DESIGN AND FABRICATION TWO DEGREE OF FREEDOM FREE VIBRATION TRANLATION MOTION TEST RIG

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BORANG PENGESAHAN STATUS TESIS

JUDUL: DESIGN AND FABRICATION TWO DEGREE OF FREEDOM FREE VIBRATION TRANSLATION MOTION TEST RIG

SESI PENGAJIAN: 2012/2013

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MUHAMMAD MAGHRIBI BIN SELAMAT

Report submitted in partial fulfillment of the requirements
For the award of Diploma in Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2013

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this report and in my opinion, this report is adequate in terms of scope and quality for the award of the Diploma of Mechanical Engineering.

Signature : _____

Name : MUHAMMAD HATIFI BIN MANSOR

Position : LECTURER

Date :

STUDENT'S DECLARATION

I hereby declare that the work in this report is my own except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any degree and is not concurrently submitted for award of other degree.

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Date :

ACKNOWLEDGEMENT

I would like to express my highest gratitude to Allah the Almighty for blessing me in finishing this project. Besides, I would like to take this opportunity to express my sincere gratitude and appreciate especially to my supervisor, Mr. Muhammad Hatifi bin Mansor for his constant guidance, consideration and constructive idea in leading me to accomplish this project.

Moreover, I wish to express my sincere appreciation to all staff in Mechanical Engineering Laboratory, whom I owe particular debt of gratitude for their suggestion, endless effort in helping finding solutions and experiences that has supported me and assisted me tremendously in many aspects.

Last but not least, I acknowledge my sincere indebtedness and gratitude to my parents for their help, love and sacrifice throughout my life. These are the appropriate words that could properly describe my appreciation for their devotion, support and faith in my ability to attain my goals. Special thanks also should be given to all my friends whose have helped me in the completion my Final Year project. I sincerely appreciate all of your help.

ABSTRACT

This project is about the designing and fabrication the two degree of freedom free vibration translation motion test rig. The objective of this project is to design and fabricate the two degree of freedom free vibration translation motion test rig. The study on the free vibration system of two degree of freedom is very important. This theory need to be carried out by doing experimental study. This test rig will be developed based on the vibration fundamental knowledge. The fabrication process starts with understanding the fundamental of mechanical vibration. Sketching and design process will be developed in multiple choices in order to select the best design concept of the test rig. Material selection and the factor of the selection also have been listed based on the appropriate criteria predetermined. The selection material will undergo several fabrication process based on the chose design. Finally the test rig will be tested in the vibration laboratory.

ABSTRAK

Projek ini adalah mengenai mereka bentuk dan penghasilan alat uji kaji getaran bebas dua darjah dalam pergerakan yang sehala. Objektif projek ini adalah untuk mereka bentuk dan menghasilkan alat uji kaji getaran bebas dua darjah dalam pergerakan yang sehala. Kajian ke atas getaran bebas dua darjah adalah sangat penting. Teori ini hendaklah dilaksanakan dengan menjalankan kajian uji kaji. Alat uji kaji ini akan dihasilkan dengan berlandaskanckepada pengetahuan asas getaran. Proses penghasilan bermula dengan pemahaman kepada pengetahuan asas getaran mekanikal. Beberapa lakaran dan rekaan bentuk akan dihasilkan supaya satu rekaan bentuk yang terbaik dapat dipilih daripada rekaan bentuk yang lain. Pemilihan bahan dan faktor pemilihan itu juga telah disenaraikan berdasarkan kriteria yang sesuai yang telah ditetapkan. Bahan yang telah dipilih akan menjalani beberapa proses penghasilan berdasarkan kepada rekaan bentuk yang telah dipilih. Akhirnya, alat uji kaji ini akan diuji di dalam makmal getaran.

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x	Displacement of the mass
x_1	Displacement of first mass
x_2	Displacement of second mass
θ_1	First angular displacement
θ_2	Second angular displacement
m	mass
m_1	First mass
m_2	Second mass
k	Spring stiffness
k_1	First spring stiffness
k_2	Second spring stiffness

LIST OF ABBREVATIONS

LVDT	Linear Variable Differential Transformer
RVDT	Rotary Differential Transformer
DOF	Degree of freedom
RPM	Revolution per minute
3D	3-Dimentional

CHAPTER 1

INTRODUCTION

1.1 GENERAL INTRODUCTION

Vibration study is very important and useful in our life. Vibration is not only applied in the mechanical structural system, but it is also exhibited in our respiratory system that generates our heart beat. Moreover, the sound produced in this world is actually created by the vibration. The sound wave that moves in air is invisible, only the effect and energy of the sound wave can be identified by human being. The modern physics also say that even the atoms which consist of the entire universe vibrate incessantly. Thus vibration and its effects are very common in our daily life. However, most vibrations are undesirable in machines and structures because the vibration can cause energy loss, machine damage or break down, induce fatigue and many more. Therefore, the study of mechanical vibration filed is very important to overcome these problems.

This project is about to design and fabricate the two degree of freedom free vibration test rig. Vibration can be identified as a response of a system to an internal or external stimulus that caused it to oscillate and vibrate. In this project, the vibrating systems were fabricated. The test was conducted upon this test rig in order to study the two degree of freedom free vibration. Hence, through this project the further understanding about the vibration will be enhanced.

1.2 PROBLEM STATEMENT

In the UMP vibration laboratory there are only have one degree of freedom vibration test rig, either free or forced vibration. With the significant of vibration knowledge and had been decided to extend the knowledge to the two degree of freedom vibration test rig. This test rig organized free vibration on the translation motion.

1.3 PROJECT OBJECTIVE

The objective of this project is to design and fabricate two degree of freedom free vibration translation motion test rig.

1.4 PROJECT SCOPE

This project focuses on the following matter:

1. Carry out the literature review from previous fellow research and other sources such as journal and text book.
2. Sketch and design the concept of the test rig.
3. Select the material for the chose design.
4. Fabricate the chose design with the fundamental of vibration knowledge.
5. Evaluate and test the test rig.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will be more focused on the two degree of freedom free vibration translation motion. The vibration fundamental study will be briefly explained. In addition, several types of sensor that have been used in the vibration laboratory such as accelerometer, LVDT and tachometer will be briefly explained in term of its function and the way how to use it.

2.2 VIBRATION

Any repeated motion of an object after in a time interval is to be said as a vibration or oscillation. The continuous alternating of energy from potential energy into kinetic energy and from kinetic energy to potential energy is occurred upon an object during the vibration and oscillation process. Basically there are two types of vibrations, which are forced vibration and free vibration. The damped vibration occurred when the vibrating system undergoes damping process. The damped vibration can be categorized into two types which are damped force vibration and damped free vibration. On the other hand, when the damping process is neglected upon the vibrating system, this vibration is called as undamped vibration. The undamped vibration also divided into two categories which are undamped free vibration and undamped force. (Bhave Srikant, 2004)

Vibration is a result of the combination of inertia and elastic forces effects. Inertia of a moving object can be expressed in terms of the mass, moment of inertia and the displacement of the object. And the elastic force can be expressed in terms of the displacement or stiffness of the elastic member like spring. (A.A. Shabana, 1996)

2.2.1 UNDAMPED FREE VIBRATION

A free vibration is a vibration that occurred naturally with no energy or force being added to the vibrating system. An object will undergo free vibration process when it oscillated or vibrated only with an initial disturbance and with no external forces acting on that object after the initial disturbance. In this case, when an object is moved away from it rest position, there is a natural force that will return that object to its rest position. The damped vibration will be occurred when the object energy is dissipated during the motion. While if there is no dissipation of the energy of an object during its motion, so it is called as undamped free vibration. (J.S. Rao and K. Gupta, 1998).

An Undamped free vibration of a system is vibration that occurs in absence of any damping. The total mechanical energy due to initial conditions is conserved and the system can vibrate forever because of the continuous exchange between the kinetic and potential energies. (Rao V. Dukkipati and J. Srinivas, 2004) In many cases, the damping will still occurred during the oscillation, but in this case the amount of the damping is too small so that it can be disregarded for most engineering purpose. (J.S. Rao and K. Gupta, 1998) The figure below shows the amplitude of the undamped free vibration remains constant since there is no dissipation of the energy.

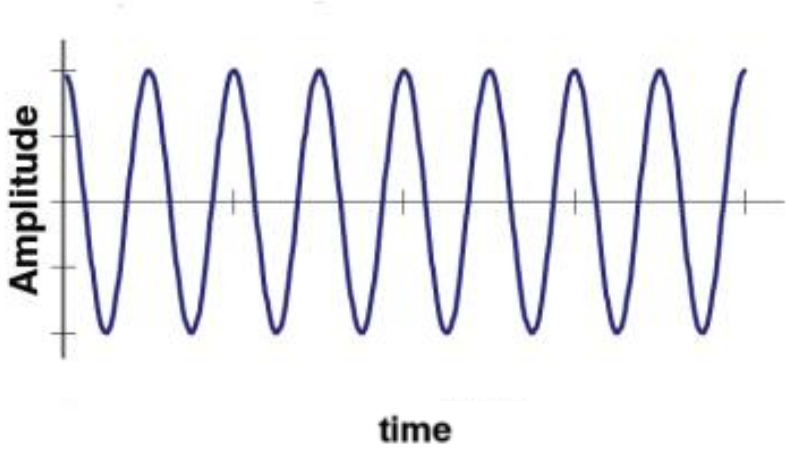


Figure 2.1: The graph of undamped free vibration.

Source: Jay Newman, 2008

2.2.2 DAMPED FREE VIBRATION

Basically the damping will occur in most situations. This is because the resistance and obstruction will happen due to the surrounding factor like friction. Therefore the amplitude of the damped free vibration is gradually becomes smaller and smaller until the oscillation stop as shown in the figure below. (J.S. Rao and K. Gupta, 1998)

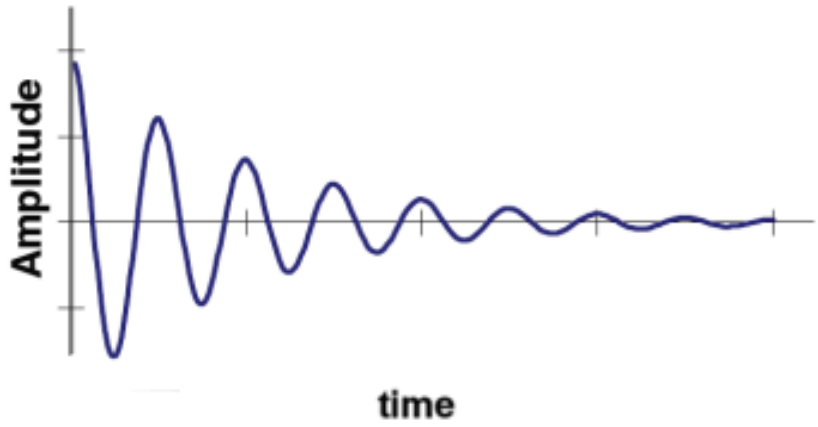


Figure 2.2: The graph of damped free vibration.

Source: Jay Newman, 2008

2.3 DEGREE OF FREEDOM

The position of a system of an object is called its configuration. The configuration is defined as the geometric location of all the masses of a system. The independent coordinates is required to specify the configuration of a dynamic system is called generalized coordinates. The number of generalized coordinates is known as the number of degree of freedom (DOF) of a dynamic system. There are six number degrees of freedom. Three coordinates are to define the translation motions which are moving up and down (heaving), moving left and right (swaying) and moving forward and backward (surging). While others three coordinates to define the rotation motions which are tilts forward and backward (pitching), swivels left and right (yawing), pivots side to side (rolling). (Rao V. Dukkipati and J. Srinivas, 2004)

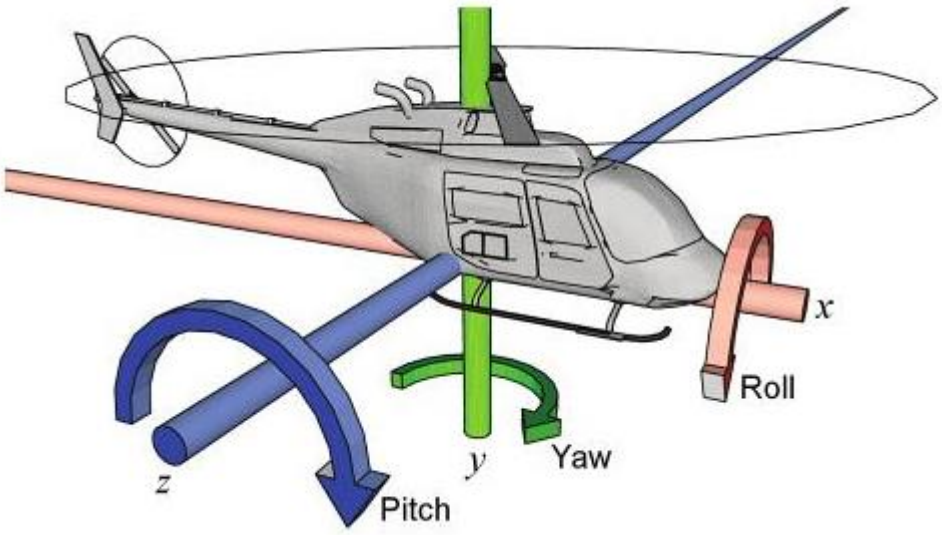
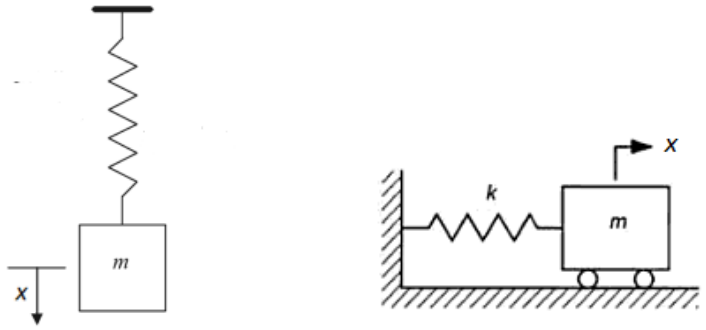


Figure 2.3: Six degrees of freedom of helicopter model.

Source: Edward Ashford Lee and Sanjit Arunkumar Seshia, 2011

2.3.1 ONE DEGREE OF FREEDOM VIBRATION SYSTEM

A vibration system is said to be have one degree of freedom if it geometrical position moves in one direction only. One degree of freedom system is the simplest vibration system system. It moves by translation along one direction or rotate about one axis. The motion of one degree freedom system is a sinusoid which having only a single frequency. This one degree of freedom system has been applied in the mechanical structural system. (J.P. Den Hartog, 1985)



(a) (b)

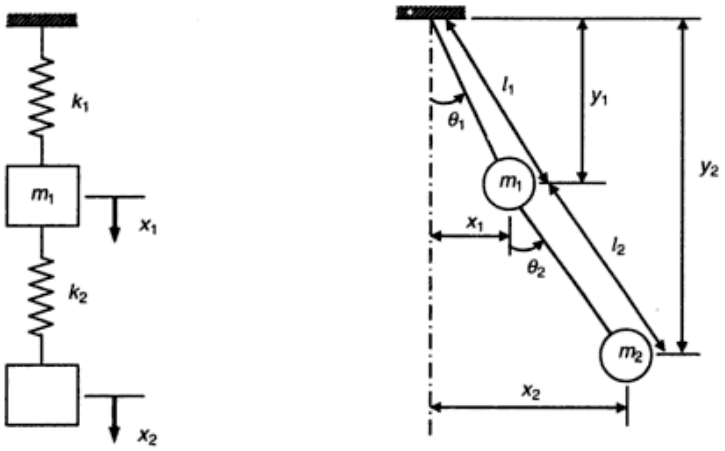
Figure 2.4: One degree of freedom system models (a) Vertically manner, (b) Horizontally manner. *x*

Source: Rao V. Dukkipati and J. Srinivas, 2004

2.3.2 TWO DEGREE OF FREEDOM VIBRATION SYSTEM

Even though single of freedom models can approximate many mechanical or structural systems, most of the system have several restrains and therefore required to be represented by several degrees of freedom. The number of degrees of freedom that a system processes is equal to the number of independent coordinates necessary to describe the motion of the system. A system that moves in two directions is called two degree of freedom vibration systems. (S. Graham Kelly, 2011)

Some example of two degree of freedom models of vibrating systems are shown in figures below. Figure 2.5 (a) Shows a spring mass system where the masses m_1 and m_2 are constrained to move vertically, then the displacement x_1 and x_2 define the location of mass at any time. For the double pendulum shown in Figure (b), one can select θ_1 and θ_2 to be the system's degree of freedom. The angular displacement θ_1 and θ_2 are sufficient to determine the displacement of two masses.



(a) (b)

Figure 2.5: Two degree of freedom system models (a) Undamped spring mass system, (b) Double pendulum.

Source: Rao V. Dukkipati and J. Srinivas, 2004

2.4 MATERIAL AND APPARATUS

2.4.1 ALUMINIUM PROFILE

For the existing test rig, aluminium profile was selected to be the frame of the test rig. The dimension of the test rig frame is 4 cm x 8 cm. Then it length, height and width are 120 cm, 168.5 cm and 50 cm respectively. Bolt and nut were used to combine the frame.

2.4.2 SPRING

Basically only one spring was used for the existing test rig. This is because the single degree of freedom free vibration system was applied by the existing test rig.

Figure 2.6: Spring

2.4.3 MASS

The mass was used to be the weight for vibration test rig. The different weight of the mass will be used in every vibration test rig experiment in order to get the different output results.

Figure 2.7: Masses

2.5 SENSOR

Recently there are various types of the sensors used to measure the vibration shock. In the UMP vibration laboratory, the common three types of sensors were used such as accelerometer sensor, Linear Variable Differential Transformer (LVDT) sensor and tachometer sensor.

2.5.1 ACCELEROMETER SENSOR

Accelerometer is a device that measures proper acceleration, the acceleration experience relative to free fall. Single and multi-models are available to detect magnitude and direction of the acceleration as a vector quantity and can be used to measure acceleration, vibration shock and falling. Accelerometer is quantified in the SI unit meters (m/s^2). (Anthony Lawrence, 2001) Accelerometer sensors measure the difference between any linear acceleration in the acceleration's reference frame and the earth's gravitational field vector. In absence of linear acceleration, the acceleration output is a measurement of the rotated gravitational filed vector and can be used to determine the accelerometer angular orientation. (J. Valldorft and W. Gessner, 2004)

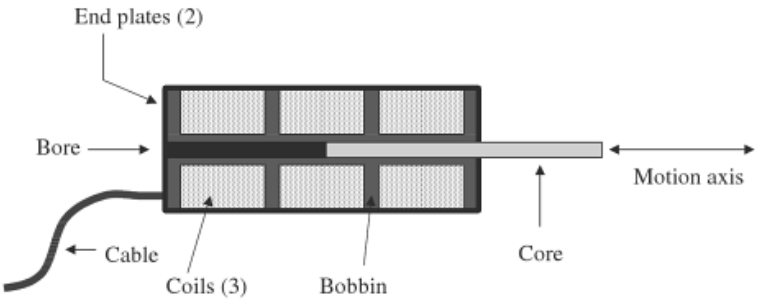
Figure 2.8: Accelerometer sensor

2.5.2 LVDT SENSOR

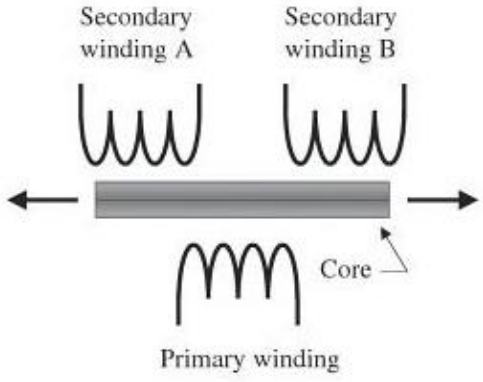
The Linear Variable Differential Transformer (LVDT) is type of electrical transformer used for measuring linear displacement. A counterpart of this device is used to measure rotary displacement is called Rotary Differential Transformer (RVDT). The linear variable differential transformer has three solenoid coils placed end to end around a tube. The center coil is the primary and two outer coils are the secondary. (U.A. Bakshi and A.V. Bakshi, 2008)

A cylindrical ferromagnetic core, slides along the axis of the tube. An alternating current is driven through the primary causing a voltage to be induced in each secondary proportional to its mutual inductance with the primary. The frequency is usually in the range 1 to 10 kHz. As the core moves, these mutual inductance changes causing the voltages induced in the secondary to change. The coils are connected in reverse series so that the output voltage is the difference between the two secondary voltages. When the core in these two coils so the output voltage is theoretically zero. In practice minor variations in the way in which the primary is coupled to each secondary means that a small voltages is output when the core is central. When the core is displaced in one direction, the voltage in a coil increased as the other decreased causing the output voltage to increase from zero to a maximum. This voltage is in phase with the primary voltage. When the core moves in the other direction the output voltage also increase from zero to a maximum but its phase is opposite to that of the primary. The magnitude of the output voltage is proportional to the distance moved by the core which is why the device is described as having a linear response to displacement. The phase of the voltage indicates the direction of the displacement. (David S. Nyce, 2003)

(a)



(b)



(c)

Figure 2.9: (a) LVDT sensor, (b) Cross-sectional view, (c) Part of LVDT sensor

Source: David S. Nyce, 2003

2.5.3 TACHOMETER SENSOR

The tachometer also called revolution counter which is an instrument used to measure the rotation or speed of a shaft and disc. Generally these measurements are rated in round per minute (R.P.M). The traditional tachometer is actually exposed to the high dangerous level and less safety. Recently digital tachometers giving a direct numeric value output that commonly used nowadays. In its many cases, a tachometer is used to measure the speed at which a mechanical device is rotating. Basically the traditional tachometer is required the physical contact between the instrument and the device that need to be measured. Therefore the traditional tachometer is more dangerous compared to the recently tachometer which can take the measurement in a distance and contactless to the device that need to be measured. (M. Jouneh, 2002 and Alan S. Morris and Reza Langari, 2012)

2.5.3.1 VOLTAGE BASED TACHOMETER

Voltage based tachometer is required a source of voltage to determine the speed and perform various other tasks. An example of voltage based tachometer is the DC generator tachometer. It has a very simple way of it operation. The amount of voltage which is being produced will be directly proportional to the speed of the tachometer.

2.5.3.1 FREQUENCY TYPE TACHOMETER

Another type of tachometer is frequency type tachometer. This type of tachometer is calculated the amount of pulse produced due to a rotating filed tachometer. It is required a higher of precision and digital circuitry as opposed to the voltage based tachometer which is barely simple to use.

2.5.3.3 LASER TACHOMETER

The common type of tachometer that had been used recently is the laser tachometer. This type of tachometer is required no contact between the instrument and an object that need to be measured due to safety reason. The laser tachometer is used in order to take measurement from a safer distance.

Figure 2.10: Tachometer sensor

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will briefly describes the process to design and fabricate the two degree of freedom free vibration translation motion test rig. The process was conducted step by step as shown in the flow chart below. The literature review was carried out for further understanding on the vibration theory before starting the designing and fabrication process. The design was developed in multiple concepts in order to select a best design. These designs were implemented by using the SolidWorks software. Finally the fabrication process was conducted which involving several appropriate manufacturing processes.

3.2 METHODOLOGY PROCESS FLOW CHART

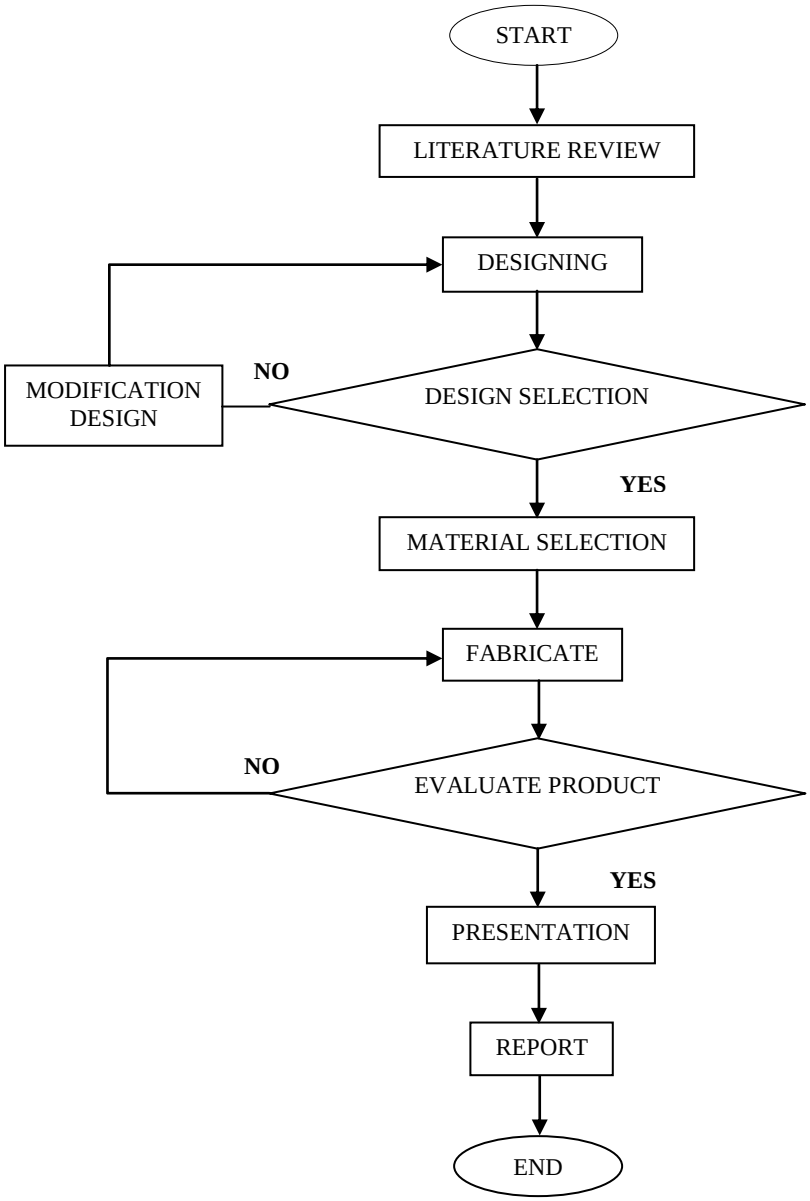


Figure 3.1: Flow Chart

This project is basically beginning with the topic selection and discussion regarding the project topic about the project objectives and project scopes with the supervisor. Then, the literature review process was performed to investigate the existing test rig in term of size, material used, purpose and quality of the test rig. Others references materials like text books and journals had been studied to get further understanding about this project topic.

After that, the designing process was carried out starting with the design sketching and then improves into proper design drawing by using SolidWorks software. The design generation and design selection were implemented in order to select a best design among the others design. The selection of the design was carried out by using the concept scoring method based on the some criterions. Next, the necessary materials were selected to fabricate the test rig.

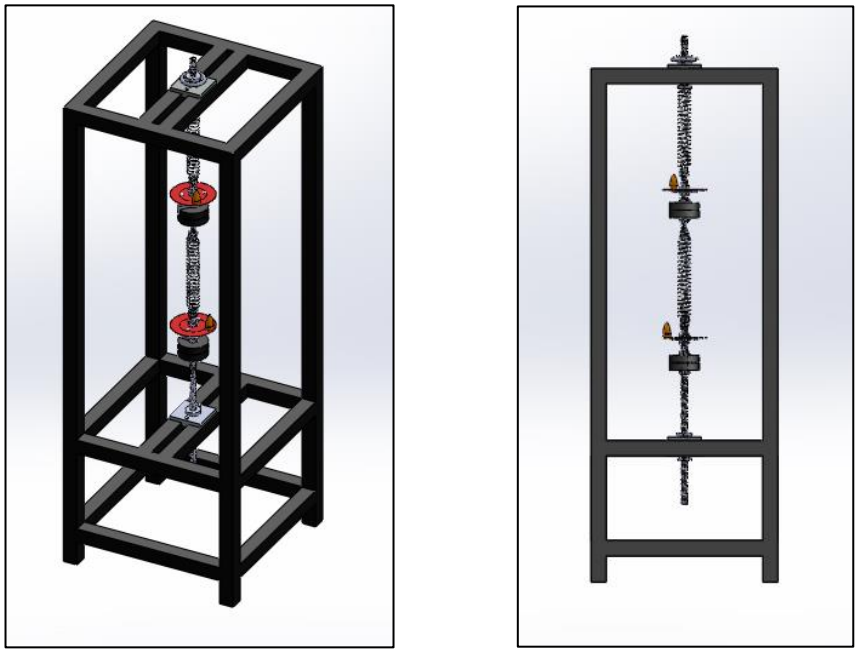
Then, the fabrication process of the selected design was conducted by using appropriate fabrication process. After the fabrication process had been done, the evaluation on the test rig was performed in order to know whether the test rig can operate or not. Finally the report of this final project needed to be completed and submit before the due date.

3.3 DESIGN CONCEPT

In this project, the design concept was beginning with the designing of eight sketching of the test rig. Then, only four appropriate designs sketching were chose from the previous eight designs sketching. Next, the selected designs sketching were improved into Three Dimensional (3D) drawing by using the SolidWorks software. In this case, the precision of the test rigs' dimension was very important during performing the SolidWorks drawing process in order to get the real and better shape of the test rig.

3.3.1 FIRST DESIGN

The first design is mainly shows the two degree of freedom free vibration translation motion in a vertically manner because the springs and the loads are arranged in a vertically line. The frame of the test rig will be made of square hollow steel. The frame will be painted to prevent from rusting. The welding process is required to combine the frames. This design concept has advantages of easy to use, stable and requires low space to place it. While the disadvantages of this design concept are heavy and a lot of raw material needed in order to fabricate it.

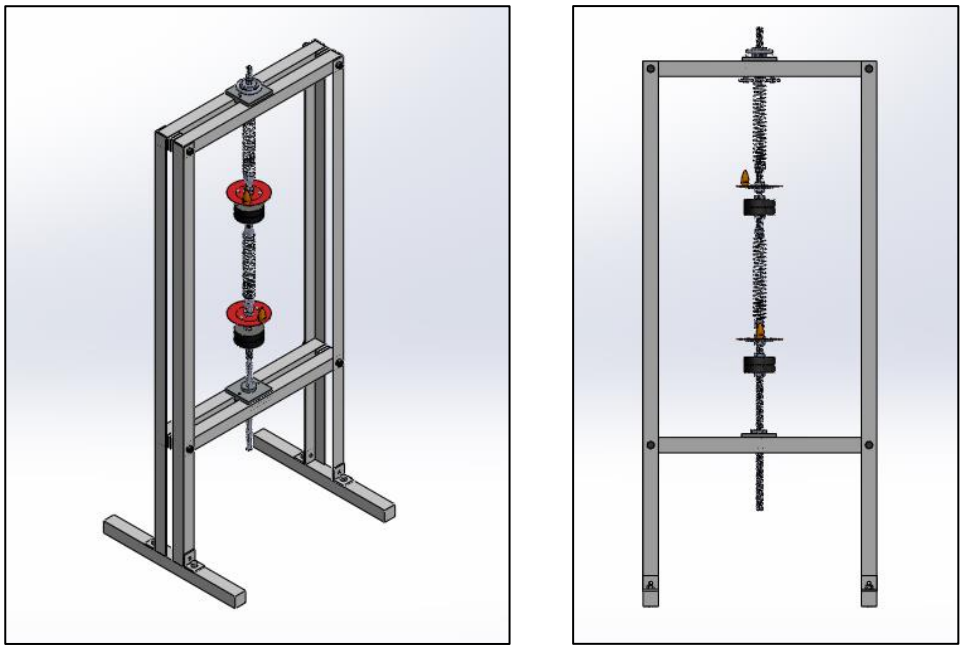


(a) (b)

Figure 3.2: First design: (a) 3D view, (b) side view

3.3.2 SECOND DESIGN

The second design is also mainly shows the two degree of freedom free vibration translation motion in a vertically manner because the springs and the loads are arranged in a vertically line. The material of aluminium will be selected to make the frame of the test rig. The used of bolt and screw needed to combine the frames. This design concept has advantages of easy to use, stable, lightweight and easy for maintenance. While the disadvantage of this design concept is difficult to fabricate the frame of the test rig.

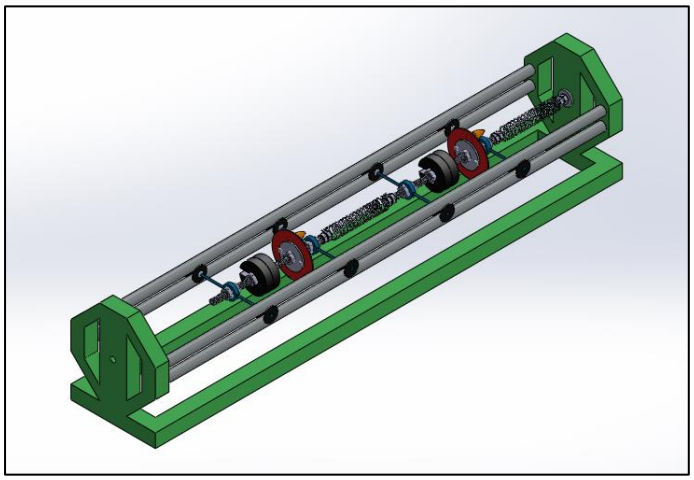


(a) (b)

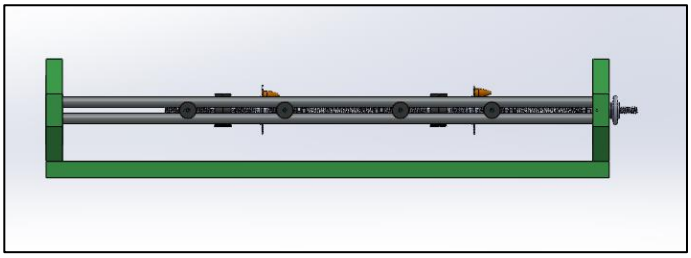
Figure 3.3: Second design: (a) 3D view, (b) side view

3.3.3 THIRD DESIGN

The third design is basically shows the two degree of freedom free vibration translation motion in a horizontal manner because the springs and the loads are arranged in a horizontal line. The frame of the test rig will be made from the square hollow steel. The frame will be painted to prevent from rusting. The welding process is required to combine the frames. The advantages of this design concept are easy to use and stable. While the disadvantages of this design concept are high cost production, low spring elongation, difficult for maintenance and friction occurs between the rollers with the rod surface.



(a)

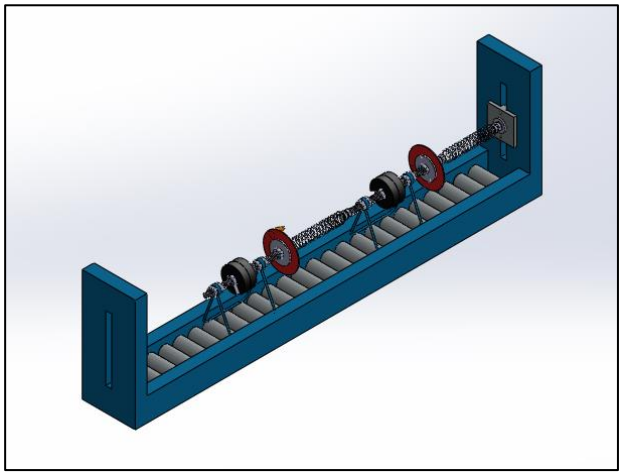


(b)

Figure 3.4: Third design: (a) 3D view, (b) side view

3.3.4 FOURTH DESIGN

The fourth design is also basically shows the two degree of freedom free vibration translation motion in a horizontal manner because the springs and the loads are arranged in a horizontal line. The frame of the test rig will be made from the square hollow steel. The frame will be painted to prevent from rusting. The welding process is required to combine the frames. The advantage of this design concept is easy use. While the disadvantages of this design concept are not stable, high cost production, low spring elongation, difficult for maintenance, difficult to fabricate it and has low operation performance.



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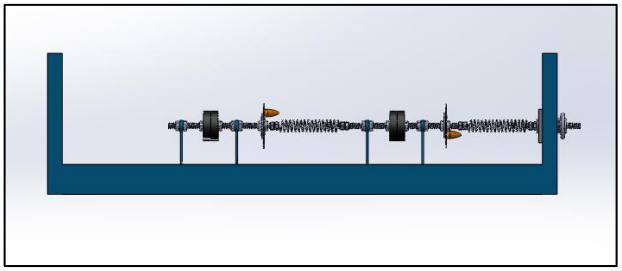


(b)

Figure 3.5: Fourth design: (a) 3D view, (b) side vie

3.4 DESIGN SELECTION

Design selection is very important in order to select a best design. In this topic some desired criteria was listed which to be rated by each of the design concept. Table below shows the concept selection process.

Table 3.1: Concept selection

	Criteria	1st Design	2nd Design	4th Design	3rd Design (Reference)
1.	Easy to use	+	+	-	0
2.	Easy for maintenance	0	+	-	0
3.	Cost production	-	+	-	0
4.	Easy to keep	0	0	0	0
5.	Safety	+	+	0	0
6.	Performance	+	+	0	0
7.	Size	-	0	0	0
8.	Weight	-	+	0	0
9.	Location for sensor	+	+	0	0
10.	Work area	0	0	0	0
11.	Spring elongation	+	+	0	0
Plus		5	8	0	
Same		3	3	8	
Minus		3	0	3	
Net		2	8	-3	
Rank		2	1	3	
Proceed?		No	Yes	No	

3.5 FINAL DESIGN

After all the design concepts had rated with respect to each criterion, the second design was showed the highest total net rating compared to others design concepts. The second design concept was ranked as the first desirable concept. Therefore, the second design concept was selected to be a best design and was proceed into fabrication process.

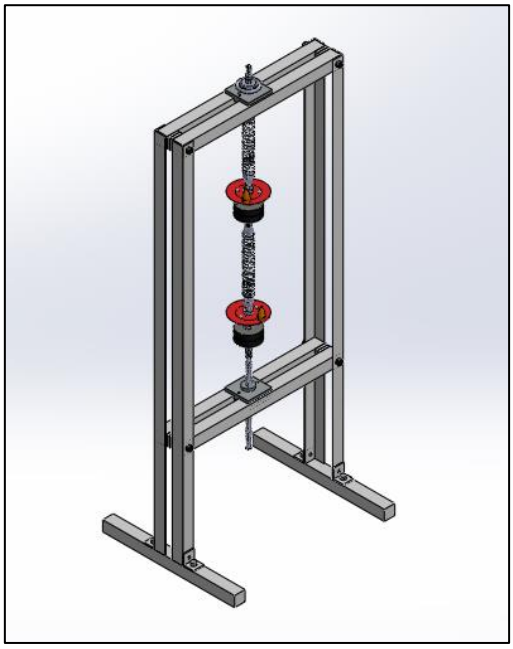


Figure 3.6: Final design

This design concept was showed the smaller size than the existing vibration test rig in the UMP vibration laboratory. This test rig had the height of 1.5m, the length of 0.7m and the width of 0.6m. Thus, it is easy to move and easy for the maintenance.

3.6 MATERIAL SELECTION

The appropriate material selection should be highly concerned because it is very important to ensure the test rig has the best quality and performance.

3.6.1 FRAME

In this project, aluminium profile, aluminium L-bar and aluminium bar were selected to be the frame of the test rig. This is because the aluminium has lower weight compared to the steel. Thus, it is easier to move from one place to another place. The aluminium also has high rust resistance and corrosion resistance to ensure it is can be used for long period and it is long lasting. In addition, the aluminium is strong enough to withstand the vibration during the vibration test process. The surface treatment such as painting can further improve the aluminium property.

Figure 3.7: Aluminium profile

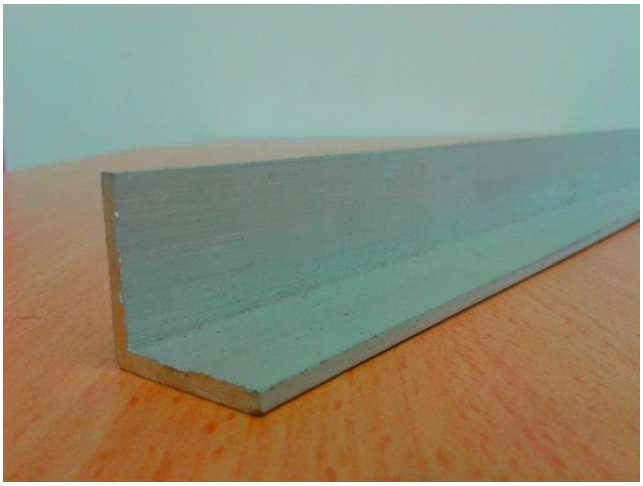


Figure 3.8: Aluminium L-bar

3.6.2 ROD

The rod that was used in this project was made from the mild steel material. Basically the cost of the steel rod is lower compared to the aluminium rod. The rod then was cut into desired length and painted to avoid from rusting. The function of the rod is to hold the mass and disc with the used together with screw nut. Then it will be connected with the spring and hung up in the vertically manner.

3.6.3 DISC

The material selection for the disc was aluminium sheet metal. This aluminium disc is to place the sensor on it. This aluminium disc is lightweight an easy to be shaped.

Figure 3.9: Aluminium sheet metal

3.6.4 BOLT AND NUT

The used of bolt and nut that made of from stainless steel has been selected to be used in this project. The advantages of using bolt and nut are easy to assemble and disassemble. This is because the bolt and nut is the non-permanent joint rather than welding joint shows permanent joint which is cannot be dissembled. Therefore,

the test rig can be adjustable into appropriate size and shape. This bolt and nut also have high strength to hold the test rig frame in fix shape.

Figure 3.10: Bolt and nuts

3.7 FABRICATION METHOD

There are several types of fabrication methods that were conducted in order to complete this project. The fabrication methods involved were measuring, cutting, drilling, milling, turning, threading and finishing.

3.7.1 MEASURING

The measuring process is the collection of the quantitative data which is to determine the length of an object. The measuring process was carried out at the beginning of the fabrication process. The measuring instruments that had used in this project are the measuring tape and the ruler. Every material or part of the test rig was measured before to be proceed in other process like cutting, drilling and others appropriate process. The precision of the dimension should be highly concerned in the measuring process in order to get a better result of the shape of the test rig. In spite of that, during measuring process there are some precautions have been taken to

prevent the measurement error. First of all, the eye must be parallel to the measuring scale before marking on the object to get accurate dimension. Next, the measuring instrument should be in well manner to avoid from the calibration error. (Madhu Viswanathan, 2005)

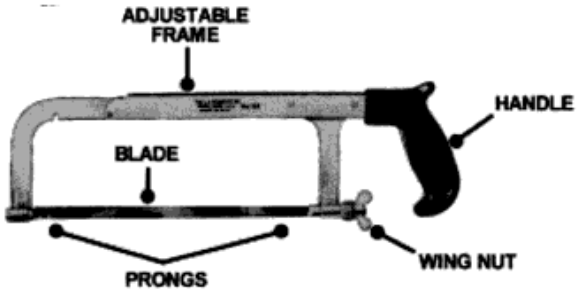
(a)

(b)

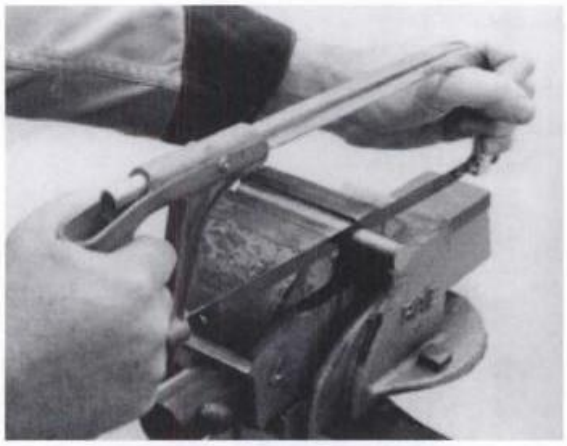
Figure 3.11: (a) Measuring process (b) Measuring instruments

3.7.2 CUTTING

The cutting process was done mostly in the making of the test rig frame process. The examples of cutting equipment that was used to cut the test rig are hand saw and power saw. There are many types of the hand saws in the market and laboratory. Each of the hand saw has different type of blade which is to cut the different type of the material. Therefore, the appropriate hand saw was selected to cut the material of aluminium and steel for this project.



(a)



(b)

Figure 3.12: (a) Part of hand hacksaw, (b) Correct way to hold hand hacksaw.

(Steve Krar, Arthur Gill, Peter Smid and Paul Wanner, 2002)

3.7.3 DRILLING

Drilling process is the process of creating a hole in the shape of circular cylinder onto the workpiece by a rotating cutting tool called drill bit. Before drilling the hole is located by drawing two lines at right angle and a center punch is used to make an indentation for the drill point at the center to help the drill in getting started. A suitable drill is held in the drill machine and the drill machine is adjusted to operate at the correct cutting speed. (Rajendra Simha, 2006 and J.J Azar and G. Robella Samuel, 2007) In this project, the drilling process was implemented onto the test rig frame and disc. The different diameter of hole was created by using different diameter of the drilling tool bit. The spindle speed of the drilling machine was controlled during the drilling process in order to get the better surface finish and to avoid from the tool wear. The lubrication also was used in order to achieve a better surface finish and to avoid from the tool wear and also to increase the performance of drilling process. Before the drilling process the workpiece was clamped tightly with the provided clamper.

Figure 3.13: Drilling process

3.7.4 MILLING

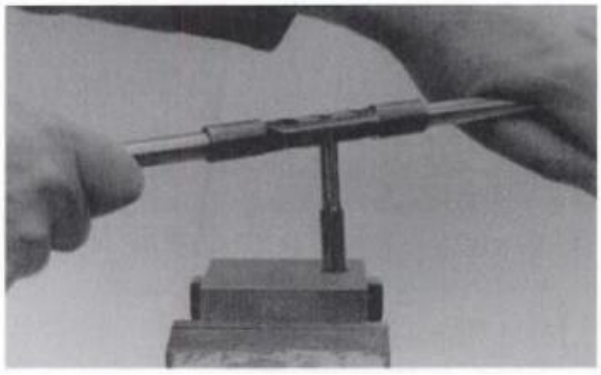
Milling process is the material removal process which can create variety of the shape features by cutting away the unwanted material. In milling machine, the metal is cut against a rotating cutter. The milling cutter rotates at high speed and it removes metal at a very fast rate with the help of multiple cutting edges. As the workpiece moves against the cutting edges of milling cutter, metal is removed in form of chips. There are two type of milling machines which are face milling and peripheral milling. (Rajendra Simha, 2006) In this project, the face milling was implemented to shape the plate and also to make holes onto the plate and screw nut. Same with the drilling process, the spindle speed in the milling process also was controlled and the used of coolant is necessary to achieve the better surface finish and to prevent from tool wear and also to increase the machining performance. The workpiece also needed to be clamped tightly with the provided clamper before starting the face milling process.

Figure 3.14: Milling process

3.7.5 THREADING

The threading process is carried out to create the threaded part for placing the nut or the screw. (Steve Krar, Arthur Gill, Peter Smid and Paul Wanner, 2002). In this project, there are two type of threading processes that had been conducted. First is internal threading and the second one is external threading. For the internal threading, the tapping and tap wrench had used. A hole was created before performing the tapping process. And the hole should have smaller diameter than the diameter of the tap in order to move the tap into the hole. This internal threading was implemented onto the screw nut. (Steve Krar, Arthur Gill, Peter Smid and Paul Wanner, 2002).

(a)

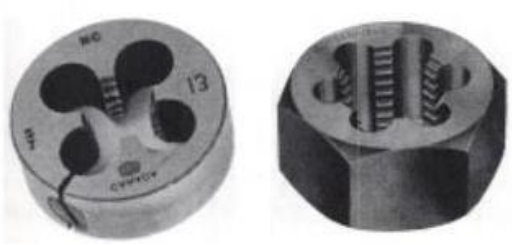


(b)

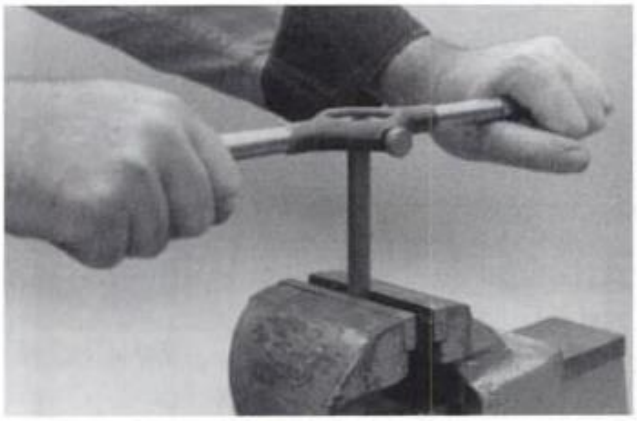
Figure 3.15: (a) Taps, (b) Threading process by using tap wrench

Source: Steve Krar, Arthur Gill, Peter Smid and Paul Wanner, 2002

While for the external threading, the die and die holder had been used. This external threading was implemented onto the tip of the steel rod. The external threading process was done together with the turning machine. (Steve Krar, Arthur Gill, Peter Smid and Paul Wanner, 2002).



(a)



(b)

Figure 3.16: (a) Dies, (b) External threading by using die holder

Source: Steve Krar, Arthur Gill, Peter Smid and Paul Wanner, 2002

3.7.6 FINISHING

The final fabrication process is the finishing process which is involving of assembly process and painting process. Before assemble all the parts of the test rig, the parts were painted earlier with the spraying paint. This is because to improve the part appearance and to make the material used long lasting especially for the steel material based. After that, the assembly process was performed by assembly all the part as shown in the design concept.

Figure 3.17: Spray paint

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

This chapter will discuss the result of the test rig that was fabricated. The purpose of every part of the test rig will be briefly explained. Then the evaluation process upon the test rig had stated in this chapter to determine the operation reliability. This chapter also includes the discussion on the comparison between the existing test rig and the new test rig. The problem faced throughout this project also will be discussed.

4.2 TEST RIG

Mainly the objective in this project is to design and fabricate the two degree freedom free vibration test rig. Thus evaluation process had conducted on the test rig to determine whether the test rig can be operated or not in order to accomplish this project objective. The masses were inserted into the vibrating system. Each mass was placed below of each spring. Then the masses were exerted initial disturbance simultaneously with no external force acted after the initial disturbance. Then the vibration process upon the vibrating system was observed. This process was repeated by adding the amount of the masses. According to the evaluation process on this test rig, the maximum load that be withstand by each of the spring was 50N. From the result from the evaluation process, the test rig that had fabricated was able to operate

in a well manner and the project objective was achieved and accomplished. The figures below were showed the test rig that had completely fabricated.

(a) (b)

Figure 4.1: Test rig (a) Front view, (b) Isometric view

As mentioned above, the evaluation process had conducted on the test rig. The test rig was tested in the vibration laboratory. In this experiment, the weight of the mass was manipulated. The different weights of masses were inserted into the vibrating system. The figure below shows the experiment process where the 60N of weights was inserted into the test rig. The highest weight of mass that was tested in this experiment was 100N.

Figure 4.2: Experiment process on the test rig by using 60N of load weight

4.3 PART OF THE TEST RIG

4.3.1 TEST RIG FRAME

The test rig frame was mainly made of aluminium profile, aluminium L-bar and aluminium. The test rig frame was used to place and hold the spring–mass vibrating system. Moreover, the aluminium was strong enough to withstand the vibration shock during the vibration test process.

(a) (b)

Figure 4.3: Test rig frame (a) Front view, (b) Isometric view

4.3.2 STEEL ROD

The steel rod in this vibrating system was used to hold others vibrating system like spring, aluminium disc, mass and screw nut. This steel rod also became an important vibrating tool in order to perform the vertically vibration system.

Figure 4.4: Steel rods

4.3.3 STEEL PLATE

In this project, four of the steel plates were fabricated. The two steel plates were placed at the upper frame and the others two steel plates were placed at the bottom frame. A hole was created at the center of the bottom steel plate to allow the movement of the steel rod.

Figure 4.5: Steel plates

4.3.4 ALUMINIUM DISC

This aluminium disc was placed below the spring and connected together with the steel rod and screw nut. The purpose of the aluminium disc was to place the sensor on it such as accelerometer and tachometer. Thus, the sensor can measured the vibration that created by the movement of this aluminium disc during vibration test.

Figure 4.6: Aluminium discs

4.3.5 SCREW NUT

The function of the screw nut was to hold aluminium disc and the mass in the vibrating system. There were six of screw nuts that had used in this project.

Figure 4.7: Screw nuts

4.4 DISCUSSION

4.4.1 COMPARISON WITH THE EXISTING TEST RIG

Some comparisons were discussed between the existing test rig and the new test rig that was fabricated in this project. The comparisons were showed at the table below.

Table 4.1: The comparison between existing and new test rig

Criteria	**Existing test rig**	**New test rig**
Height	1.7 m	1.5 m
Length	1.2 m	0.7 m
Width	0.5 m	0.6 m
Material of the frame	Aluminium plate	Aluminium plate Aluminium L-bar Aluminium bar
Size	Larger	Smaller
Weight	Heavier	Lighter

Refer to the table above, the new test rig was smaller than the existing test rig in term of it height and length. Therefore, the new test rig was able to place in a small area compared to the existing test rig. It also easy to move since the new test rig was more lightweight than the existing test rig. There was a similarity between these two test rigs which both of the test rig were made from the aluminium based material. This is because the aluminium is more lightweight rather than use the steel as the test rig frame. The aluminum also had properties of rust resistance and long lasting.

4.4.2 PROBLEM DESCRIPTION

In order to complete this project, there were some problems occurred mostly in the fabrication process. First of all, the deflection was occurred on the test rig. A wrong hole had created on the frame of the aluminum L-bar. Thus, the combination process to join the L-bar with the others frames cannot be conducted. In spite of that, another appropriate hole had been created based on the accurate dimensioning to insert the bolt to join the aluminium L-bar with the other frames. This problem was occurred caused by the wrong dimensioning process due to lack of the attention when measured on that material.

Besides, the second problem was occurred when to fabricate the aluminium disc. The low thickness of the aluminium disc was made it difficult to be shaped in the circular pattern. This low thickness of the aluminium disc was very easy to bend when conducting the material removal process by using the grinding machine. Thus, the low thickness of the aluminium was not suitable to be used as the vibrating system because it had the property of easy to bend. Therefore, the material selection of the high thickness of aluminium disc had been implemented. Since the current aluminium disc thickness was higher than the previous aluminium disc so it is able to withstand the vibration shock.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The objective of this project which is to design and fabricate the two degree of freedom free vibration test rig was successfully achieved. The design of the test rig had developed by using the SolidWorks software.

The test rig was produced by conducting several fabrication processes such as measuring, cutting, milling, drilling and threading. The frame of this test rig was made from aluminium. Thus, it is light weight and easy to be moved from one place to another place. Besides, it is long lasting because the aluminium had the properties of corrosion resistance and high strength. This frame also easy to assemble and dissemble since it was combined by using the bolt and nut. Moreover, the test rig was strong enough because it can withstand the weight of loads up to 100 N.

At the end of this project, the concept of two degree freedom free vibration was understood. The differences between one and two degree of freedom free vibration also were identified. Then, by performing the fabrication process it will develop the skills to handle the machines in the laboratory. Furthermore, the fundamental of manufacturing knowledge also can be enhanced. Throughout this project, the critical thinking and problem solving were fostered in order to overcome the problems occurred.

5.2 RECOMMENDATIONS

The weight of the aluminium bar that had been used as the base of the test rig was slightly heavy and costly. Since the cost is one of the main factor to increase the productivity. Thus, the used of the aluminium bar was not very suitable. Therefore, others appropriate material should be replaced the aluminium bar like steel hollow square or steel bar which had lower cost compared to the aluminium bar.

Besides, the further evaluation upon the two degree freedom free vibration test rig can be made by using the various types of the sensor in the vibration laboratory in order to get the appropriate data and analysis. Thus the comparison and the different between the single degree of freedom free vibration test rig and two degree of freedom free vibration test rig will be more understand.

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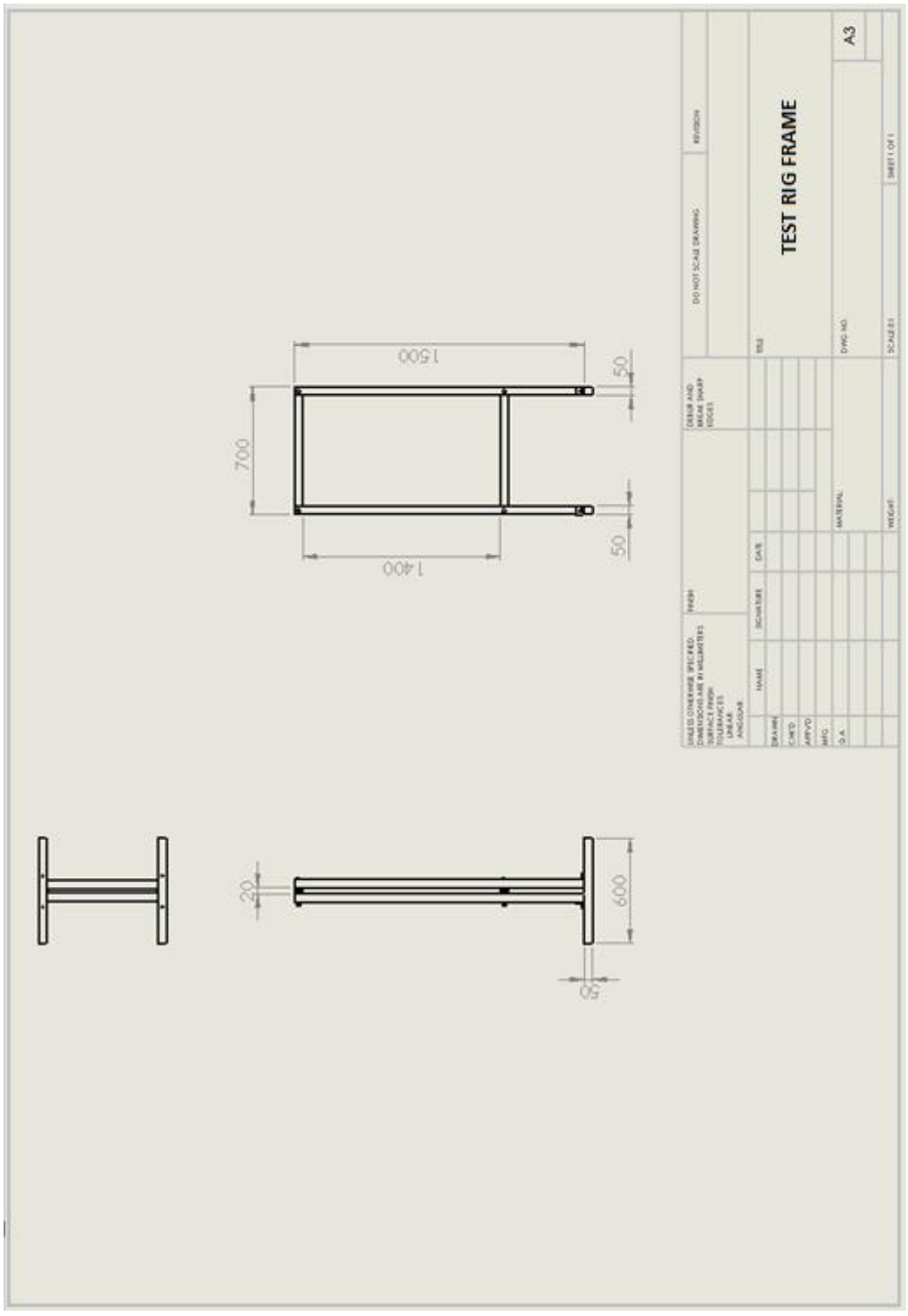
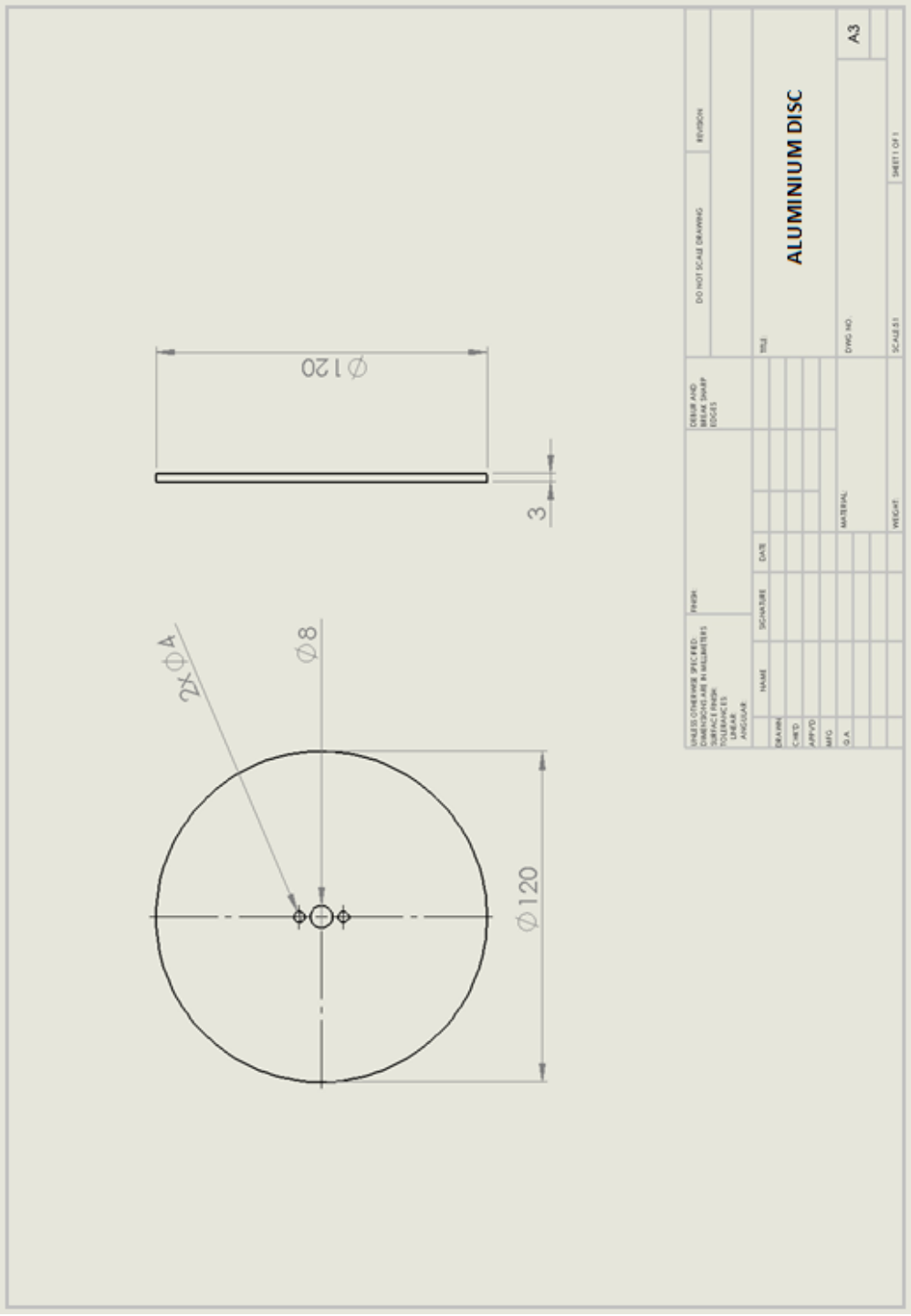
APPENDIX A1

Test rig frame drawing with dimension by using SolidWork software



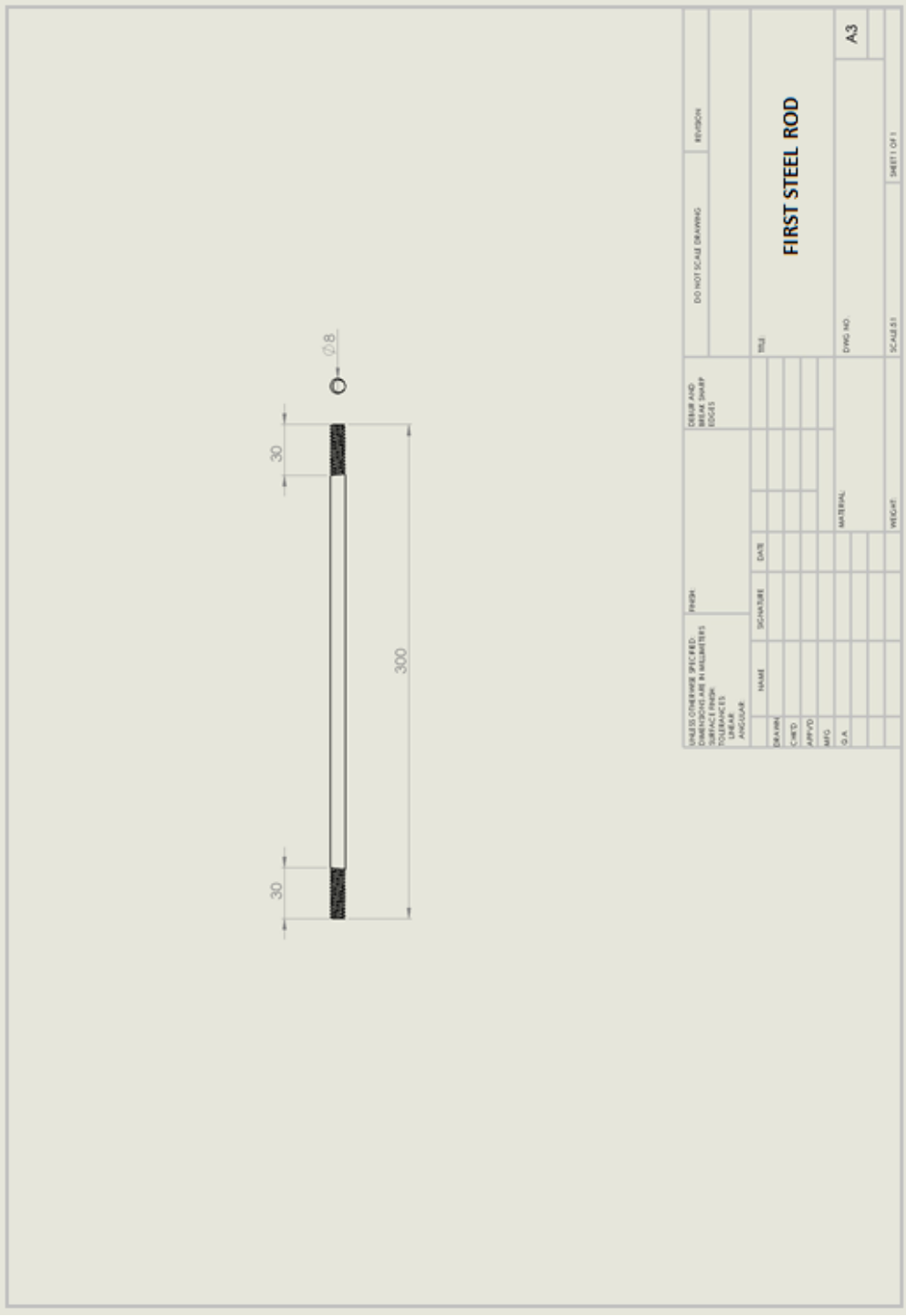
APPENDIX A2

Aluminium disc drawing with dimension by using SolidWork software



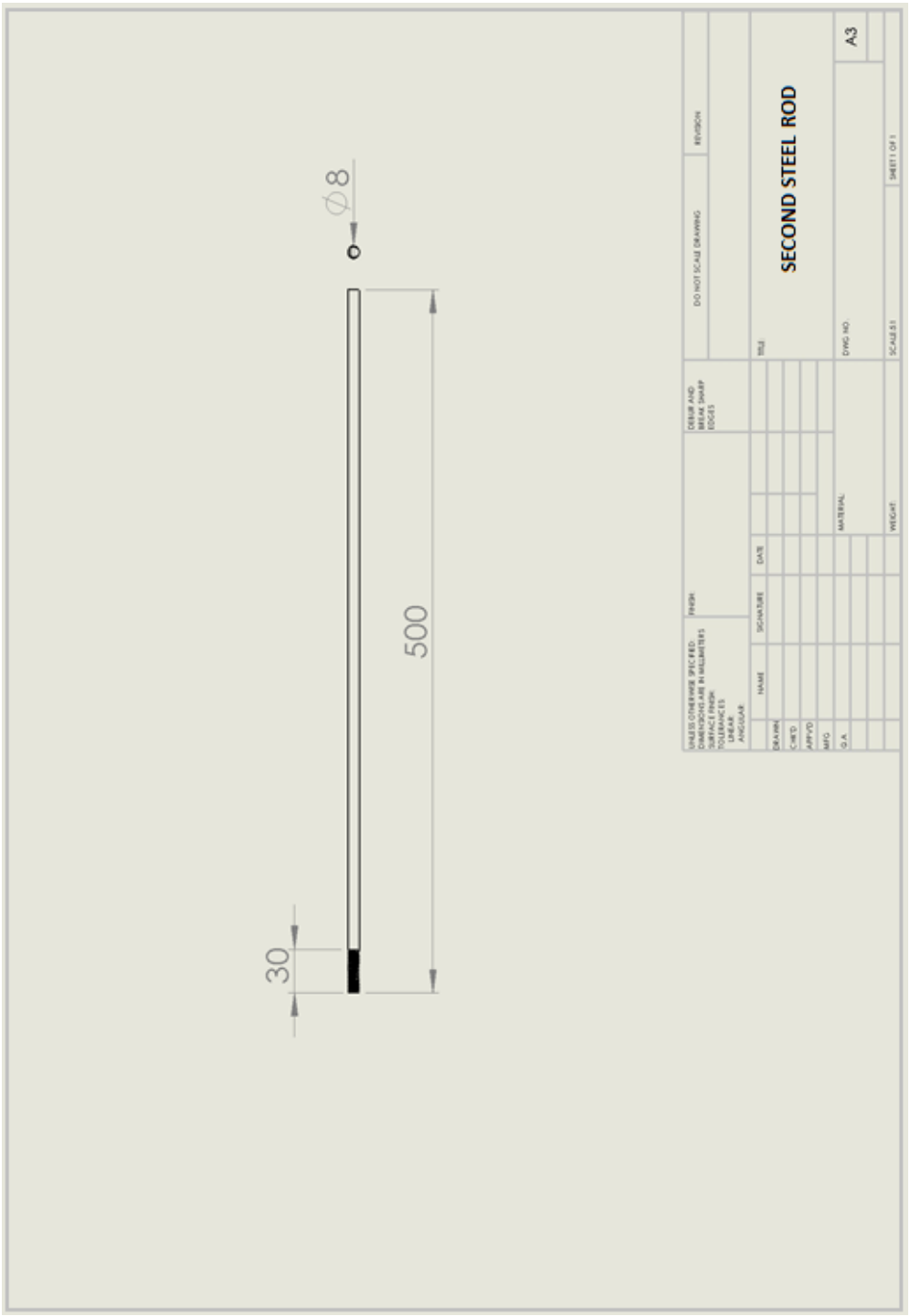
APPENDIX A3

First steel rod drawing with dimension by using SolidWork software



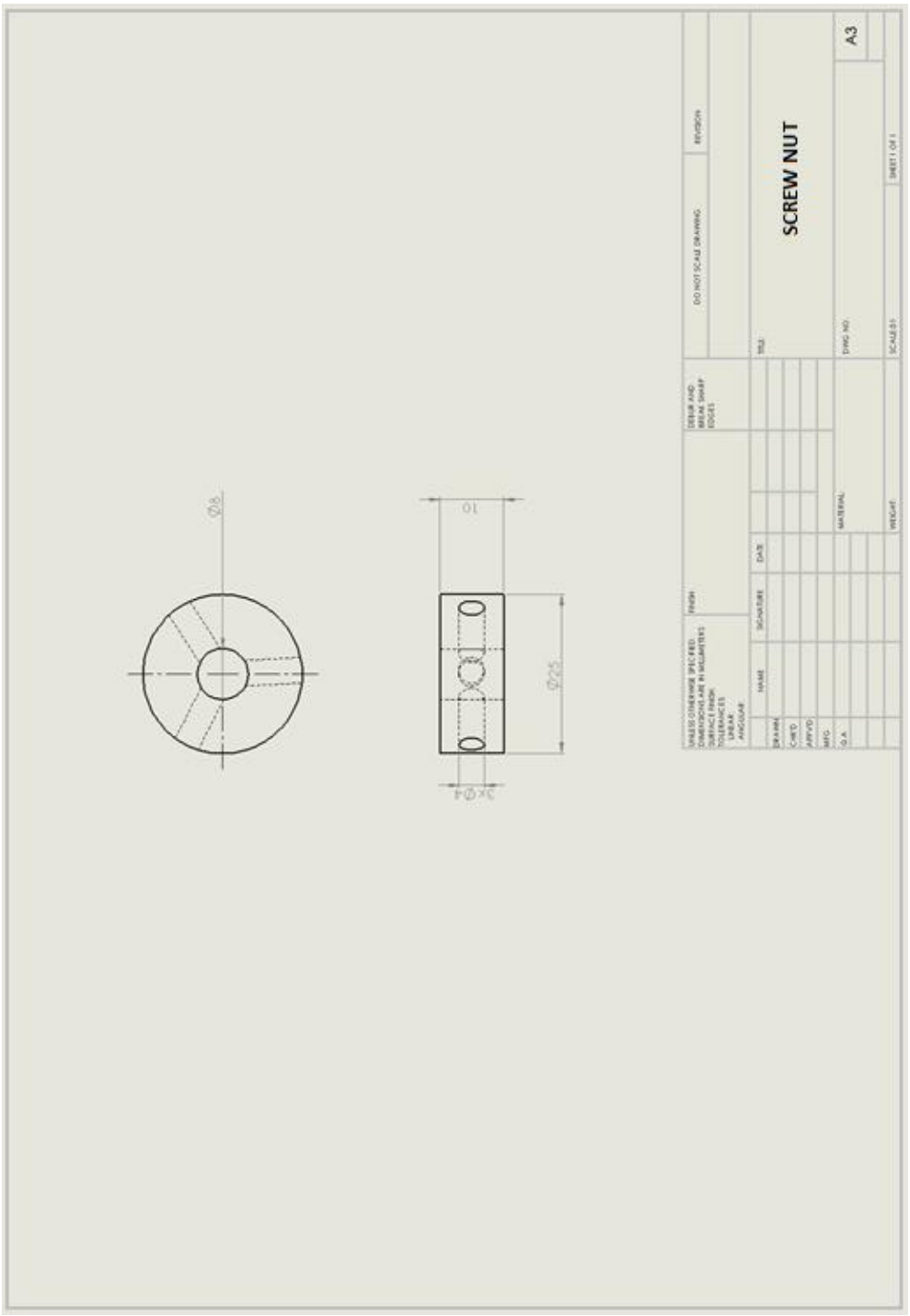
APPENDIX A4

Second steel rod drawing with dimension by using SolidWork software



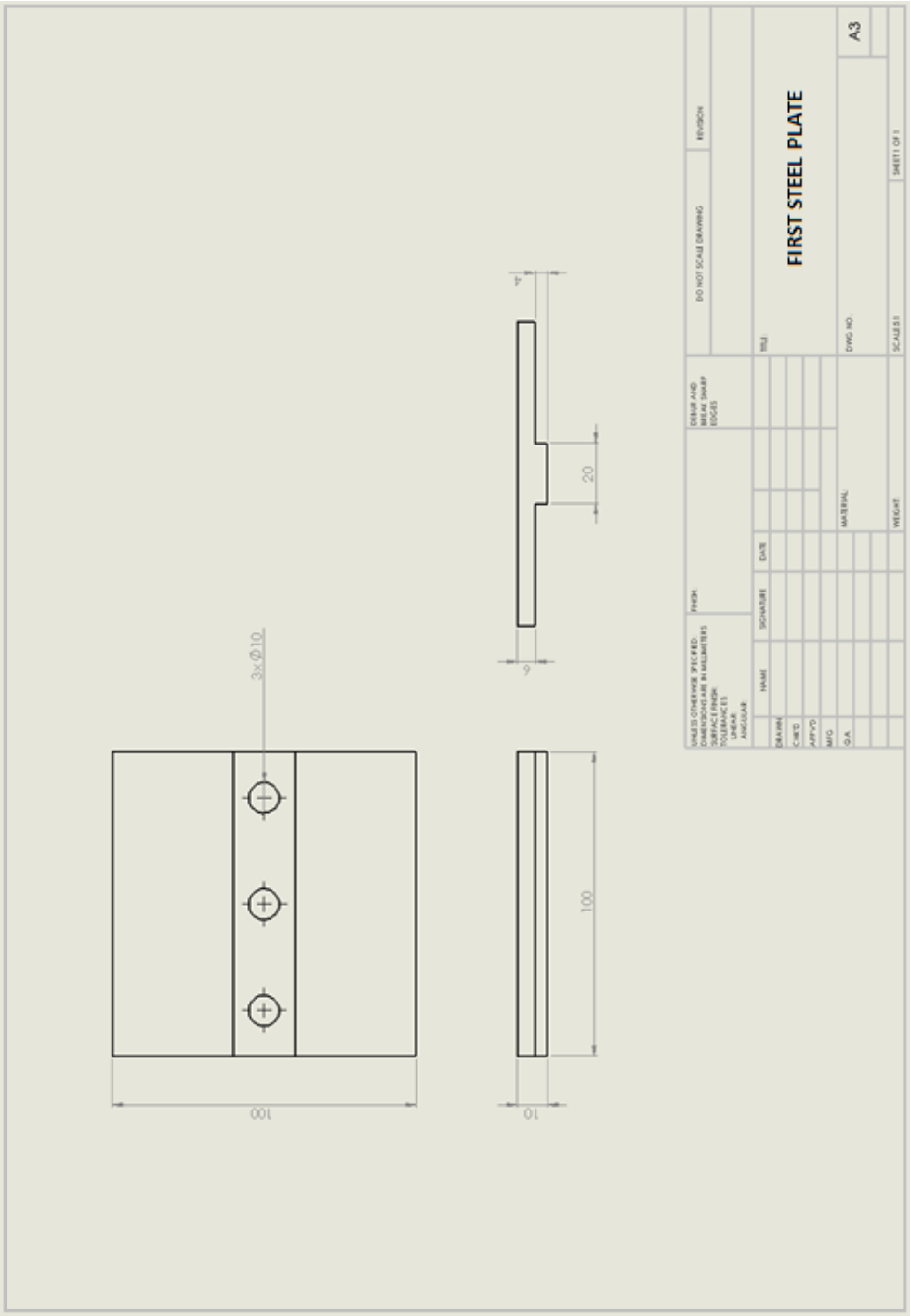
APPENDIX A5

Screw nut drawing with steel plate by using SolidWork software



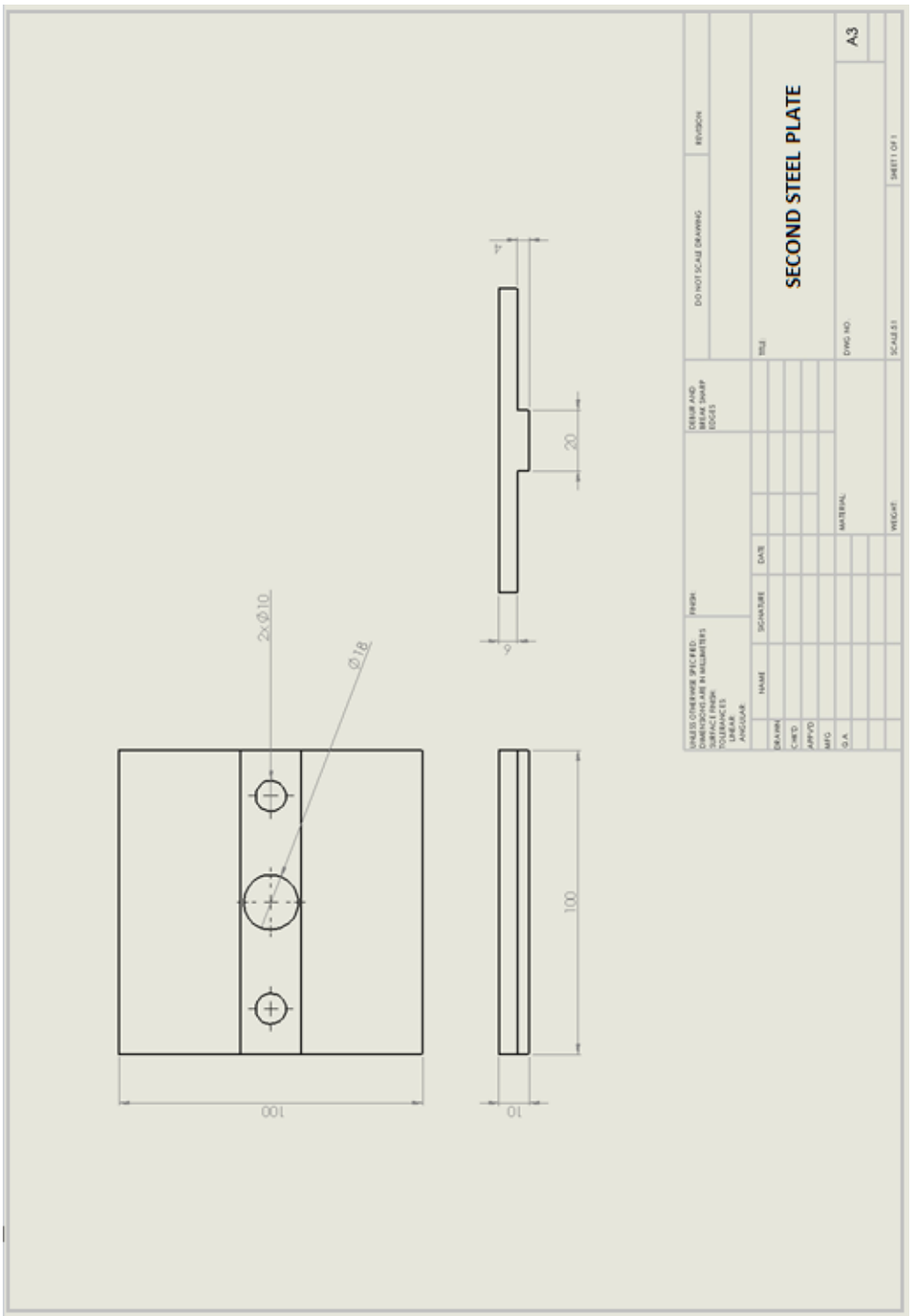
APPENDIX A6

First steel plate drawing with dimension by using SolidWork software



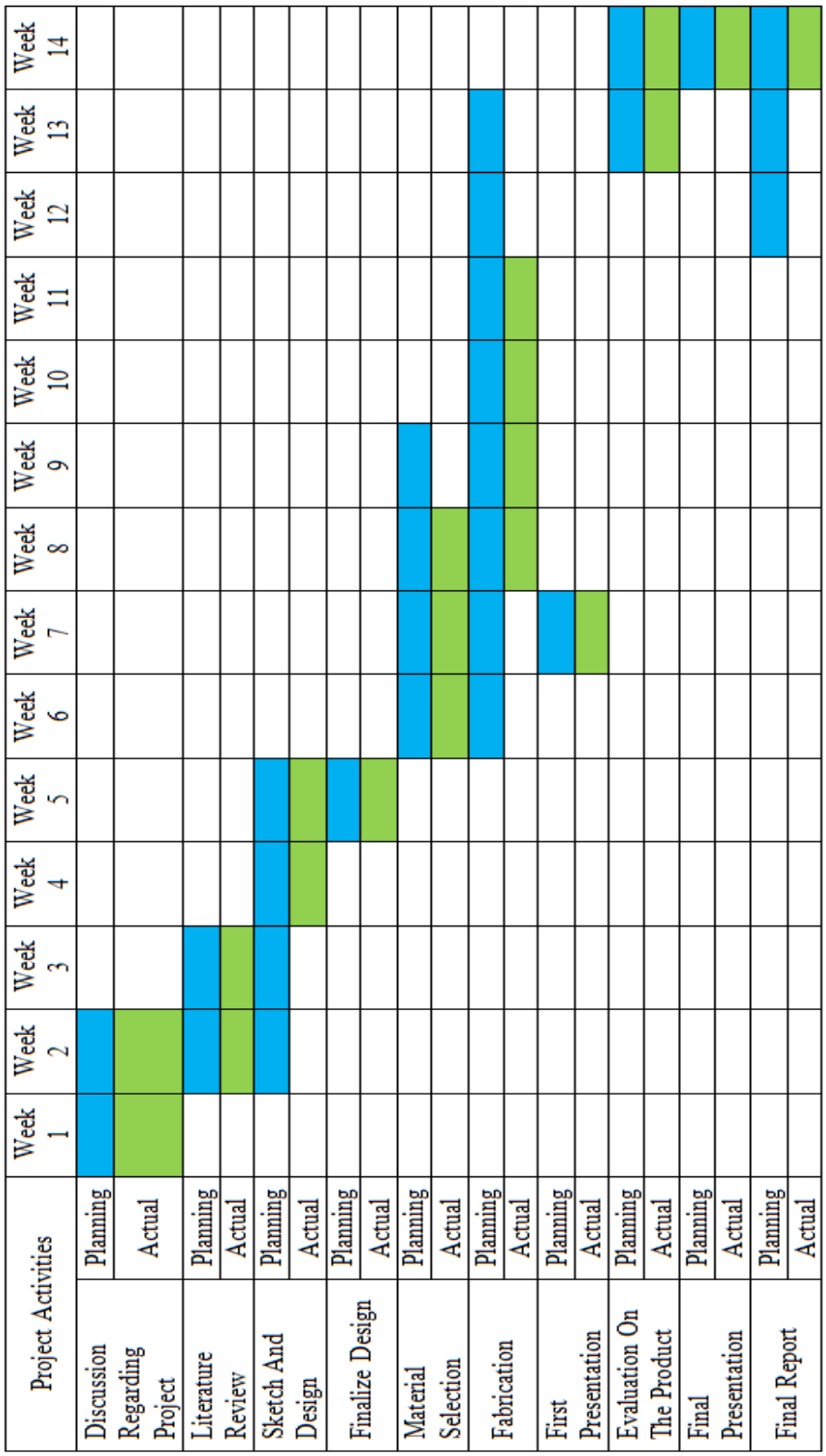
APPENDIX A7

Second steel plate drawing with dimension by using SolidWork software



APPENDIX B1

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														
Sketch And Design	Planning														
	Actual														
Finalize Design	Planning														
	Actual														
Material Selection	Planning														
	Actual														
Fabrication	Planning														
	Actual														
First Presentation	Planning														
	Actual														
Evaluation On The Product	Planning														
	Actual														
Final Presentation	Planning														
	Actual														
Final Report	Planning														
	Actual														