools in the laboratory.

To my parent, Azmi bin Mohd; Zain and Zaiton binti Zakaria, thank you for all the support and sacrifice that both of you gave me. Your sacrifice is too great to be measured and it will be never forgotten. Also to my brothers Muhammad Haniff bin Azmi, Imran Shakir bin Azmi, Shahrul Ikram bin Azmi my sister Nurul Shahira binti Azmi.

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ABSTRACT

This project report has been conducted because of the Unmanned Aerial Vehicle (UAV) power plant development performance testing (static test) facilities is not fully deployed. The main purpose of this project is to fabricate a test bed for the UAV propulsion system. To test the capability of measuring aircraft performance namely thrust, available power, brake shaft power, propulsive efficiency, brake specific fuel consumption and thrust coefficient. In this study, the test bed model was designed to test the nitro engine Radio Control (RC) which is a model of Thunder Tiger PRO .36. The unknown value of parameters can be determined by reading the sensors. Some sketches software had been used such as Autocad and Solidwork to draft out the shape of the test bed. The fabrication process for this project must through a lot of process that must be followed step by step. This is to ensure that the design had been fabricated by following the design specification. From this experiment, the result shows that the fabricated test bed can be used to study the engine performance and performance parameters are directly proportional to the engine speed which mean the speed of the engine affects the increasing of the parameters. Some methods of improvement for the combination of test bed are also provided for further improvement of the test bed. As the conclusion, all the engine performance parameter can be calculated from the test bed.

ABSTRACT

Laporan projek ini telah dijalankan kerana di dalam Pesawat Udara Tanpa Pemandu (PUTP), pembangunan fasiliti untuk ujian prestasi (ujian statik) jana kuasa tidak dilaksanakan sepenuhnya. Tujuan utama projek ini adalah untuk memfabrikasi ujian katil untuk PUTP ujian sistem dorongan perlu untuk mengukur prestasi kapal terbang seperti teras, kuasa yang ada dan kuasa brek aci, kecekapan pendorongan,penggunaan bahan api brek dan kecekapan teras. Dalam kajian, model ujian katil yang direka untuk menguji enjin nitro Kawalan Jauh (KJ) iaitu model Thunder Tiger PRO .36. Prestasi nilai parameter boleh dikira dengan mengukur nilai yang tidak diketahui boleh didapati melalui bacaan sensor. Dengan menggunakan Auto-Cad dan solidwork, draf atau gambaran asal mengenai reka bentuk ujian katil dapat diihat dengan jelas. Proses mencipta melalui beberapa langkah yang perlu dituruti secara tersusun, ini adalah untuk memastikan hasil pembuatan akan mengikut spesifikasi rekacipta. Dari eksperimen ini, hasilnya menunjukkan bahawa katil ujian yang direka boleh digunakan untuk mengkaji kebolehan engin dan parameter prestasi adalah berkadar terus dengan kelajuan enjin yang mana bermakna semakin laju kelajuan enjin yang dilaksanakan semakin meningkat parameter prestasi. Idea penambahbaikan untuk alat uji katil juga disediakan untuk pembaharuan masa akan datang. Kesimpulannya, semua parameter prestasi enjin boleh dikira dari ujian katil ini.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

UAV	Unmanned Aerial Vehicle
RC	Radio Controlled
RPM	Revolution Per Minute
ASTM	American Society for Testing and Materials
BSFC	Brake Specific Fuel Consumption
LVDT	Linear Variable Differential Transformer

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

The term UAV is an abbreviation of Unmanned Aerial vehicle, meaning aerial vehicles which operate without a human pilot. At first, UAVs are commonly used in both the military and police forces in situations where the risk of sending a human piloted aircraft is unacceptable, or the situation makes using a manned aircraft impractical. Now days, more advanced UAVs used radio technology for guidance, allowing them to fly missions and return. They were constantly controlled by a human pilot, and were not capable of flying themselves. This made them much like todays RC model airplanes which many people fly as a hobby. Modern UAVs are controlled with both autopilots, and human controllers in ground stations. This allows them to fly long, uneventfully flights under their own control, and fly under the command of a human pilot during complicated phases of the mission. Sometime, for specifics Unmanned Aerial Vehicle (UAV) mission, power plant performance is not fully deployed.

The mission used for the test is traffic monitoring and the test bed will be developed to conduct the testing. Test bed can be designed that will work with different types of engines, props and other equipment in the system. Engine performance will be evaluated according to engine type and size of the props used.

The purpose of study is to find the engine performance parameters such as force, available power, shaft brake power, propulsive efficiency, brake specific fuel consumption and thrust coefficient from the testing and to suggest suitable power plant.

1.2 PROBLEM STATEMENT

In Unmanned Aerial Vehicle (UAV) power plant development performance testing (static test) facilities is not fully deployed. Therefore, less information of the power plant performance can be measured which causes the limitation of the power plant selection. A test bed is required to measure operational characteristic performance of UAV propulsion.

1.3 PROJECT OBJECTIVES

The objectives of this project are listed as follows:

i. To fabricate a test bed for UAV propulsion system testing capable of measuring the following performance parameters:-
   a. Thrust
   b. Available Power
   c. Shaft Brake Power
   d. Propulsive Efficiency
   e. Brake Specific Fuel Consumption.
   f. Thrust coefficient.

ii. To design a set of data instrumentation system for data collection during experiment.

1.4 PROJECT SCOPE

The scope for this project are listed as follows:

i. Design the test bed by using design software namely Solidwork and Autocad.
ii. Materials selection for every part.
iii. Fabricate a test bed using the suitable materials based on the requirements of the project.
iv. Installations of the sensors system at the test bed such as anemometer and tachometer.
v. Evaluate and test to run the fabricated test bed for reliable operation.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, the discussion is more on about the engine test bed. The detail on existing engine test bed, materials used by others and design of the test bed. Some discussion about UAV propulsion system is conducted on this chapter. From that we can determined the engine performance parameters from output for each engine type such as thrust, available power, shaft brake power, propulsive efficiency, brake specific fuel consumption and thrust coefficient. The idea for pilotless drones began almost as soon as planes were invented. During World War II, the US built several drones. UAV's were used to spy on the enemy during the Vietnam War. As the US became involved in wars in the Middle East in the 1990s and 2000s, it added several advanced types of UAVs to its fleet of aircraft. The technological objective of UAVs is to serve across the full range of missions cited previously. UAVs present several basic advantages compared to manned systems that include better maneuverability, lower cost, smaller radar signatures, longer endurance and minor risk to crew (Rogelio Lozano, 2007). There many usage of UAV which is as state by (Herwitz et. all, 2004; Herwitz et. all, 2005), potential civil and commercial applications include, communication relay linkages, surveillance, traffic monitoring, search-and-rescue, emergency first responses, forest fire fighting, transport of goods, and remote sensing for precision agriculture.

2.2 TEST BED

An engine test bed is a facility used to develop, characterize and test engines. The facility, often offered as a product to automotive original equipment manufacturer, allows engine operation in different operating regimes and offers measurement of several physical variables associated with the engine operation.

A sophisticated engine test bed houses several sensors (or transducers), data acquisition features and actuators to control the engine state. The sensors would measure several physical variables. Information gathered through the sensors is often processed and logged through data acquisition systems.

The main application of an engine test bed is for research and development of engines, typically at an original equipment manufacturer laboratory. Automobile original equipment manufacturers are usually interested in developing engines that meet the following objectives:

i. To provide high fuel efficiency
ii. To improve drivability and durability
iii. To be in compliance to relevant emission legislation

2.3 EXISTING ENGINE TEST BED.

2.3.1 VMAR Engine Test Bed.

This stand has the flexibility to work with engines that range from .09 to 1.80 cubic inches two and four stroke engines. It offers infinite adjustments to the mounting rails, fuel tank position, and throttle control. The price of this test bed is $17.95. Some of the features on this test bed were the clamp-style engine mounting rails which make it easy to quickly change from one engine to another. The mounting rails are constructed from aluminum and are attached with high quality socket head cap screws.

VMAR Engine test bed can adjust the height of the fuel tank to match the centerline of the carburetor. This helps break in the engine without worrying about rich or lean conditions with regard to the tanks position. Basically, materials that use in this product are wood, plastic and steel.

Another nice feature is the remote throttle arm. It has a pushrod that can easily be connected to the throttle arm. When set the proper RPM's of the engine, tighten the wing nut to maintain that setting. To use the mount, simply attach the engine to the stand and adjust the clamp bolts to the correct holes. Then, connect the fuel lines and throttle arm.

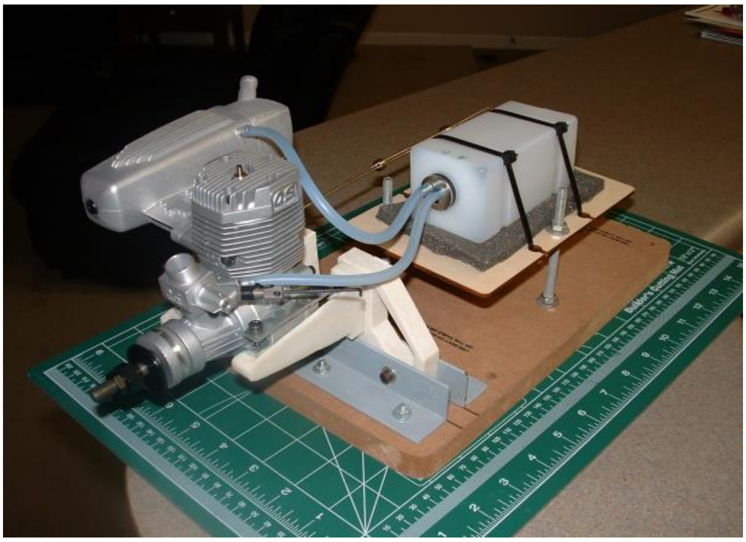

Figure 2.1: VMAR Engine Test Bed.
Source: http://rcgroup.com, (2003)

2.3.2 PSPMGS Engine Test Bed.

The PSPMFG Engine Test Bed is the most versatile and safe stand on the market. PSPMFG Engine Test Stands will accept a very wide range of engines, from the small .10 size to 2.0 cubic inches. Often overlooked is the importance of the relationship between the height of the needle valve and the centreline of the fuel tank, which is needed to obtain optimum setting for the engine. With this variable height fuel tank support this has now been made quick and easy. Also included is a whopping 14oz. (420cc) Slec Maxi Fuel Tank so that the user not constantly having to fill up. To make things safer, this product has also fitted the

Fuel Tank support with a throttle control cable so as to keep fingers away from the prop. The price of this test bed is $56.99. Same with the VMAR Engine Test Bed, the materials used in this product are wooden, steel and plastic.

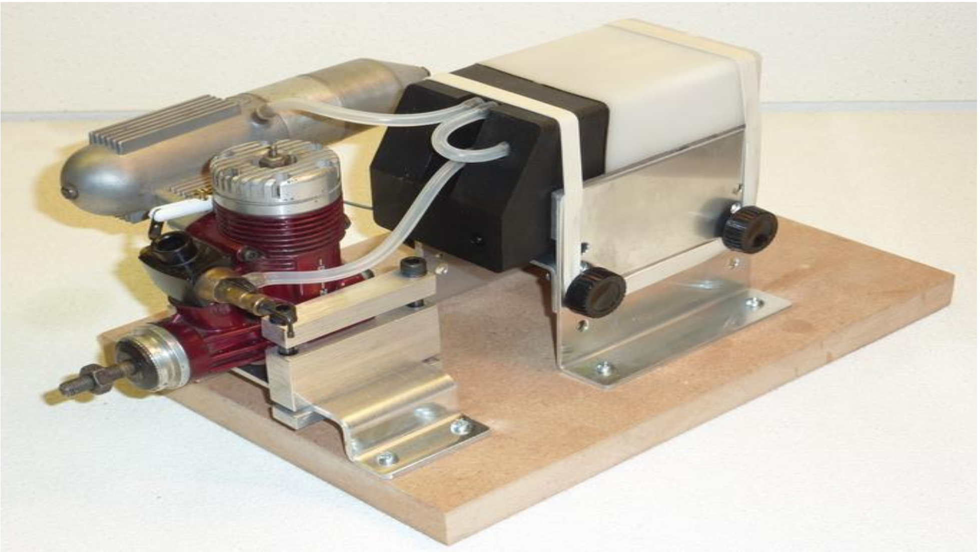

Figure 2.2: PSPMGS Engine Test Bed.
Source: http://rcgroup.com, (2003)

2.4 REQUIREMENT FOR TEST BED DESIGN

In this study, parameters that can be measure is the engine performance such as thrust, available power, shaft brake power, brake specific fuel consumption, propulsive efficiency and thrust coefficient. There is only one type of engine that will be used in this study which is 2-stroke engine. The throttle control of the engine will be used to simulate the engine operating range from idle speed condition until achievable the maximum speed.

2.4.1 Thrust of The Engine

Thrust is the driving force that propels an aircraft, helicopter, missile or rocket forward. An UAV propulsion system is simply a device that converts power into thrust to propel an aerospace vehicle. It is known that the performance of an aircraft engine is heavily dependent on the thrust it produces. Thrust is generated from the change in the momentum of the working fluid as a direct result of motion across the surface of the propeller. Torque results from the rotation of the propeller blades as a consequence of the engine power output. Any change in engine power output brings about a corresponding change in torque, which in turn affects the thrust and hence, the overall aircraft performance through the wind speed. The forces acting on the airfoil-shaped cross section of a propeller blade are complicated to determine analytically. At first glance, a seemingly simple method of calculating the thrust produced by a propeller blade would be to sum the forces for a small differential radial element (dr) along the length of the blade. It is possible to determine the differential lift (dL) and drag (dD) from the lift and drag coefficients (C_L and C_D) derived from the local airfoil shape and then integrate this equation (Ward, 1966).

From Newton's second law of motion, we can define a force F to be the change in momentum of an object with a change in time. Momentum is the object's mass m times the velocity V. According to the basic momentum theory, the propeller is reduced to a rotating disk that imparts axial momentum to the air passing through it. For the purpose of this discussion the air is incompressible. For reference, consider section 0 (far upstream), 1 (just upstream the disk), 2 (just downstream the disk) and 3 (far downstream), as shown in Figure 2.9 (Mike Tooley, 2000).

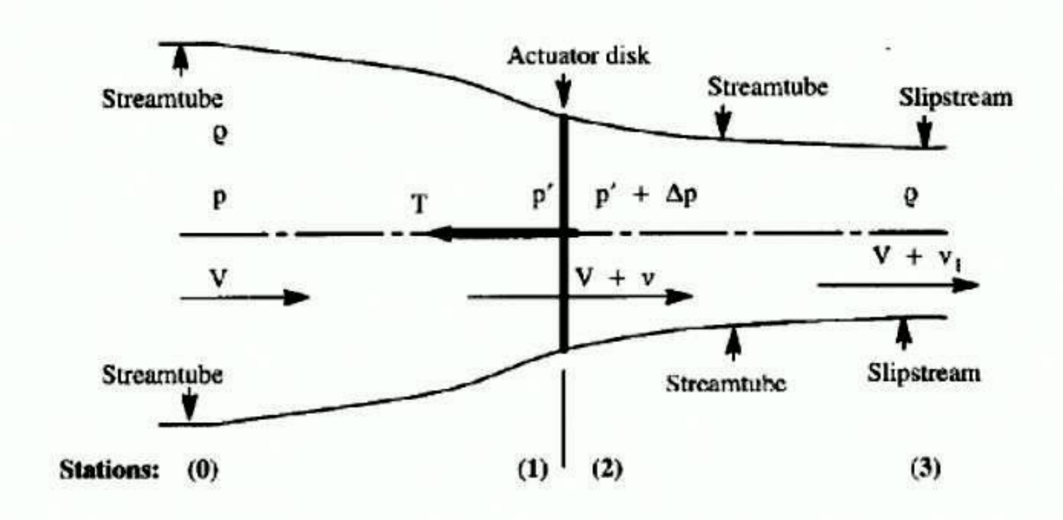

Figure 2.3: Control volumes surrounding a propeller

Source: Mike Tooley, (2000)

The theory assumes that there is no flux along the limiting streamlines and that the velocity is continuous through the propeller. The free stream velocity is equal to the speed $V_0 = V_e$. The suitable type and size of propeller is important to draw maximum power output from the nitro engine. As the ideal propeller diameter, pitch and blade area vary according to the size, weight and type of model, final propeller selection will require in flight experimentation.

There are several types of propellers in use on model airplanes. They include two, three, and four blade types. By far, the most popular propeller for a trainer plane is a two blade type made of wood or plastic (Tressler, 2008). Most used are plastic propellers. Propellers are sized using two numbers; diameter and blade pitch. A very common prop size for a 32 to 40 trainer engine is a 10-5. The first number is the diameter of the propeller in inches. The second is the blade pitch expressed as a number representing the theoretical distance the airplane travels forward for each revolution of the propeller.

The rotating propeller will produce thrust as shown in Figure 2.5. The ideal thrust equation for piston aerodynamics engines as shown in Eq. (2.1).

$$F_N = \dot{m}_e V_e - \dot{m}_o V_o = \dot{m}\left(V_e - V_o\right) \quad (2.1)$$

Where,

$\dot{m}_e$ is the air mass flow at exit(kg/s).

$\dot{m}_o$ is the air mass flow at inlet (kg/s).

V_o is the air velocity at inlet (m/s).

V_e is the air velocity at exit (m/s).

By using the measured thrust, the next calculation will reflect more accurately the actual situation the engine. For this study, assuming that the force is the same as the spring force constant as the applied if the displacement of the spring is combined. It is marked by k. Consider force F stretches the spring so that it change the equilibrium position x. Force can be measure by a simple equation known as Hooke's law as Eq. (2.2).

$$F = kX \tag{2.2}$$

Where,

k is spring constant (N/m)

x is elongation of spring during testing (m).

Hence, in term to measure the thrust exerted by propeller while the engine start, the spring was placed between the spring holders at the base with rear sliders. The value of spring constant, k already knew and the value of elongation of spring can be obtained from the linear variable differential transformer (LVDT) reading.

2.4.2 Available Power and Shaft Brake Power

Aircraft propulsion consists of two distinct parts. There is the engine that converts a source of energy, such as fuel, to work. Then there is the part of the system that converts the work of the engine into work on the surrounding environment to produce propulsion. The most obvious example is a propeller. A piston engine and propeller combination is an example of a complete aircraft propulsion system. Looking at the propulsion system from the standpoint of power, it is convenient to introduce a few terms. That power is required for flight: for supporting the weight of the airplane, for climbing, for turning or accelerating. This is the required power for flight. The power that is actually produced by the engine and delivered to the propeller will call the engine power (Anderson, 2001).

In actual piston aero engines the shaft brake power cannot be perfectly transmitted to the propeller as available power, because of losses associated with the compressibility of air. The available power is the rate that useful work is done. The equation of available power can be simplified as shown in Eq. (2.3).

$$\dot{W}_A = F_N V_o = \dot{m} V_O \left(V_e - V_o \right) \tag{2.3}$$

Where,

F_N is the force exerted by propeller (N).

$\dot{m}$ is the mass flow rate air (kg/s).

The term brake shaft power is used to specify that the power is measured at the output shaft, this is usable power delivered by the engine to the load. The equation of shaft brake power can be simplified as shown in Eq. (2.4).

$$\dot{W}_B = \dot{m} \frac{V_e^2}{2} - \frac{V_o^2}{2} \tag{2.4}$$

To solve mathematical equations, then need to find the speed of the air before and after the propeller. Hence, the anemometer is used to get the speed of air Vo and Ve in front and rear the propeller at specific engine speed so that the available and shaft brake power data can be obtain.

2.4.3 Propulsive Efficiency

Aircraft propeller change rotary motion from piston engines, turboprop or electric motor to provide propulsive force. They may be fixed pitch or variable. At first, the propeller made of solid or laminated woods. After that, the fan blades are made using metal. Based on the performance of the engine that was created on the rise, the use of composite materials of high technology in the design of the fan is good innovation. The fan is usually attached to the piston engine's crankshaft, either directly or through the reduction.

The propulsion efficiency is defined as the ratio of the thrust –power (power generated by the thrust force *F* at a speed *V*) and the rate of the production of propellant kinetic energy.

As state by (Ward, 1966), Figure 2.4 illustrates the airfoil cross section of a propeller. Early propellers generally used airfoil cross sections that were similar to those used in wings. But as new higher speed aircraft were developed these airfoils proved to be inefficient. This is because the local velocity acting on specific propeller section is higher than the speed of the aircraft. This can cause flow separation or the formation of shock waves in the propeller airstream. This phenomenon known as a compressibility burble causes thrust losses and additional drag.

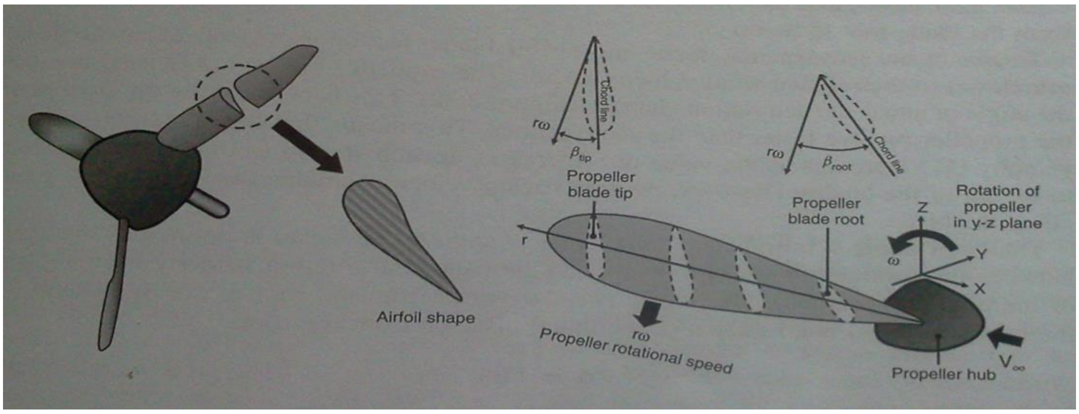

Figure 2.4: Cross-Section of a propeller

Source: Ward, (1966)

It is defined as the ratio of the power transmitted to the flight vehicle and the rate of kinetic energy generation. In this study, that relates the fraction of shaft brake power delivered to the propeller and converted into propeller thrust power (available power) as shown in Eq. (2.5).

$$\eta_{prop} = \frac{F_{N,\,prop}\, V_o}{\dot{W}_B} = \frac{\dot{W}_A}{\dot{W}_B} \qquad (2.5)$$

Where,

$\dot{W}_A$ is the available power (W)

$\dot{W}_B$ is the shaft brake power (W)

η_{prop} is the propulsive efficiency (rps).

The available and shaft brake power can be calculated as describe in previous section. Then it means the value of propulsive efficiency also can be calculated because every value needed is available and can be found by solving the mathematical equation. Typical values for propulsive efficiency range from 0.8 to 0.9 although lower and higher efficiencies are possible. How the efficiency of a propeller is determined by its design characteristics (diameter, blade geometry, number of blades, blades angle and r.p.m).

2.4.4 Brake Specific Fuel Consumption

Specific fuel consumption is the ratio that compares the fuel used by the engine to the amount of power the engine produces. Specific fuel consumption allows manufacturers to see which engine use the least fuel while still producing high amount of power. It allows engines of all different sizes to be compared to see which is the most fuel efficient.

If the specific fuel consumption is determined on the basis of indicated power, it is called the indicated specific fuel consumption (ISFC), while of it determined on the basis of brake power, it is called the brake specific consumption (BSFC).It is inversely proportional to the thermal efficiency of the engine. The term "specific fuel consumption" refers to the amount of fuel used normalized to the amount of power generated, which gives you an efficiency at certain operating point of the engine. All glow engines require a special fuel, called glow fuel. It consists of methanol as base, with some amount of nitro methane to increase the energy and pre-mixed oil into the fuel, which lubricates and protects the engine parts. Most glow engines will come with a manufacturer’s recommendation for fuel/oil mix with a type and percentage of oil specified. This is probably applicable to running in the engine and should comply with the manufacturer’s recommendation.

The fuel tank size and location will affects the engine operation. A typical fuel tank placement is shown on the picture below:

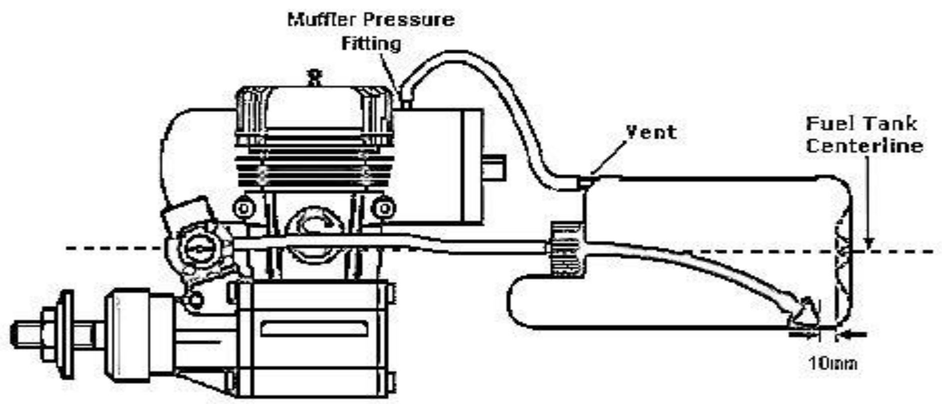

Figure 2.5: Fuel tank placements

Source: Adam, (2003)

As state by (Hobbico, 2000), when the engine is in the upright position, the fuel tank's centerline should be at the same level as the needle valve or no lower than 1cm, (3/8in) to insure proper fuel flow. A too large fuel tank may cause the motor to run "lean" during a steep climb and "rich" during a steep dive.

A lower number equals a higher efficiency because the engine is creating a high level of power while using a low amount of fuel. Diesel engines typically perform better than gasoline engines in term of BSFC.

The type of specific fuel consumption that is commonly used as a figure of merit in piston aero engines is called the brake specific fuel consumption (BSFC). It is defined as the rate of fuel consumption divided by the rate of shaft brake power production (Ward, 1966). The equation for brake specific fuel consumption can be state as shown in Eq. (2.6).

$$BSFC = \frac{\dot{m}_{fuel}}{\dot{W}_B} = \eta_p \frac{\dot{m}_{fuel}}{\dot{m}_A} \quad (2.6)$$

Where,

$\dot{m}_{fuel}$ is the mass flow rate of fuel.

The unknown that needed to get the value of BSFC is the mass flow rate of fuel. The mass flow rate of fuel can be measure by the mass of fuel divided to the time taken while run the nitro engine. Then the mass flow rate of fuel that just calculated is used again to calculate the value of BSFC. From the definition of BSFC it is clear that lower values represent more fuel efficient engines.

2.4.5 Thrust Coefficient

By consider two additional performance parameters, in addition to propeller propulsive efficiency, that are often charted with respect to advance ratio for a propeller with a given number of blades. Given that force in the propeller context is the product of dynamic pressure and area, one can produce the following correlation for thrust coefficient, C_f:

$$C_f = \frac{F_N}{\rho \eta_{prop}^2 d^4} \quad (2.7)$$

Where,

C_f is thrust coefficient.

ρ is the density of air (kg/m^3)

d is the diameter of a circular disk formed by rotating propellers (m).

The unknown that needed to get the value of thrust coefficient are density of air and diameter of a circular disk. The density can be measure by reading the anemometer. The measuring tape is used for determine the diameter of a circular disk.

2.4.6 Performance Parameters Identification

Table 2.1 shows the summarized of the equations that are used in this study and the unknown parameters to be finding from the test bed.

Table 2.1: Summary of the performance parameters

No.	Performance Parameters	Equation	Parameter to be measured
1	Thrust	$F = kX$	X
2	Available Power	$\dot{W}_A = F_N V_o = \dot{m} V_o (V_e - V_o)$	V_e , V_o
	Shaft Brake Power	$\dot{W}_B = \dot{m} \frac{V_e^2}{2} - \frac{V_o^2}{2}$	V_e , V_o
3	Propulsive Efficiency	$\eta_{prop} = \frac{F_{N,prop} V_o}{\dot{W}_B} = \frac{\dot{W}_A}{\dot{W}_B}$	V_o
4	Brake Specific Fuel Consumption	$BSFC = \frac{\dot{m}_{fuel}}{\dot{W}_B} = \eta_p \frac{\dot{m}_{fuel}}{\dot{m}_A}$	$\dot{m}_{fuel}$
5	Thrust Coefficient	$C_f = \frac{F_N}{\rho \eta_{prop}^2 d^4}$	n_{prop}, d

2.5 SUMMARY

In this chapter, the discussion is more on the others model of test bed have done. The detail on requirement parameters for the test bed will be used. The engine performance parameters such as thrust, available power, shaft brake power, propulsive efficiency, brake specific fuel consumption and thrust coefficient can determined from mathematical equations. The unknown can be obtained by data given by the apparatus used such as spring, linear variable differential transformer (LVDT), anemometer, and tachometer that are installing within the test bed design.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This section will show the design for the test bed that is made by using design software such as Solidwork and AutoCAD software. This section also will briefly describe the ways to make the test bed. This includes the selection and preparation of materials, equipment setting such as sensor and measuring device. This is very important to determine the best and accurate result for this study. Other than that, in this section also briefly explain the way how the study is being conduct, which is by doing experiment to obtain data from test bed.

This research study was conducted based on the methodology. This methodology plays an important role in implementing this research study accordingly. The details of the methodology are explained in detail in this chapter. Finally, the data obtained will be able to determine the suitable power plant.

3.2 METHODOLOGY PROCESS FLOW CHART.

First of all, the problem is being identified and the objective and scope were set up. The Research will then be conducted regarding the title of the project. This is where literature review started by reviewing the literature studies of the past papers. .

Then, the lists of the materials are being listed. Then, drawing phase was started. The design drawn into a three dimensional drawing by using the design software.

After that, the lists of the materials are being listed. The materials available in store are prepared through while the rest was searched and bought in the market. Once the materials are available, the fabrication is started. .

Once the fabrication is done, the product is tested. If the result is not satisfied, the design and fabrication is redone until satisfactory result is achieved. .

Finally, the final report writing and presentation slides were prepared. Presentation slides are then reviewed by the supervisor so that errors can be corrected. Everything regarding the project is then presented to the panels and draft report is submitted to the supervisor. Mistakes are corrected and the final product is then submitted to complete the final year project.

The Figure 3.1 shows the flow chart of the whole Final Year Project.

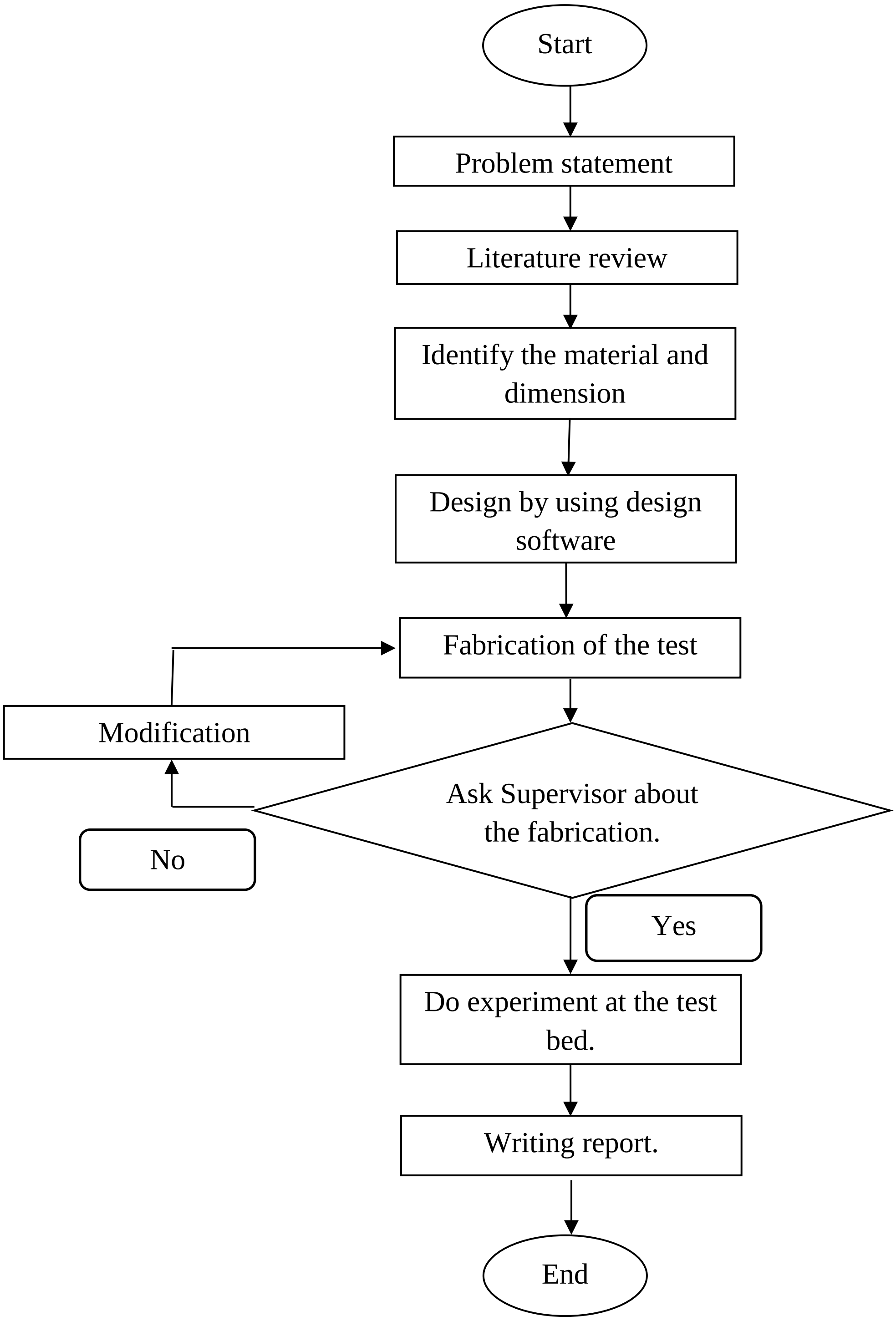

Figure 3.1: The methodology process flow chart

3.3 MATERIAL SELECTION FOR TEST BED

Material selection is a process which is performed to select the best materials which may have the potential to perform well both in industrially and commercially. It is important to choose the suitable materials to build the test bed because it will affected the result of the project either the measurement become inaccurate or not applicable.

3.3.1 Base of The Test Bed

When the test is running, the problem of engine vibration can affect the data. Therefore, the materials selected should have good ability to absorb the vibration .The wood plate is used as base of the test bed because it has the ability to absorb the vibration of the running engine. Vibration is the oscillating, reciprocating, or other periodic motion of a rigid or elastic body or medium forced from a position or state of equilibrium. The oscillations may be periodic such as the motion of a pendulum or random such as the movement of a tire on a gravel road. The lower rate of vibration will protect the oil in the oil tank from being unstable and may affect the running engine. Moreover, the wood blocks used are heavy and can avoid the test bed move from the original place.

i. Dimension : 500mm × 350mm × 100mm
ii. Weight : 20 kg

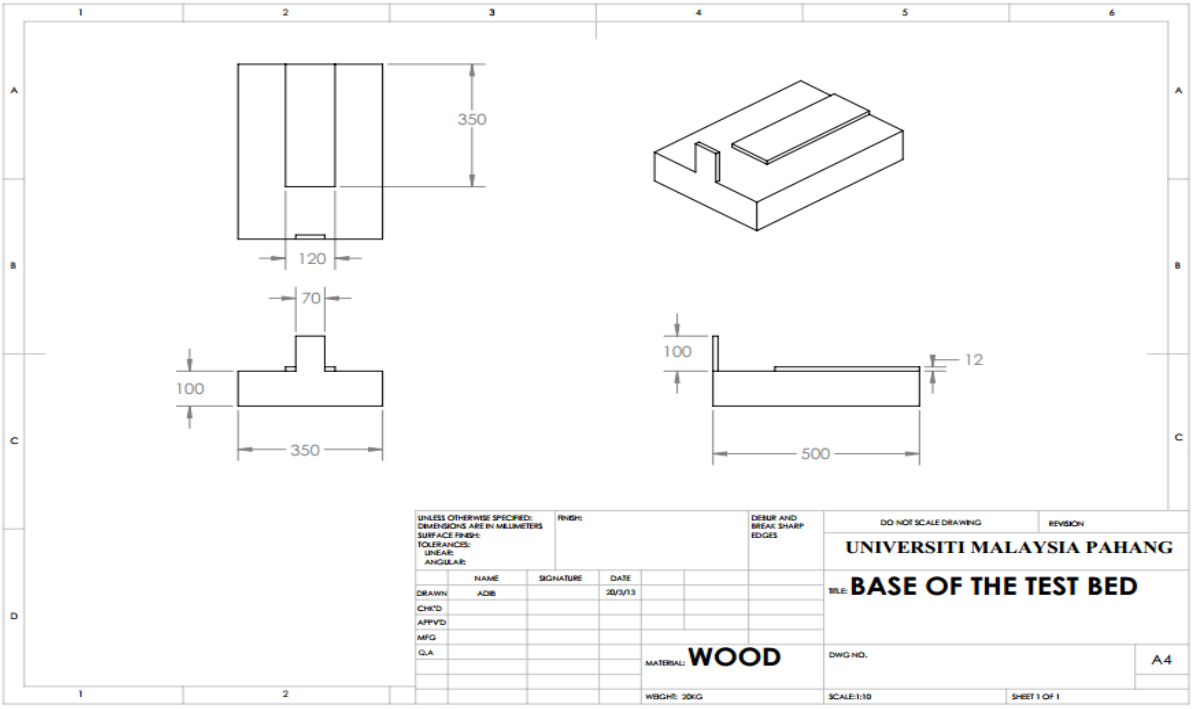

Figure 3.2: Base of the test bed

3.3.2 Engine Mounting

The engine mount will be made of steel. It is because steel have more durability compared to wood. The engine mounting is designed in order to fit with various type of engines.

i. Dimension : 100mm × 35mm × 73mm

ii. Weight : 0.3 kg

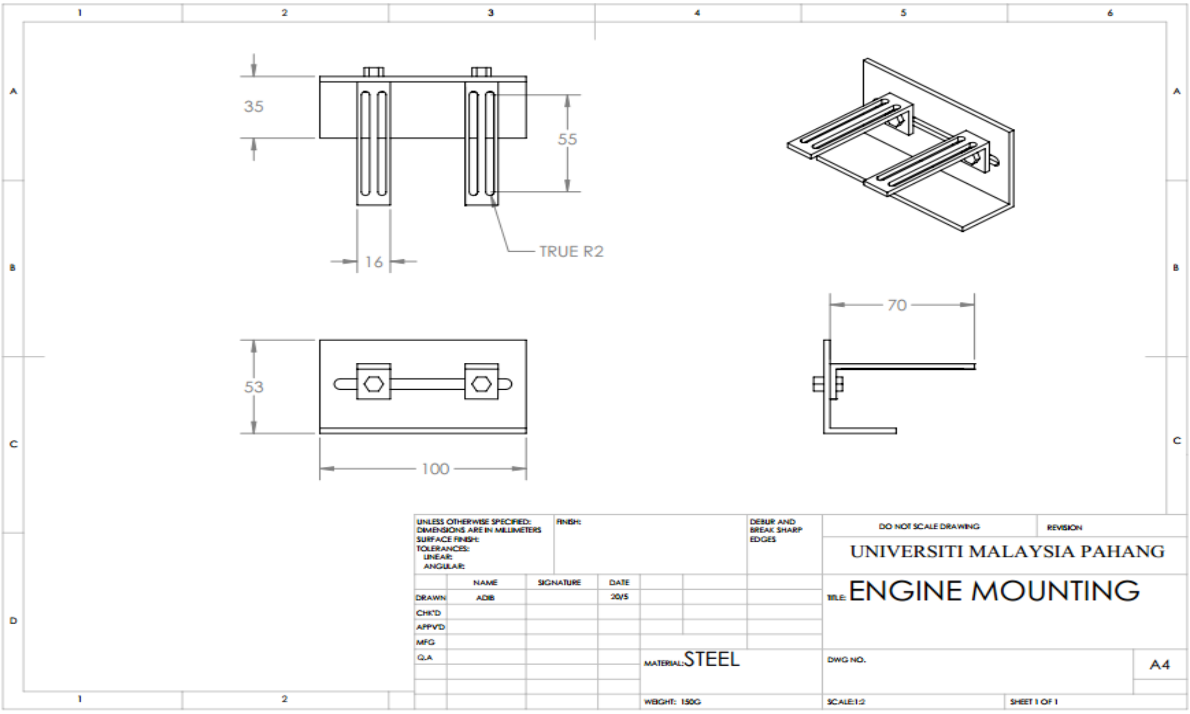

Figure 3.3: The engines mounting

3.3.3 Slider Part

For a slider part, the drawer slider from a desktop table is used. It is chosen because it has suitable size and shape to combine another two chipboard plates that act as slider. In addition, it is also able to reduce the friction forces that exist from between two wood slides.

i. Dimension : 350mm × 120mm × 90mm

ii. Weight : 0.5 kg

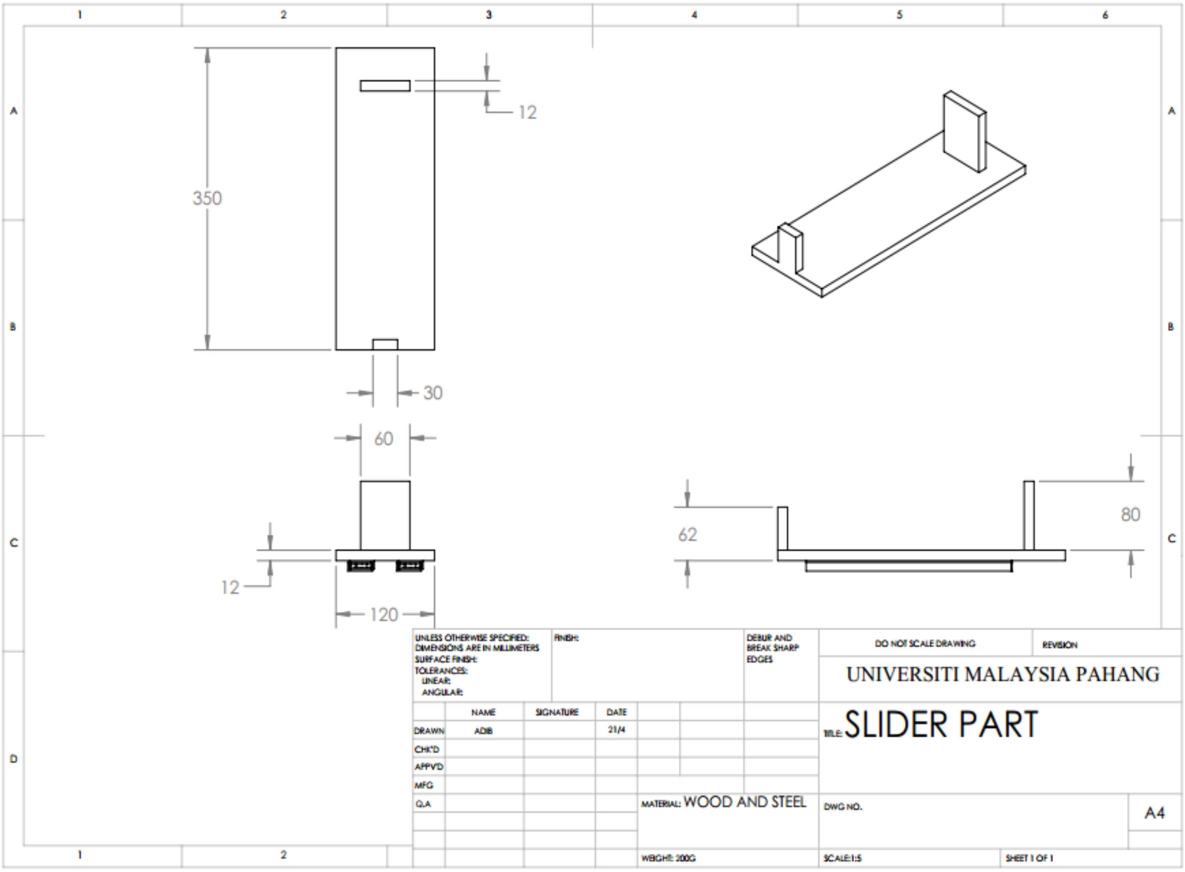

Figure 3.4: The slider part

3.3.4 Oil Tank Holder

The oil tank which contains nitro engine is used to power the nitro engine. The tank holder is made from chipboard because it is light and easily to cut.

i. Dimension : 140mm × 84mm × 140mm
ii. Weight : 0.3 kg

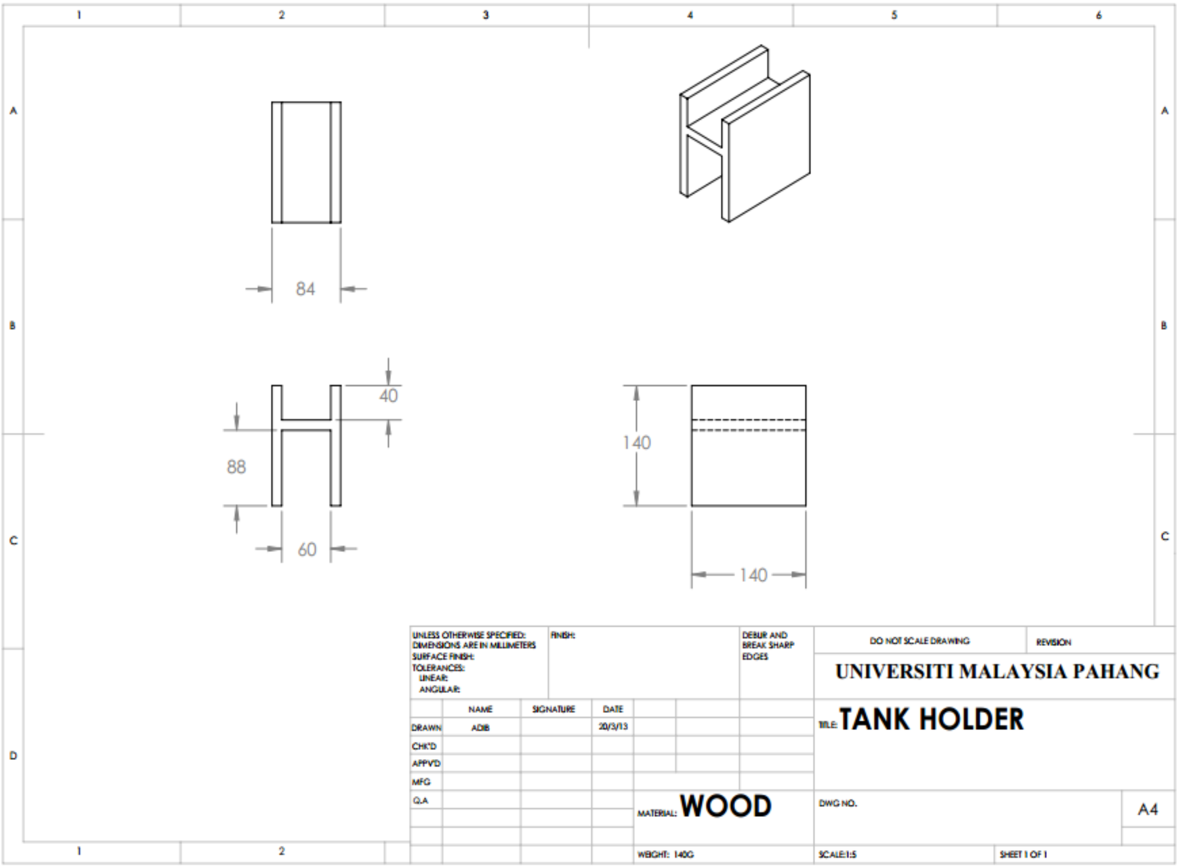

Figure 3.5: The oil tank holder

3.3.5 Spring Holder

The spring is used to calculate the force that produced from the engine. The spring holders made from steel so look that it more mechanical and attractive.

i. Dimension : 65mm × 15mm × 2mm
ii. Weight : 0.1 kg per each

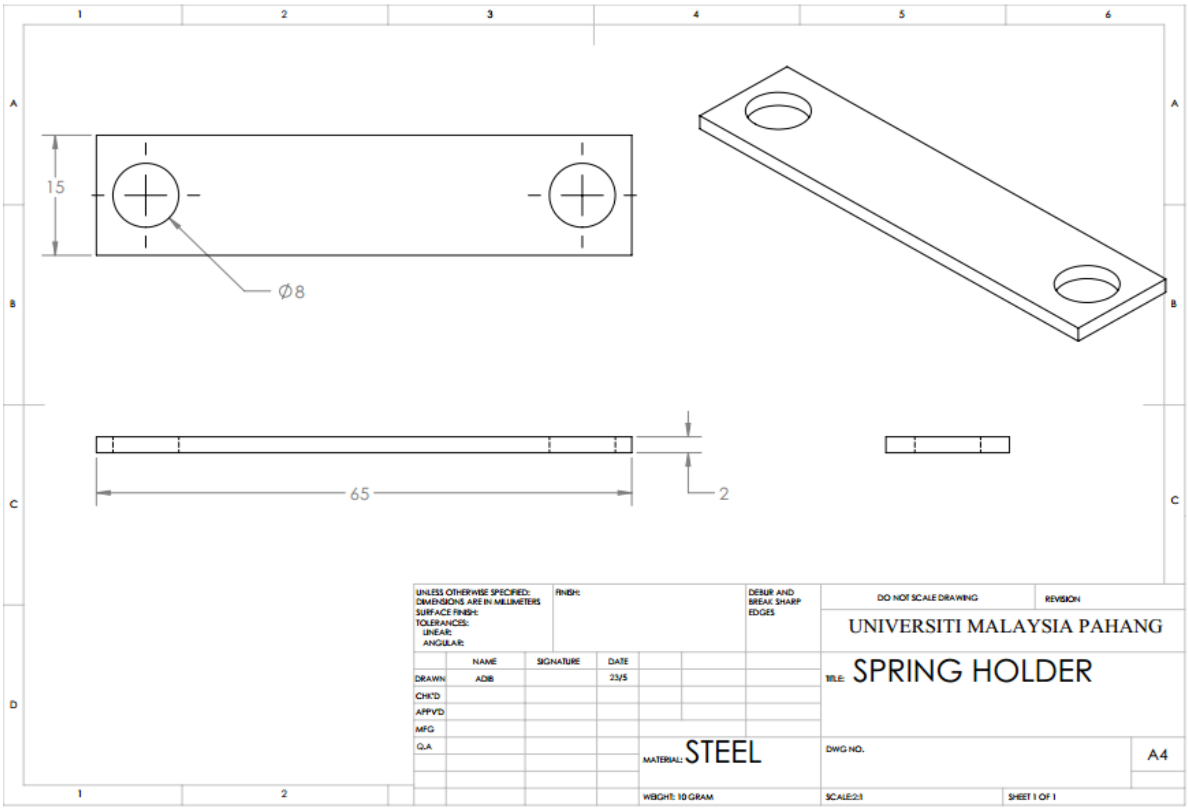

Figure 3.6: The spring holder

3.3.4 Servo Holder

The servo is used to control the speed of the nitro engine. The servo holder is made from chipboard.

i. Dimension : 60mm × 46mm × 52mm
ii. Weight : 0.2 kg

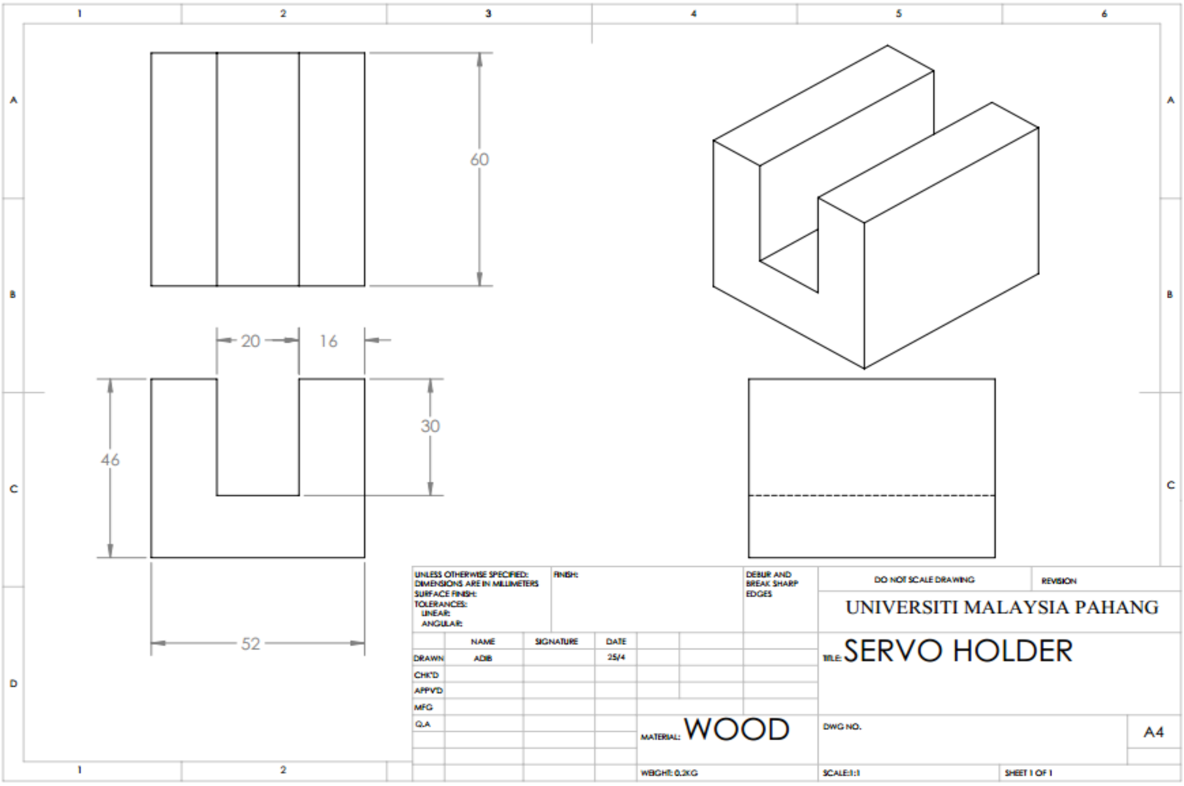

Figure 3.7 : Servo holder

3.4 TEST BED MODELING USING SOLIDWORKS

This section will explain more detail about the design of the test bed. This design is made by using Solidwork. Solidworks is a 3D mechanical CAD (computer-aided design) program. SolidWorks helps mechanical engineers to design products. SolidWorks does this by making it easy for the designer to visualize and communicate a 3D concept. The designer can make changes to the design, validate the design against requirements, and prepare the design for production in manufacturing. It uses a mouse-driven graphical user interface to enable engineers and designers to visualize and communicate 3D models of manufactured objects. SolidWorks works extremely well for mechanical design and similar industries requiring precise definition of 3D shapes and their design intent. It is very popular because of its unprecedented balance of power and ease-of-use.

Figure 3.8 show the orthographic view for the final design.

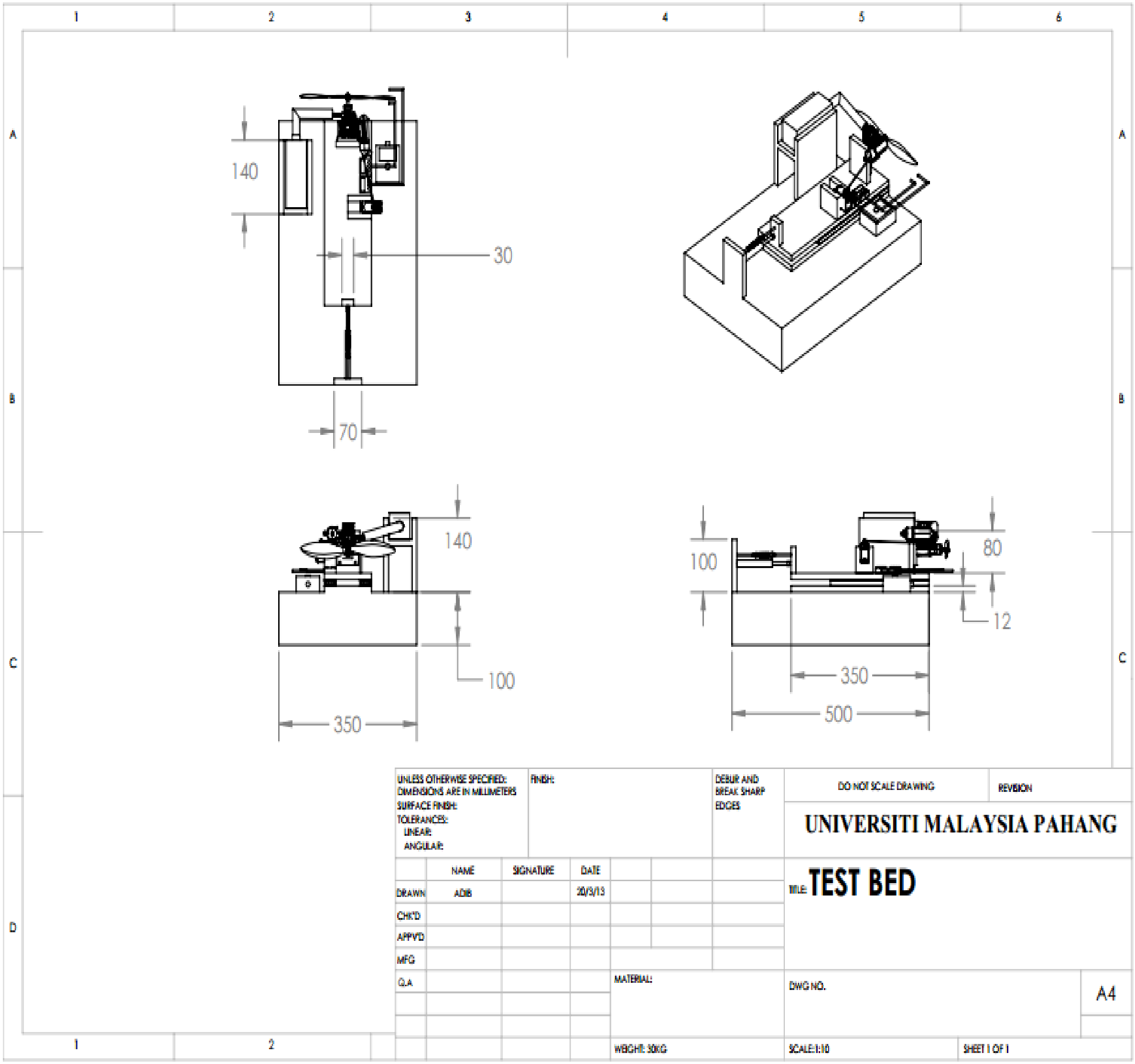

Figure 3.8 : The orthographic view for final design of test bed.

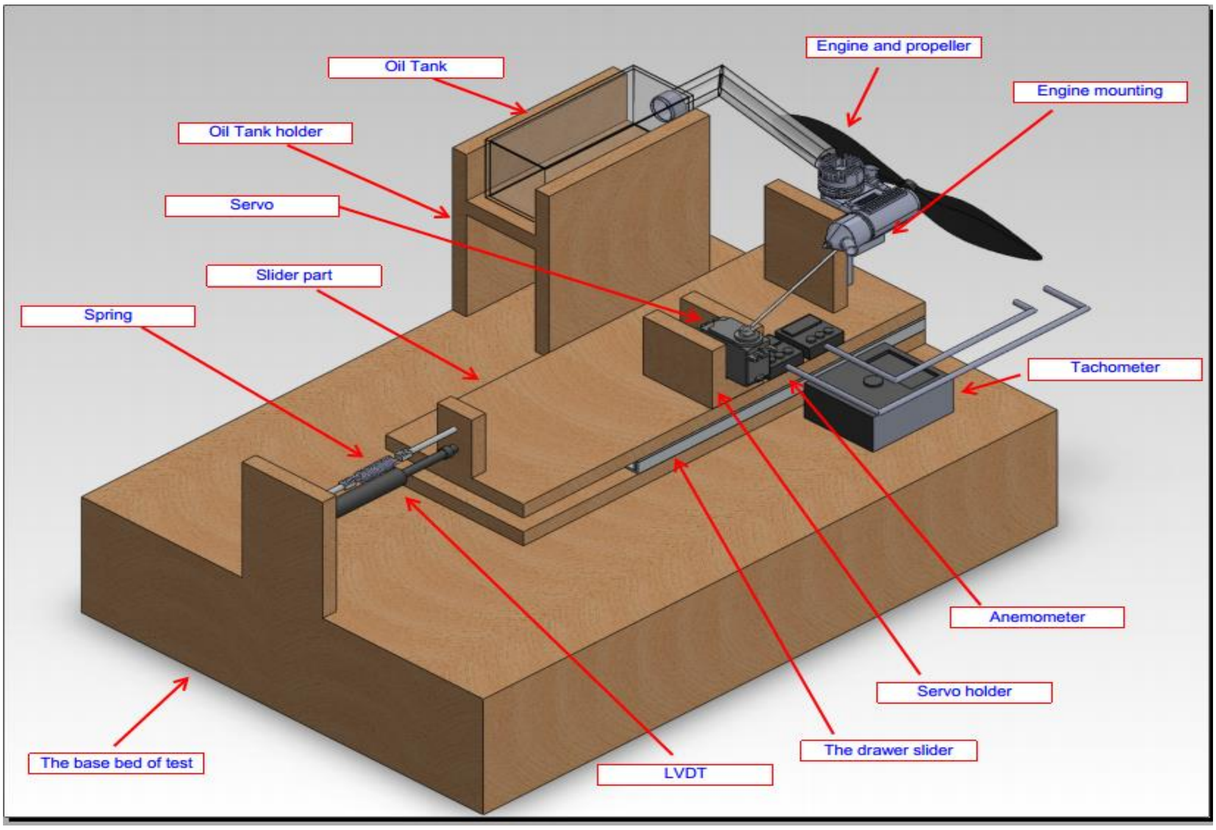

Figure 3.9: The final test bed design by using Solidworks

Figure 3.9 above is the final design of test bed by using Solidworks software. It shows the arrangement of the apparatus such as spring, engine, tachometer, anemometer, slider and linear variable differential transformer (LVDT).

3.5 Fabrication Process

After the designing phase, comes the fabrication process. These processes are about material selection for the product base on the design and resemble the design dimension. Many methods can be used to fabricate a product such as fastening, cutting, drilling and many more. Fabrication process is difference from manufacturing process in term of production quantity. Fabrication process is a process to make only one product compared to manufacturing process that focus to large scale of production. In this project fabrication process, the base, mount engine and slider part are needed to be fabricate. Fabrication process is used in the whole system production. This was include part by part fabrication until assembly to others component.

3.5.1 Process Involve

In order to make the design come to reality, fabrication process needs to be done first. The fabrication process starts from dimensioning the raw material until it is finish as a desired product. The processes that involved are:

i. Measuring: Materials are measured according to desired dimensions or location.
ii. Marking: All measured materials need to be marked to give precise dimension.
iii. Cutting: Marked materials are then cut into pieces.
iv. Joining: Materials joined by the method of screw and bolt.
v. Drilling: Marked holes are then drilled to make holes for mount engine slot.
vi. Finishing: Any uneven and rough surface was flattened by using steel files to give smooth and safe surface.

3.5.2 List of Material of The Test Bed

The table below shows the materials the test bed.

Table 3.1: List of Material of The Test Ted

BIL	TYPE	THICKNESS	SIZE	QUANTITY
1	Chipboard	16mm	2000mm×2000mm	1
2	Wooden block	150mm	560mm×300mm	1
3	Holder	-	130mm×30mm	1
4	Hook screw	-	10mm×10mm	3
5	Drawer slides	-	270mm×5mm	1
6	Screw	15mm, 25mm	- -	60 50
7	Steel plate	3mm	150mm×150mm	1

3.6 STEPS TO FABRICATE THE TEST BED

After identifying items needed to fabricate the test bed then the search process begins. Wooden blocks from previous projects is been reused because it still looks good and therefore reducing the cost of fabricating. However, the wooden block has been improved by placing a wooden box of using chipboard to cover its surface. Combining the upper slider with the base slider by using drawer slider from waste table drawer and now the upper part of the slider can be slide on that slider track. Basically, handsaws were used to cut the chipboard. The rubber mount is placed under the wood base to absorb the vibration from the nitro engine. The holder also is placed beside the wood base so that it is more portable and easy to carry out the test bed.

Secondly, assembling a board on the side of the base with screws drilled from the bottom. The board mounted with a screw hook to hold the springs that are connected with the upper sliders. In addition, the board will be drilled in order to hold the linear variable differential transformer (LVDT).

Thirdly, for the engine mount part, the design is created supposed to be able to mount every sizes and type of nitro engine whether at horizontal or vertical condition. The engine mount is created by using a steel plate, according to exact size and shape in modeling in Solidworks. Drilling machine was used to create the hole at steel plate. Then the engine mount is placed on the end of slider part. After that, tighten the nitro engine with propeller on the engine mount.

Fourthly, make the stand for the oil tank beside the slider. Design of oil tank holder is like the ‘H’ alphabet. There are two barriers placed on the holder so that the tank does not move when the engine is running. Holder is made higher or equal height to the carburetor in order to give more pressure in oil tank that makes fuel movement into the engine fluently. The sponge also placed so that not too much vibration exerted on the oil tank. It is to avoid bubble occur that can ruin the nitro engine performance.

Lastly, servo set which is servo part and electrical circuit is added to control the speed of the nitro engine automatically. Two pieces of chipboard installed on the base of the slider part. Firstly, drilled the surface of the chipboard to avoid crack occur.

3.7 EXPERIMENT SETUP

After the engine test bed had been developed for testing process. The nitro engine which is 2-stroke engine can be tested to analysis the performance of engine. For the engine testing, servo was programmed using the electrical circuit was made. Every 30 seconds the servo will move that was connected to the throttle.

The engine speed will be the controlling parameter and the performance parameters will became the variable parameter. The apparatus to measure the value of unknown will be installed to the test bed such as the anemometer to measure the speed rear and front of the propeller, the tachometer to measure the revolution per minute of the propeller, and the LVDT to measure the distance of the spring elongation to get thrust parameter. Hence, the unknown of each mathematical equation will be known by this apparatus and lastly all of the performance parameters can be obtain by solving the mathematical equations.

3.8 SUMMARY

This chapter present on how the project is being conducted. By developing the test bed, any types of engine could be tested due to the flexibility of the engine mount design. For this project, the case setups are used to experiment the engine by setting up five difference speed of the engine. The value of the performance parameters can be obtained by using the unknown that know by apparatus and calculate it by using the mathematical equations as state in Chapter 2. Hence, the suitable power plant can be suggested according to the types of RC airplanes.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter will discuss the result of the test bed that was fabricated. The purpose of every part of the test bed will be briefly explained. Then the evaluation process upon the every fabricated part had state in this chapter to determine the operation reliability.

There are several parts to be fabricated to produce test bed for performance testing. Among these parts are:

i. Base
ii. Slider part
iii. Mount engine
iv. Tank holder
v. Spring holder

4.2 Fabricated Product.

4.2.1 Base

Figure 4.1 shows the base that was fabricated.

Figure 4.1: Fabricated base.

Base is one of the basic parts of this test bed. The purpose of this part is to be made as the base for all systems including part of a slide, spring, tank and sensors. These bases are made by using solid wood and covered with chipboard that is made according to the size of the solid wood. This is due to the surface condition of the wood is not quite perky and not smooth.

The solid wood and the chipboard were combined by using 25mm screws. To strengthen the combination, small nail were used. Small nail is applied by using air gun. Because of that, small holes can be seen at chipboard surface.

Besides that, a holder was placed at side of the base. This can facilitate the test bed to be carried to anywhere. To ensure the test bed does not move when testing was in running, rubber mount is installed under the fabricated base. If this problem is not overcome, maybe the available data have some mistake.

4.2.2 Slider part

Figure 4.2 and figure 4.3 show the slider part.

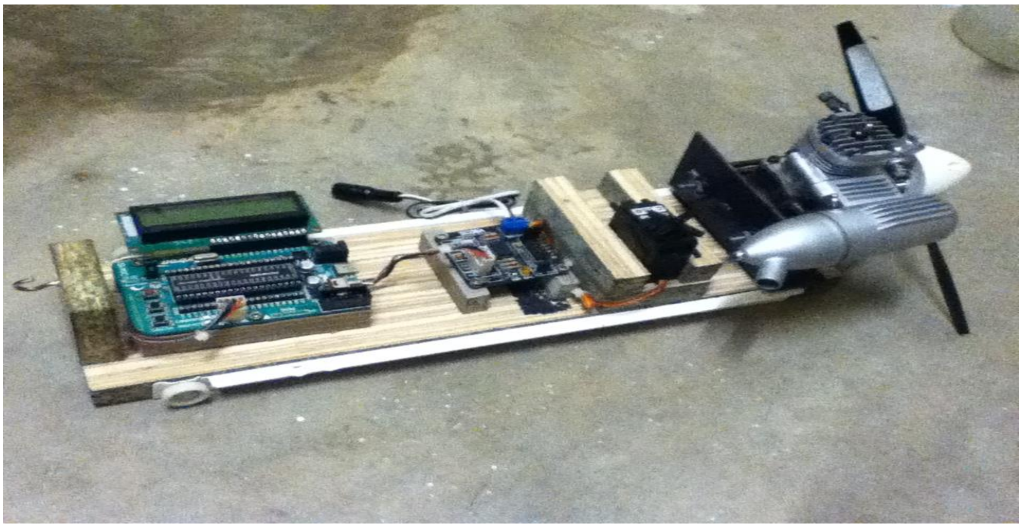

Figure 4.2 : Slider part.

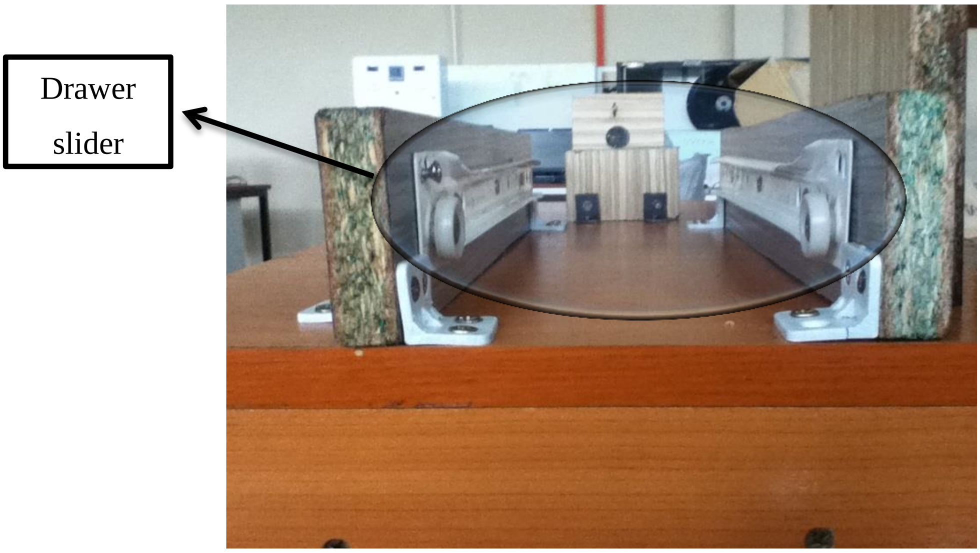

Figure 4.3 : The drawer slider on the base

The slider is the most important part of this test bed. This is because it contains mount engine, electrical circuits and servo. The slider connected using spring to get thrust value. When the engine operates, the slide will move forward and elongation occurs on the spring.

Most parts on the slider are made from chipboard because it is light. It can effect on the friction of the drawer slider. The heavier slider part, the greater the friction of drawer slider.

Consist two pair of chipboard was installed at the slider part. The chipboard is used to place the electrical circuit which is used to control the servo automatically. The servo is connected with throttle arm by using rod to control the engine speed. The electrical circuit is placed far apart from engine mounting as to avoid the oil spill.

Figure 4.4 : The electrical circuit.

The important part in this section is the drawer slider. The drawer slider is placed at side of the slider part. The drawer slider is made vertically to avoid the slider part upraised when testing was in running. It can cause any undesirable accidents. In term to reduce the fraction, some oil was placed at the drawer slider.

The servo holder has the width of 2cm which makes it can be fit with the servo. The servo holder is made from chipboard. The chipboard is chose instead of steel because it has the ability to absorb the vibration of the engine. Besides that, chipboard is easier for the assemble process.

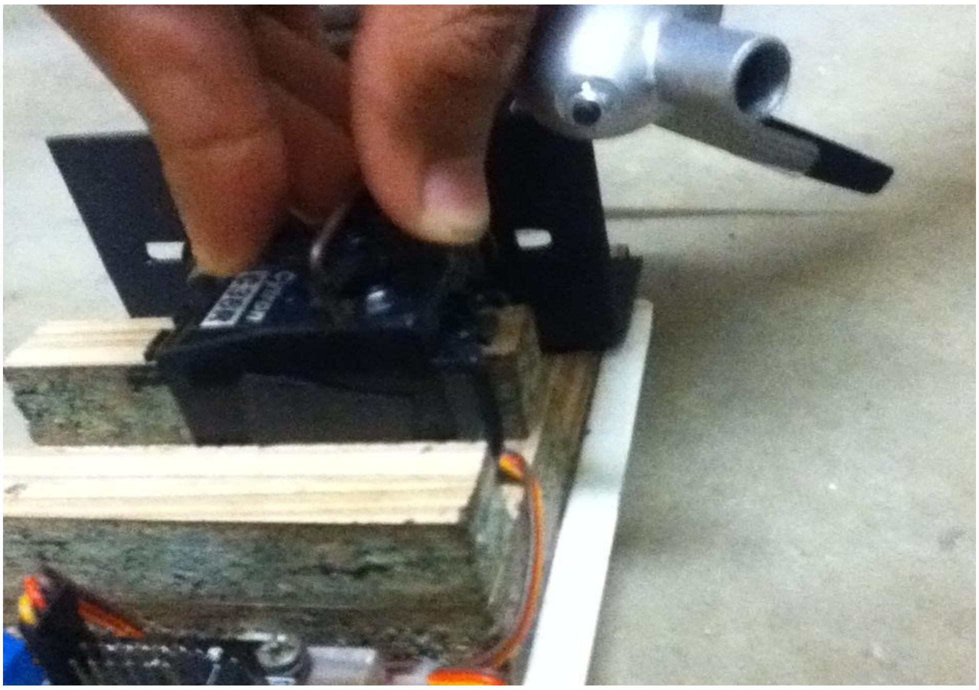

Figure 4.5 : The servo holder.

4.2.3 Engine mounting

Figure 4.5 show how the appearance of the fabricated engine mounting.

Figure 4.6 : Engine mounting.

An engine mounting is a place where engine is being placed. It keeps the engine from moving or shifting out of place while the test bed is operating. The fabricated engine mount is can be adjustable depending on the size of an engine. Not just on the size of engine only, the fabricated mount engine can fit with any type of screw configuration.

To reduce the vibration, the fabricated mount engine is lined with sliced of rubber. The resulting vibration is depends on performance and speed of an engine. If problem is not overcome, when test is running, screw on the engine will get loose and the engine shift out from engine mount.

The engine mount is made from steel because it can resist the force that is produced from an engine. To improve the strength of engine mount, three pieces of screw is installed on the mount engine and plus with slices of rubber to reduce the vibration.

4.2.4 Oil Tank holder.

Figure 4.6 show the oil tank holder.

Figure 4.7 : Oil Tank holder

The tank holder is placed higher than the fuel inlet at engine because to move down the methanol without need more pressure. This condition can be simplified in term the gravitational effect. The different height of the fuel tank from the fuel inlet engine is 4cm.

Some bubbles were produced in the methanol that caused by vibration of the engine. As a result, the flow of methanol into the engine was not very smooth and the engine will not operate very well. To overcome the problem, sponge was placed at the side and below the oil tank to absorb the vibration.

Furthermore, two pieces of chipboard installed at the oil tank holder so that the oil tank cannot move when performing the testing process. A hook screw placed at oil tank holder to keep away the pipe from contact with propeller.

4.2.5 Spring holder.

Figure 4.5 show the spring holders.

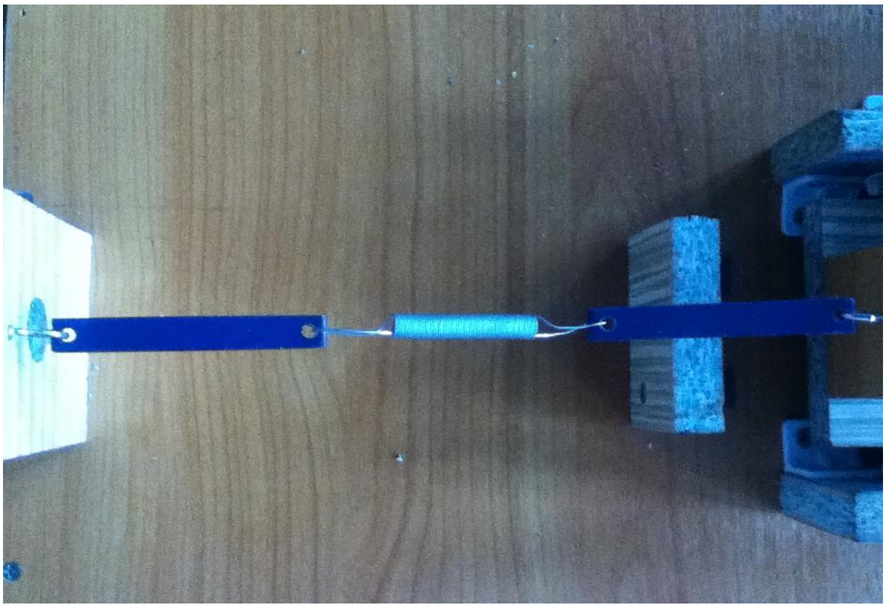

Figure 4.8 : Spring holder.

The spring holder is made from steel plate. It is used to hold the spring that is connected to the hook screw at the slider part and also connected to the base. At the spring holder there are two drill holes, one for spring and another one for hook screw.

The reasons why steel is chosen for the spring holder instead of wood or any other materials are because steel is look more attractive and mechanical. Furthermore, steel can stand high heat. In addition, steel can stand a lot of pressure.

4.2.6 The Test Bed

Figure 4.9 below shows result of the fabrication and improvement that had been proceed in chapter before. The final product was successfully done according to the design and the dimensions.

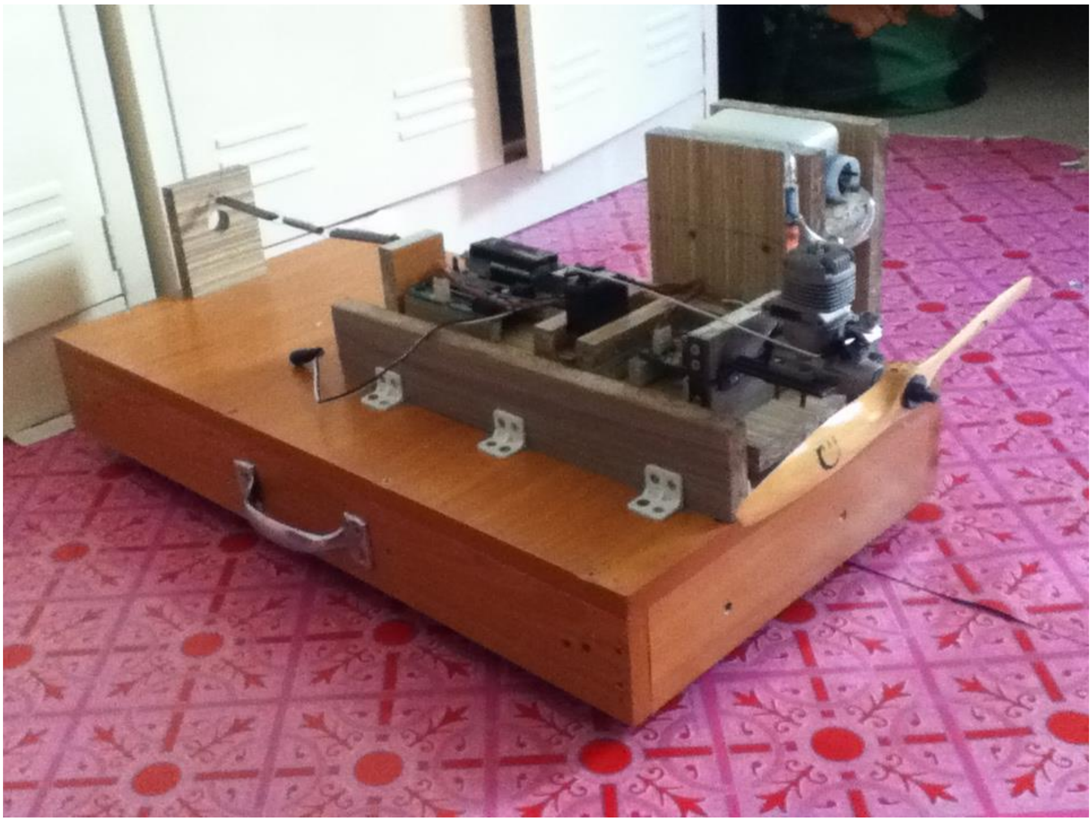

Figure 4.9 : The test bed.

After done with the fabrication process, a test conducted to see if the test bed can achieve the objectives of this project successfully or not. The Thunder Tiger PRO .36 engines is selected for the testing.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

In conclusion, the objective of the final year project was achieved. A test bed model had been produced base on the project title which is to fabricate of a test bed for performance testing of UAV propulsion system. This project also helps student gains communication skill due to presentations and meeting with supervisor.

From this project, the detail design of test bed model had been modeled by using the design software to produce the actual body of test bed model. Fabrication of the product by using any kinds of facility were exists in laboratory such as cutting the material using grinder and hand saw, join all parts with set of screw, bending the sheet metal by using bending machine.

With the fabricated test bed, at least, it will help the selection of power plant for RC airplane hobbyists. Next, the test bed is user friendly because it is easy to make the experiment and no need the high skills to carry out the experiment.

Besides that, the project will helps the student in making a good knowledge before develop one a new ideas. It also helps student learned steps how to complete the project by following a guidance.

5.2 RECOMMENDATIONS

There are some recommendations are come out from problems encounter during this project.

1. Weight of the test bed is too heavy and difficult to carry to anyway. Even the holder is provide, this method cannot reduce the problem. However, this problem can be overcome by changing the material for base of the test bed with a box of chipboard.

2. The further study can of finding more parameters on the test bed. Parameters that can recommend are air ratio, induced power, induced efficiency and power coefficient.

3. The further study can be made by using various type of engine such as make a test bed that also appropriate with electrical motors. The data that will obtain also can be compared to this data on this study.

4. When the engine is at full throttle, vibration of the engines is so severe. Due to this problem, the bolts and nuts will baggy. For the recommendation, the further test bed must reduce the vibration of engine to avoid undesirable incidents.

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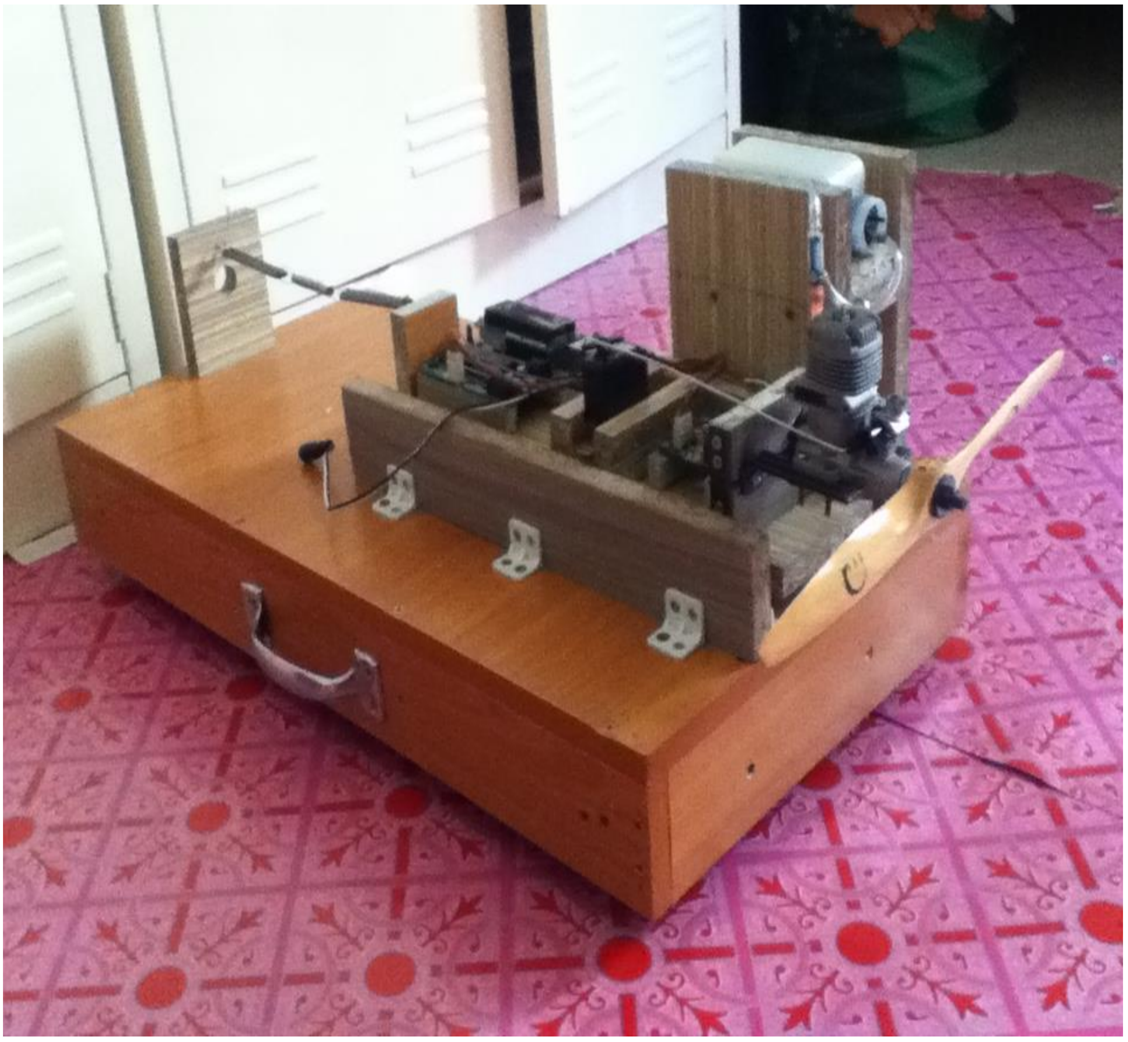
APPENDIX A1

Gantt Chart

PROJECT ACTIVITIES		WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK 12	WEEK 13	WEEK 14
Discussion Regarding Project	PLANNING	■	■												
	ACTUAL	■	■												
Literature Review	PLANNING	■	■	■	■	■	■	■	■	■	■	■	■		
	ACTUAL	■	■	■	■	■	■	■	■	■	■	■	■		
Finalize Design	PLANNING			■	■										
	ACTUAL			■	■										
Fabrication	PLANNING					■	■	■	■	■	■				
	ACTUAL					■	■	■	■	■	■	■	■	■	■
First Presentation	PLANNING								■						
	ACTUAL								■						
Test and Discussion	PLANNING											■	■	■	■
	ACTUAL												■	■	■
Modification	PLANNING													■	■
	ACTUAL													■	■
Report Writing	PLANNING										■	■	■	■	■
	ACTUAL											■	■	■	■
Final Presentation	PLANNING														■
	ACTUAL														■

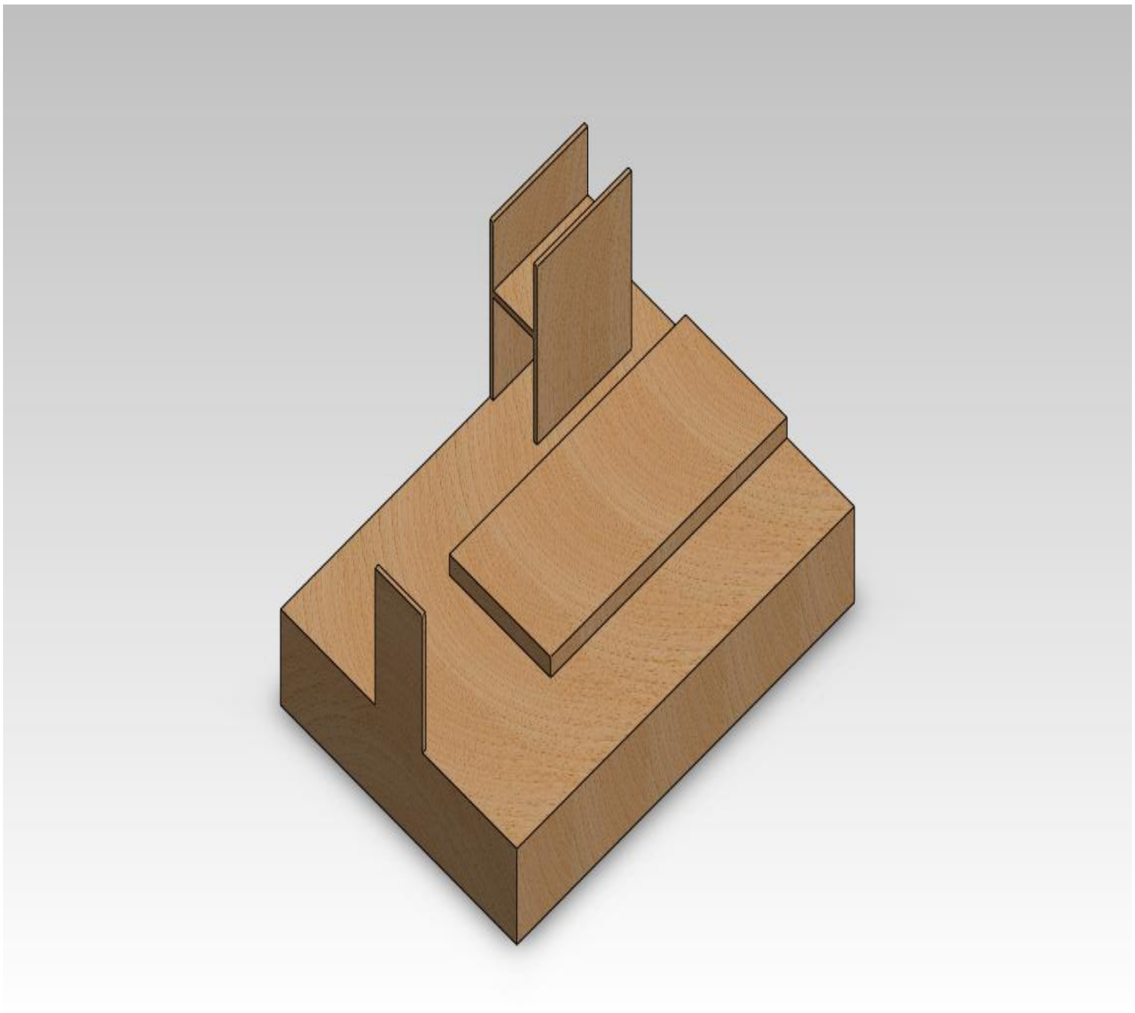
APPENDIX B1

Actual test bed was produced.



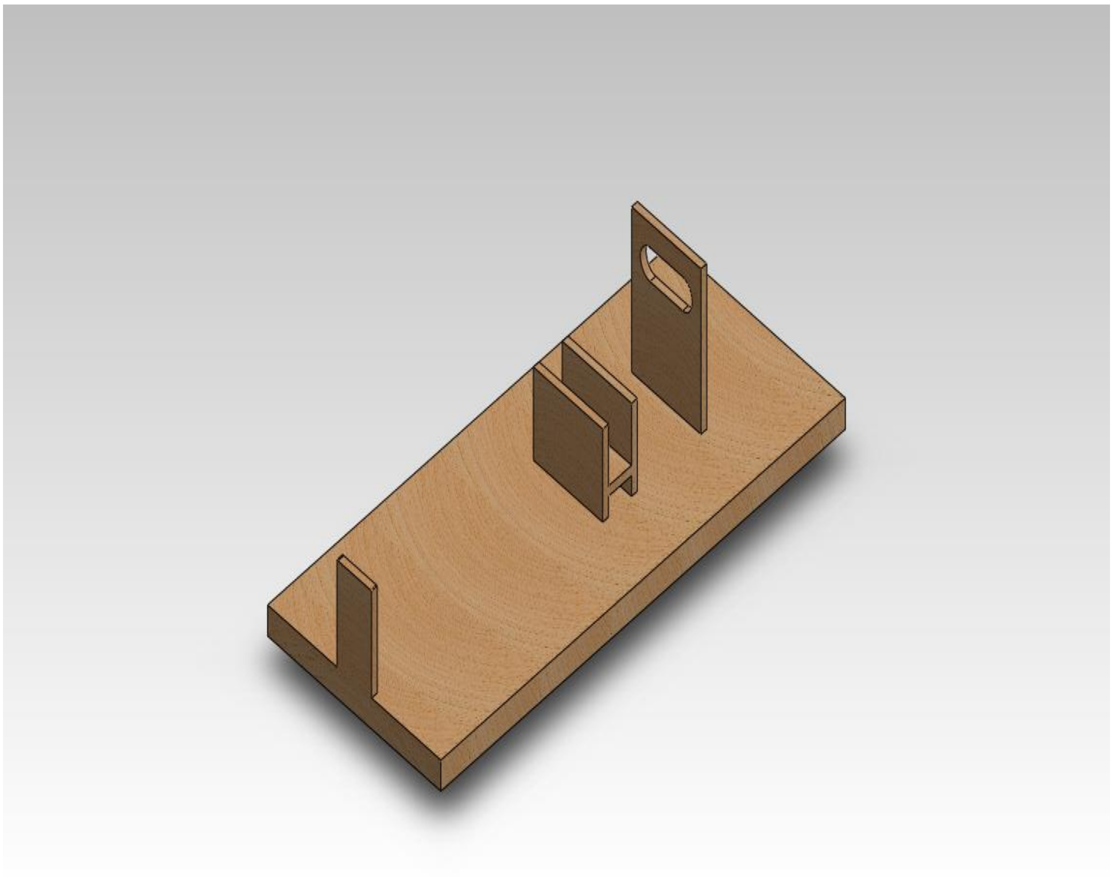
APPENDIX C1

Base of test bed.



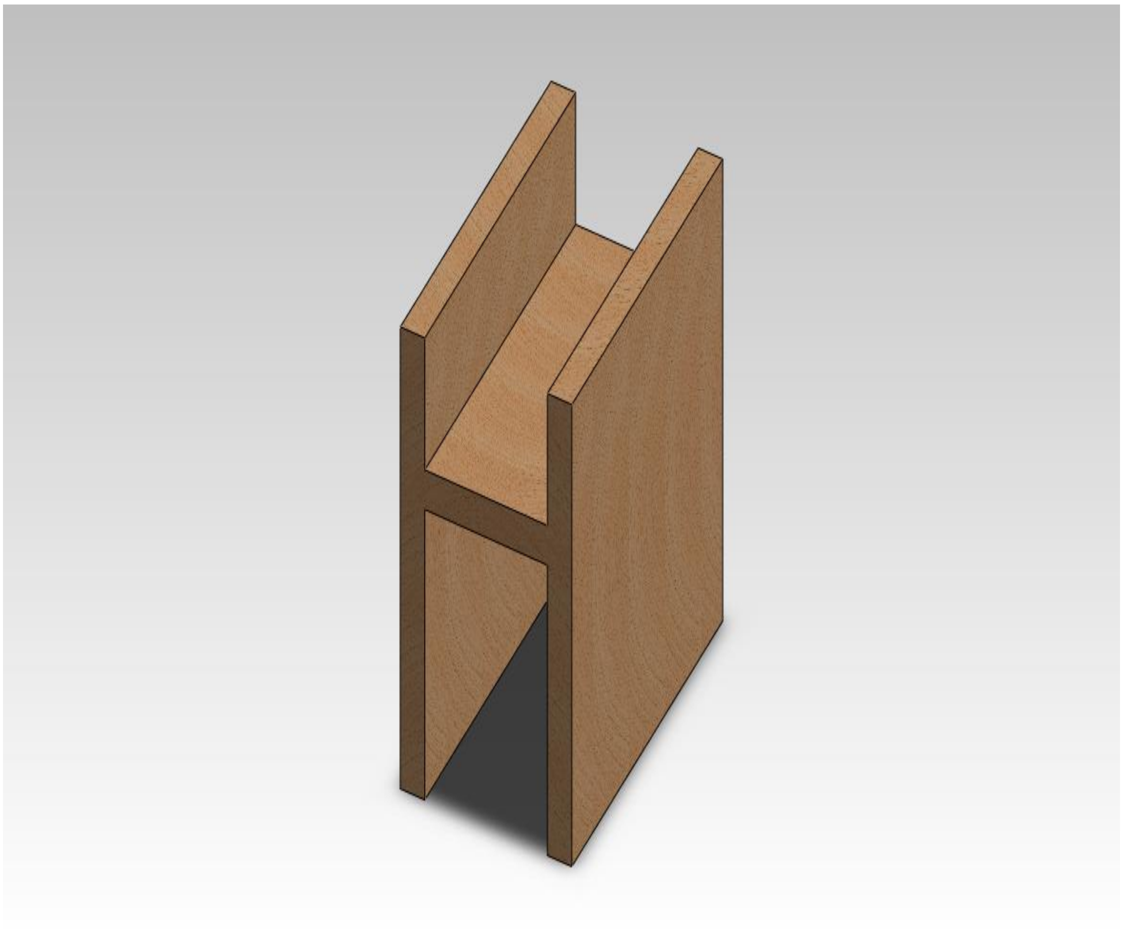
APPENDIX C2

Slider part.



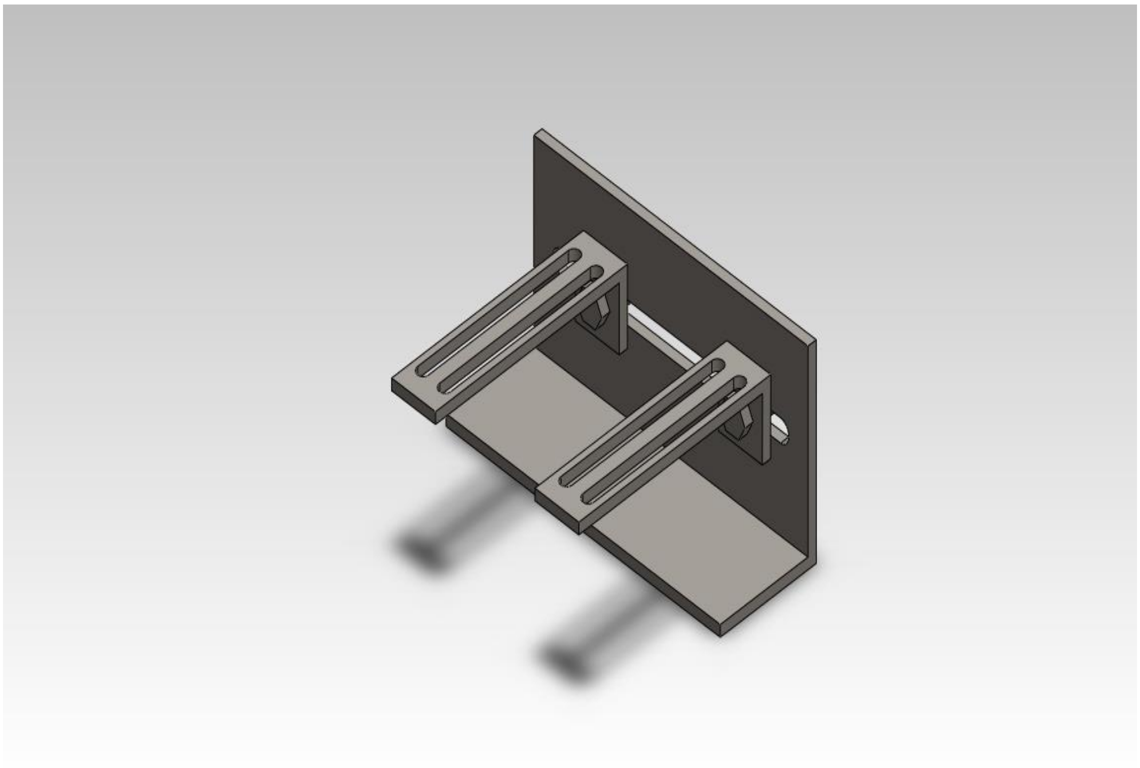
APPENDIX C3

Oil Tank holder.



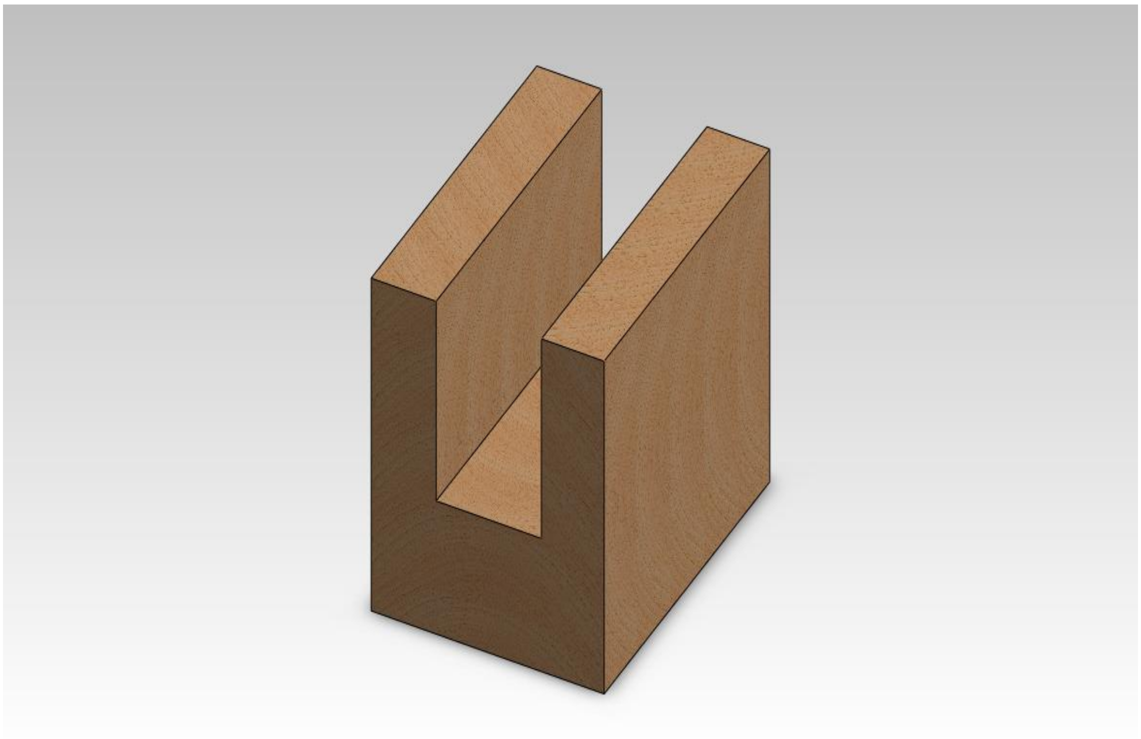
APPENDIX C4

Engine Mount.



APPENDIX C5

Servo holder.



APPENDIX C6

Exploded view.