DEVELOPMENT OF SHAKER (MECHANICAL)

MUHAMMAD IQBAL BIN JAFAR

Report submitted in partial fulfilment of the requirement for the award of degree of Bachelor of Mechatronic Engineering

Faculty of Manufacturing Engineering
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JUDUL: **DEVELOPMENT OF SHAKER (MECHANICAL)**

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(HURUF BESAR)

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Alamat Tetap:

TAMAN PO HING 1, BLOK N, LOT 6
JALAN BATU SAPI, 90009 SANDAKAN
SABAH

WAN HASBULLAH BIN MOHD ISA
(Nama Penyelia)

Tarikh: **19 JUN 2013**

Tarikh: : **19 JUN 2013**

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Date :

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Signature :
Name of Supervisor : Mr Wan Hasbullah Bin Mohd Isa
Position : Head of Mechatoronic Engineering Program
Date :

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Dedicated to my parents

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ABSTRACT

Vibration test machine is widely applicable to the defence, aerospace, communications, electronics, automobiles, and other industries. Direct drive shaker is one of types of vibration testing machine that available in industries today. The direct-drive vibration machine consists of a rotating eccentric or cam driving a positive linkage connection which forces a displacement between the base and table of the machine. From multi speeded machines to medium, large and extra-large machines, these machines come in various types and categories, performing a range function. To design and build a small's scale direct drive shaker that meets a requirement for vibration test machine in industries, fabrication of direct drive shaker will be done in this project by using Scotch yoke mechanism which is a mechanism for converting the linear motion of a slider into rotational motion or vice-versa and DC motor is used to create a rotational movement that will be control by L238D motor driver.

ABSTRAK

Mesin ujian getaran secara meluas digunakan berkaitan dengan pertahanan, aeroangkasa, komunikasi, elektronik, kereta, dan industri lain. Pengoncang langsung pandu adalah salah satu jenis getaran mesin ujian yang terdapat dalam industri hari ini. Mesin getaran langsung pandu terdiri daripada aneh berputar atau cam memandu sambungan hubungan positif yang memaksa anjakan antara dasar dan meja mesin. Dari mesin pelbagai kelajajuan kepada mesin sederhana, besar dan lebih besar, mesin ini datang dalam pelbagai jenis dan kategori, melakukan fungsi pelbagai. Untuk merekabentuk dan membina mesin pengoncang langsung pandu yang berskala kecil yang memenuhi keperluan untuk mesin ujian getaran dalam industri, ianya akan dilakukan dalam projek ini dengan menggunakan *Scotch yoke* mekanisme yang merupakan mekanisme untuk menukarkan gerakan linear ke gerakan putaran atau sebaliknya dan (*direct current*) *dc motor* digunakan untuk mewujudkan sebuah gerakan putaran yang akan kawalan oleh L238D pemandu motor.

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θ_1	Angle in Link 1
θ_2	Angle in Link 2
θ_3	Angle in Link 3
ω_2	Speed of Cam
r_1	Displacement from centre of Cam to Link 4
r_2	Displacement from the centre of Cam and the crank pin
r_2	Displacement from the centre of yoke and the crank pin
⌀	Diameter
v	linear velocity (shaker speed)
r	Radius in meter
ω	Angular velocity

LIST OF ABBREVIATIONS

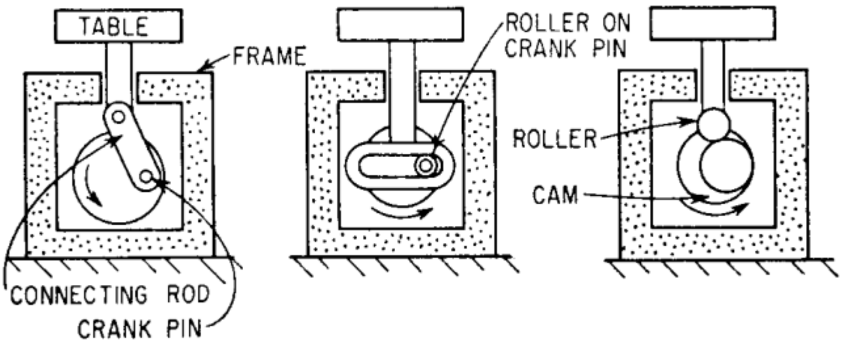
RPM	Revolution per minutes
DC	Direct current
STL	Stereo Lithography
RP	Rapid Prototyping
Al	Aluminium
RM	Ringgit Malaysia

CHAPTER 1

1.0 INTRODUCTION

1.1 Background information

The direct-drive vibration machine consists of a rotating eccentric or cam driving a positive linkage connection which forces a displacement between the base and table of the machine. Except for the bearing clearances and strain in the load-carrying members, the machine tends to develop a displacement between the base and the table which is independent of the forces exerted by the load against the table. If the base is held in a fixed position, the table tends to generate a vibratory displacement of constant amplitude, independent of the operating RPM. Figure 1.1 shows the direct-drive mechanical machine in its simplest forms. This type of machine is sometimes referred to as a brute force machine since it will develop any force necessary to produce the table motion corresponding to the crank or cam offset, short of breaking the load-carrying members or stalling the driving shaft.



(A) (B) (C)

Figure 1.1: Elementary direct-drive mechanical vibration:
(A) Eccentric and connecting link (B) Scotch yoke (C) Cam and follower [5]

The simplest direct-drive mechanical vibration machine is driven by a constant-speed motor in conjunction with a belt-driven speed changer and a frequency-indicating tachometer. Table displacement is set during shutoff and is assumed to hold during operation. An auxiliary motor driving a cam may be included to provide frequency cycling between adjustable limits. More elaborate systems employ a direct-coupled variable-speed motor with electronic speed control, as well as amplitude adjustment from a control station. Machines have been developed which provide rectilinear, circular, and three-dimensional table movements the latter giving complete, independent adjustment of magnitude and phase in the three directions. Many types of mechanisms are used to adjust the displacement amplitude and frequency of the mounting table. For example, the displacement amplitude can be adjusted by means of eccentric cams and cylinders.

1.2 Problem Statement

To design and build a direct drive shaker that meets a requirement for vibration test machine in lab used, fabrication of direct drive shaker will be done in this project by using Scotch yoke mechanism which is a mechanism for converting the linear motion of a slider into rotational motion or vice-versa and DC motor will be used as a shaker motor. This machine is inexpensive, easy to operate and build in a small-scale size.

1.3 Objectives of the project

Basically these projects are listing three main objectives. The objectives are a guideline in order to complete this project. This project is conducted to achieve the following objectives:

i. To design a direct drive shaker by using Scotch Yoke mechanism.
ii. To fabricate a small-scale direct drive shaker as a vibration testing machine.

1.4 Scope of Project

Project scope is the part of project planning that involves determining and documenting a list of specific project goals, deliverables, tasks, costs and deadlines. In this project, the scope of the project is including a design and fabrication of a small-scale direct drive shaker. In this project, the direct drive shaker size will be only in desktop size. This project only focuses on mechanical part only. There is no programming or coding will be used throughout this project. Catia software will be used to design the mechanical part of the shaker. Maximum frequency that can be drive from this shaker will be 50 Hz.

1.5 Flow chart

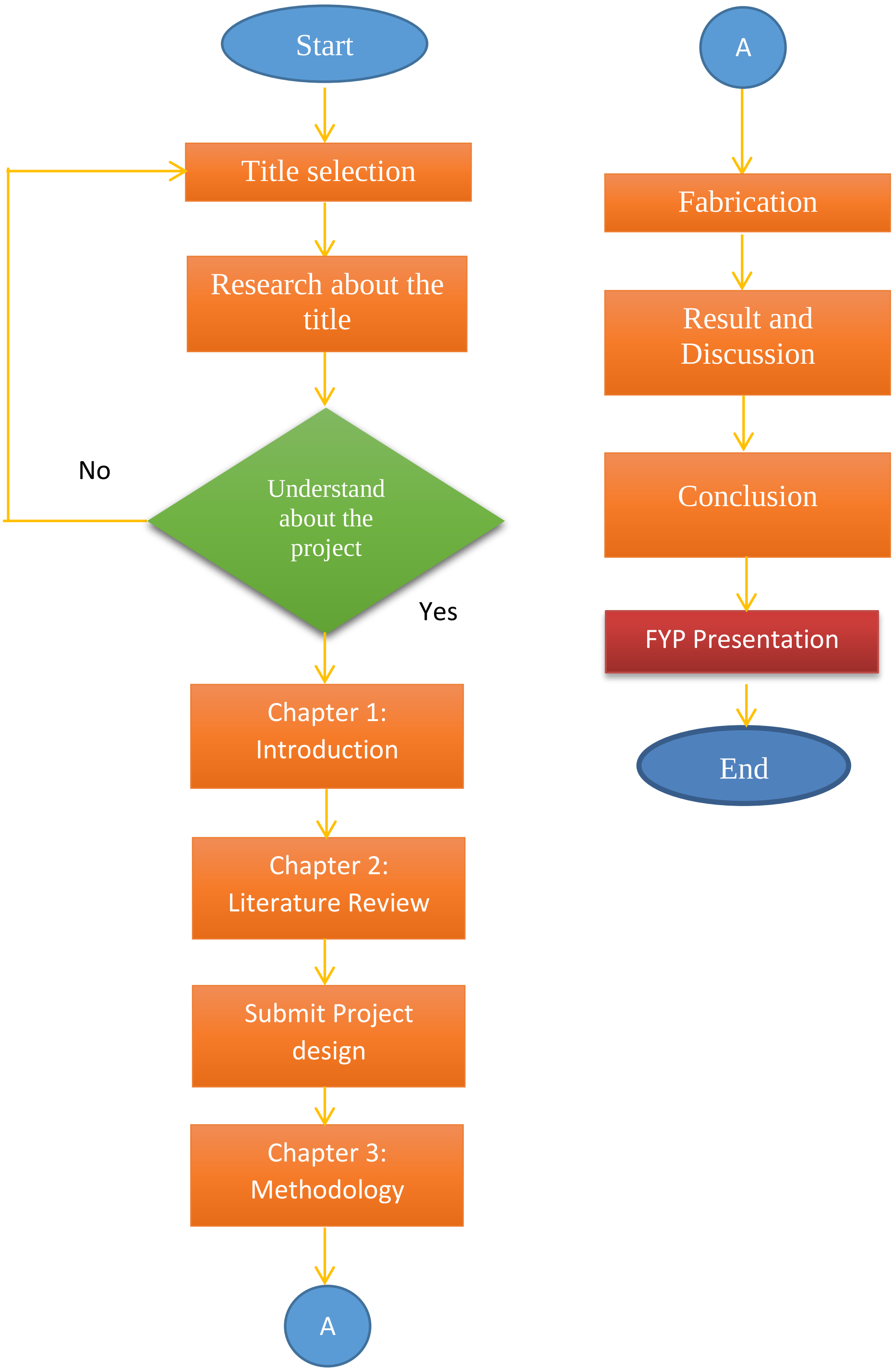


Figure 1.2: Project Flow Chart

1.6 Thesis Overview

The development of shaker thesis is a compilation of five chapters that contains and elaborates specific topics such as the Introduction, Literature Review, Methodology, Result and discussion, and Conclusion.

i. Chapter 1: Introduction

This Chapter 1 is an introduction which is the overview of the project, objective of the project, problem statement, scope of project and project flow chart through in order to complete the project.

ii. Chapter 2: Literature review

This Chapter 2 content is about literature review on the design of the shaker and the type of mechanism that have been used in the previous shaker fabrication.

iii. Chapter 3: Methodology

This chapter will explain about the project methodology through this project. Project Flow chart, design has been decided and also the type of material that will be used in this project.

iv. Chapter 4: Result and Discussion

This chapter contains the hardware design and calculation of the shaker speed and acceleration. The results that can be achieved at the end of this project by completed and also discussion on all the results obtained and the limitation of the project. All discussions are concentrating on the result and performance of the direct drive shaker.

v. Chapter 5: Conclusion

Discuss the conclusion about the project from the beginning until the end. Also conclude all the advantage and disadvantage through the project for further improvement.

Chapter 2

2.0 Literature Review

2.1 Introduction

This chapter reviews about previous studies of shaker. Before any project was started, proper and deep analysis is required to understand the basic function of the system. From that analysis and appropriate design can be selected to deal with the project function.

2.2 Type of shaker

2.2.1 Direct drive shaker

This shaker consists of a rotating eccentric or cam driving a positive linkage connection which forces a displacement between the base and table of the machine. There are three types of direct drive shaker that is (A) Eccentric and connecting link. (B) Scotch yoke. (C) Cam and follower. Figure 2.1 shown is the design of scotch yoke mechanism for the direct drive shaker. (Smallwood, 2010) [5]

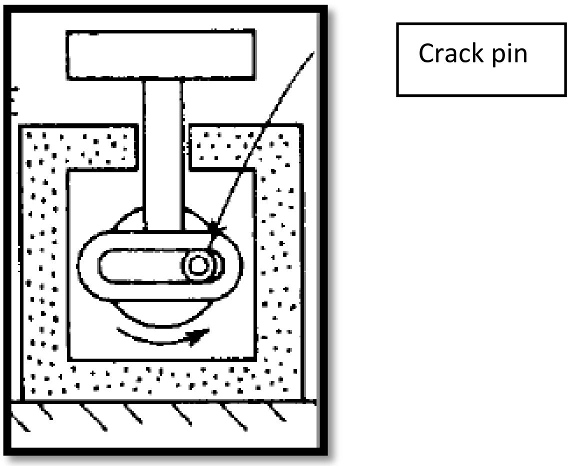


Figure 2.1: Scotch Yoke Mechanism (Smallwood, 2010) [5]

2.2.2 Electrodynamics Shaker

The electrodynamics shaker functions to deliver a force proportional to the current applied to its voice coil. These devices are used in such diverse activities as product evaluation, stress screening, squeak-and-rattle testing and modal analysis. These shakers may be driven by sinusoidal, random or transient signals based upon the application. They are invariably driven by an audio-frequency power amplifier and may be used "open loop" (as in most modal testing) or under closed-loop control where the input to the driving amplifier is servo-controlled to achieve a desired motion level in the article under test. (Lang, Corporation, & Jose, 1997) [2]

The magnetic circuit is made from soft iron which also forms the body of the vibration machine(Smallwood, 2010) [5]. The body is magnetically energized, usually by field coils as shown in Figure 2.2.

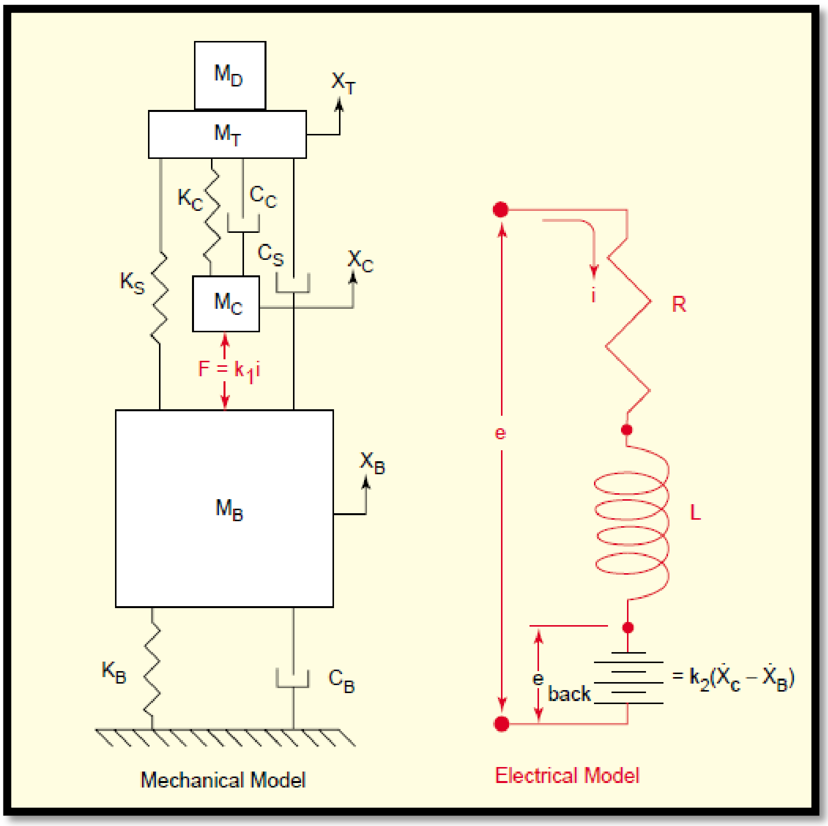


Figure 2.2: Mechanical and electrical model of electrodynamics shaker(Lang, Snyder, Corporation, & Jose, 2001) [3]

2.2.3 Hydraulic Shaker

The hydraulic vibration machine is a device which transforms power in the form of a high-pressure flow of fluid from a pump to a reciprocating motion of the table of the vibration machine. Figure 2.4 shown the example, a two-stage electrohydraulic valve is used to deliver high-pressure fluid, first to one side of the piston in the actuator and then to the other side, forcing the actuator to move with a reciprocating motion.

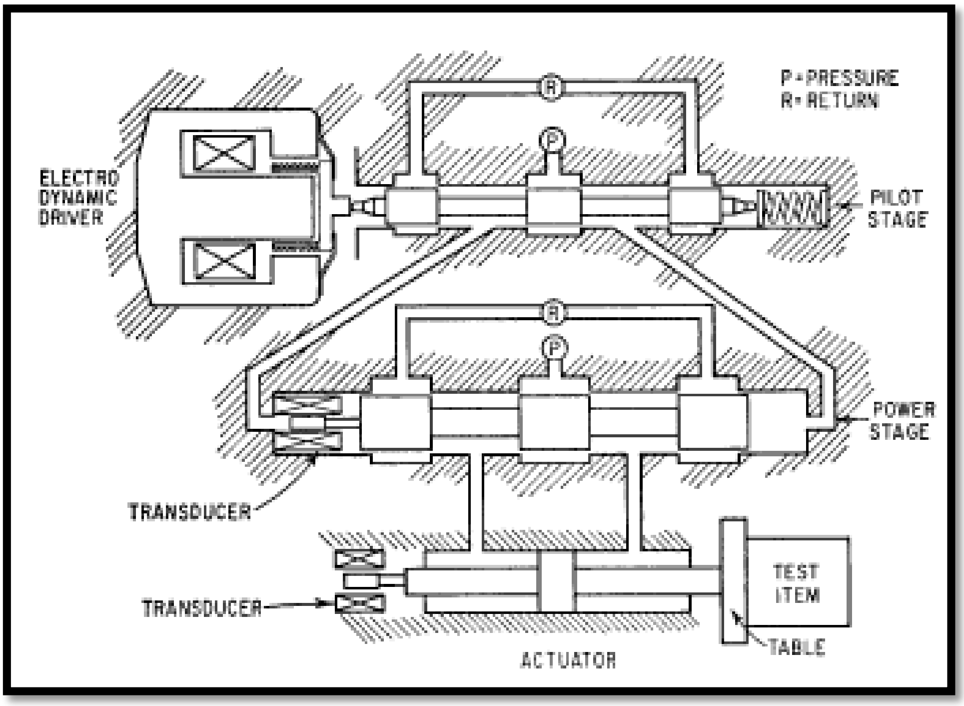


Figure 2.4: Schematic diagram for hydraulic shaker(Smallwood, 2010) [5]

2.3 Scotch Yoke Mechanism

Scotch yokes have been used for many years in a wide variety of uses. They may be actuated either manually or automatically. When a load is placed on the input rod of the scotch yoke by an actuator, sideward thrust causes the input rod and yoke arm to bow and twist. This increases the friction on the sliding nut. At the extreme positions of travel of the sliding nut, the bowing and twisting become severe and the yoke arm tends to bind.(Carlson, 1978) [1]

The “Scotch Yoke” is a linkage that achieves exact simple harmonic motion in response to a constant speed rotation. Figure 2.5 shown the replacing the joint (full joint to half joint) at the end of Crank 2 increases the degrees of freedom by one, but removing Link 3 reduces the degrees of freedom by one, resulting in a linkage that maintains one degree of freedom. (Norton, 2008) [4]

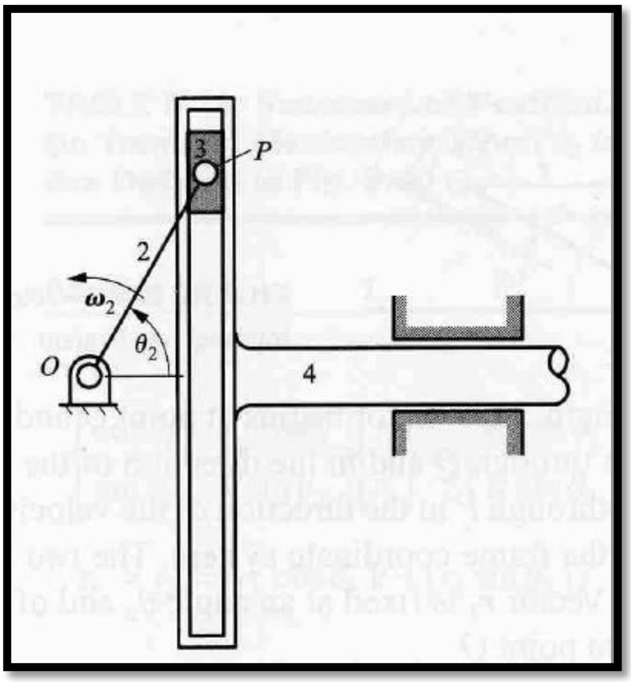


Figure 2.5: Scotch yoke mechanism (Waldron & Kinzel, 2003) [6]

2.4 Equation of motion of scotch yoke

Figure 2.5 shown a scotch yoke mechanism, angular velocity ω_2 must be find using a speed detector instrument such as tachometer. The $\theta_2 = 60^o$ since $\theta_1 = 0^o$ and $\theta_3 = 90^o$ .Figure 2.6 shown the detail of the vector diagram of scotch yoke mechanism.

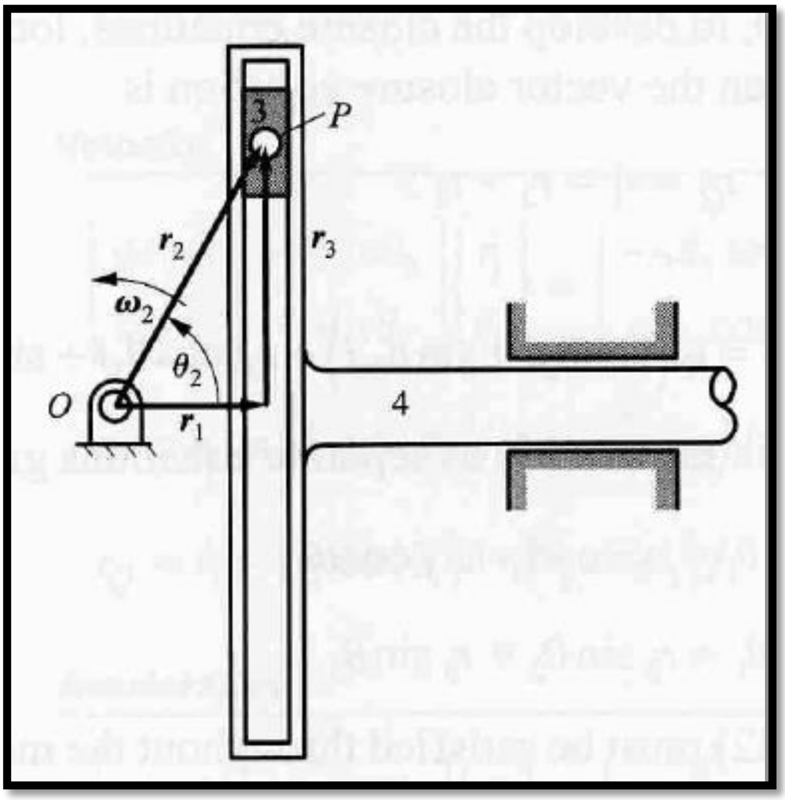


Figure 2.6: Vector diagram for scotch yoke (Waldron & Kinzel, 2003) [6]

From figure 2.6, the velocity and acceleration of link 4 can be determined since the angular velocity, ω_2 is constant. The equation can be deriving from this vector diagram where r_2 the displacement from the centre and the crank pin slider. The equations are:

Equation [2.1] to determine displacement

$$\begin{bmatrix} \cos\theta_1 & \cos\theta_3 \\ \sin\theta_1 & \sin\theta_3 \end{bmatrix} \begin{Bmatrix} r_1 \\ r_3 \end{Bmatrix} = \begin{Bmatrix} r_2\cos\theta_2 \\ r_2\sin\theta_2 \end{Bmatrix}$$

Eq [2.1]

Equation [2.2] to determine speed

$$\begin{bmatrix} \cos\theta_1 & \cos\theta_3 \\ \sin\theta_1 & \sin\theta_3 \end{bmatrix} \begin{Bmatrix} \dot{r}_1 \\ \dot{r}_3 \end{Bmatrix} = \begin{Bmatrix} -r_2\dot{\theta}\sin\theta_2 \\ r_2\,\dot{\theta}\cos\theta_2 \end{Bmatrix}$$

Eq [2.2]

Equation [2.3] for acceleration

$$\begin{bmatrix} \cos\theta_1 & \cos\theta_3 \\ \sin\theta_1 & \sin\theta_3 \end{bmatrix} \begin{Bmatrix} \ddot{r}_1 \\ \ddot{r}_3 \end{Bmatrix} = \begin{Bmatrix} -r_2\ddot{\theta}^2\sin\theta_2 - r_2\dot{\theta}^2\cos\theta_2 \\ r_2\,\ddot{\theta}^2\cos\theta_2 - r_2\,\dot{\theta}^2\sin\theta_2 \end{Bmatrix}$$

Eq [2.3]

CHAPTER 3

3.0 Methodology

3.1 Introduction

This chapter will cover the details explanation of methodology that is being used to make this project complete and working well. A good explanation will give more information about how the methodology can accomplish a perfect result. Methodology is very important because it can influence the result. This direct drive shaker project is consist mechanical part development.

3.2 Hardware Development

In order to develop any product, In order to design the mechanical part of direct drive shaker, a lot of studies have been done to choose a desirable design. In this project the scotch yoke mechanism was used as a rotation to linear movement conversion. Beside that the type of axis must be selected, the z-axis is chosen as this shaker will only move toward upward and downward direction.

3.3 Catia Design

Using CATIA V5 software, designing process was done and there are 7 parts just only for the scotch yoke mechanism. Figure 3.1: shown the scotch yoke mechanism design using Catia V5 software. For the detail drawing refer to Appendix C.

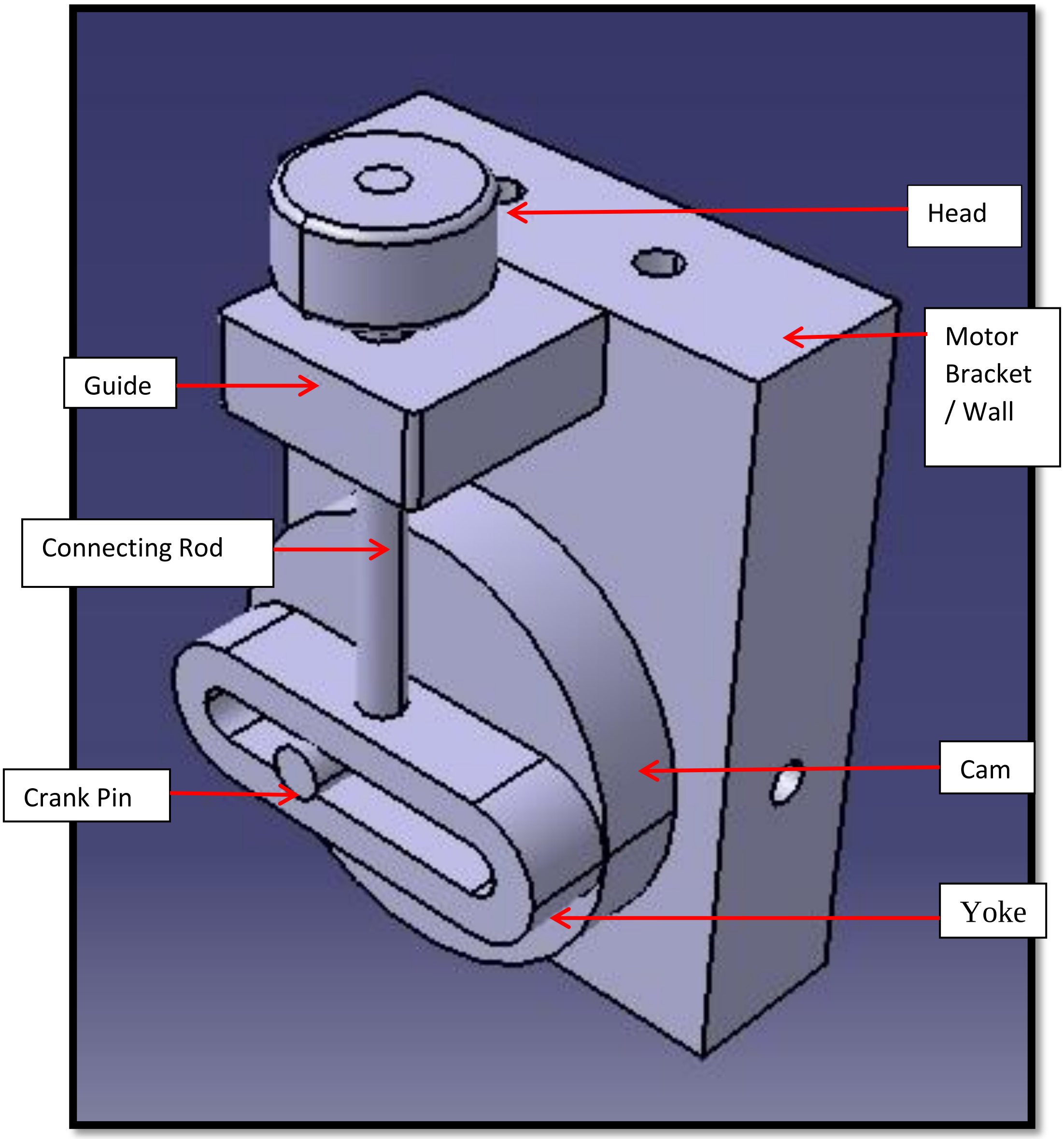


Figure 3.1: Mechanism design

The frame will be covering the mechanism as a safety so the mechanism cannot be touch because it may change d alignment of the scotch yoke. Figure 3.2: shown the complete product design of the shaker.

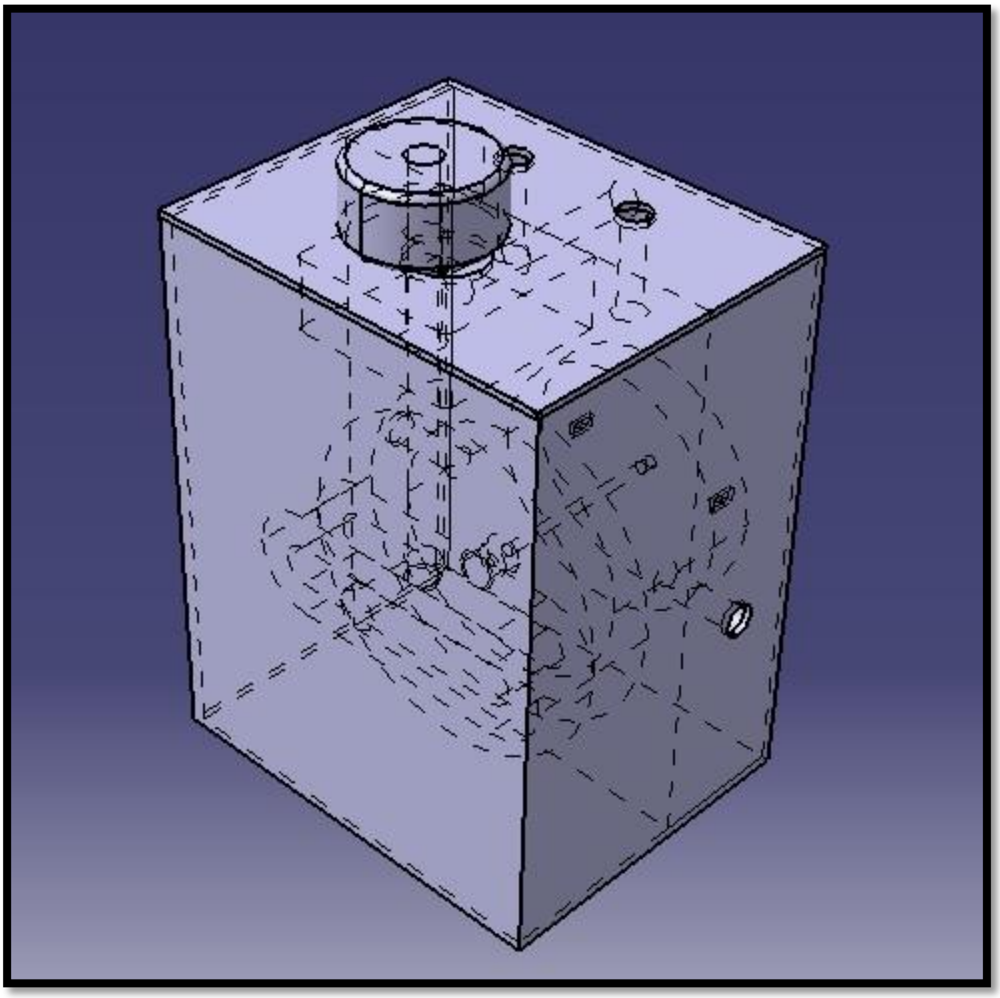


Figure 3.2: Complete design of shaker

Last but not least the circuit box design. This circuit box design was made from an acrylic. This will be a safety the place for the circuit and it will be protected from people to touch the circuit. Figure 3.3: shown the design of the shaker circuit box.

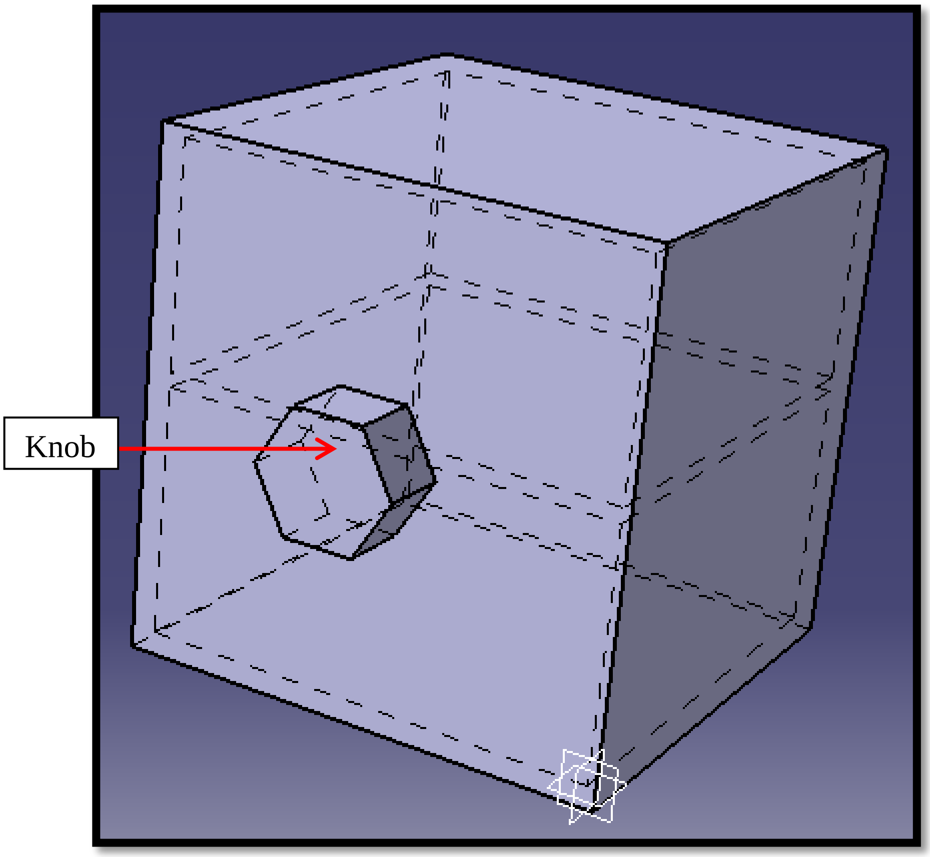


Figure 3.3: Design of the shaker circuit box.

3.4 Part Detail

Table 3.0 is describe the detail of the part have been design and also the function of each part that used in this shaker. For the detail dimension refer to Appendix C.

Table 3.1: Part Detail

Part	Dimension (mm)	Material	Function
Motor Bracket	20X60X80	Al	Hold motor and also as wall between motor and moving mechanism
Cam	⌀50mm	Plastic RP	As coupling to transfer rotation movement from motor to yoke
Yoke	Pocket size = 5mm	Plastic RP	To convert rotation to linear motion
Crank Pin	⌀5mm	Iron	As a slider to force yoke
Connecting Rod	⌀5mm length 60mm	Iron	To further the linear movement
Guide	Hole ⌀5mm	Al	To ensure rod is move straight
Head	Hole ⌀5mm	Plastic Rp	Attach testing element
Frame	60X50X80 mm 60X50 mm	Stainless Stell	Housing to cover the moving mechanism

3.5 Material Selection

Some of the part must be design using Plastic (Rapid Prototyping). The part will be using RP is Cam and its Yoke. This is because of to ensure the load is not high so motor can transfer the maximum speed to the Cam and Yoke.

As some part is using aluminium material the part is motor bracket and guide. The motor bracket is using aluminium because it need be high strength to avoid motor from forcing loss from it bracket. For the guide it needs to be strong because there is a lot of friction in sliding the connecting rod, so when using aluminium it will avoid it from wear.

The iron part is choosing because to it needs to be strong so it cannot break. The iron part is use as shaft that connecting head and yoke. This part is using iron because yoke will drive the shaft with a very high speed. So using steel the shaft will not break.

Last but not least, the housing is made from sheet steel plate because to avoid oxidation. A part from that the sheet steel plate is easy to bend because it only 1mm thickness. For the detail of the dimension of this part and its material refer to Appendix C.

3.6 Motor Selection

The motor that is in this project is DC geared motor SPG30 series. Some modification is needed to give more speed for the motor. The gear was dismantling so the speed is higher. From the datasheet in Appendix A, the motor can be up to 7000 rpm. That mean this shaker can be drive a frequency about 100 Hz. Figure 3.4 shown the motor of SPG30 series.

The price of this motor is RM53. The motor that use in this project is SPG30-150K. This motor input voltage is 12V. DC motor was use because of the characteristic of continues running. This motor was selected because of its maximum no load speed that is 7000 rpm.

Figure 3.4: SPG30 series [7]

3.7 Machine Used

3.7.1 Milling Machine

First machine would be a milling machine. Makino KE55 will be used in order to fabricate bracket for motor and also guide. Using milling machine can give an accurate vertical machining centre can perform a wide range of machining operations, including oblique and circular cutting as well as tapping without using attachments. On single part runs, it outperforms the competition in speed, accuracy and machining reliability.

Figure 3.5: Milling Machine [8]

3.7.2 Shearing Machine

This machine is use for cutting the steel plate in order to make housing for the shaker. LVD shearing machine is the ideal solution for cutting the plate type material. The machine will be use was CS Series LVD-HD shearing machine .This machine is easy to use and the range up to 1000mm. The LVD CS Series was high quality standards, utilizing electronic, electrical, hydraulic and pneumatic components that meet the stringent accuracy and reliability requirements. Figure 3.6 shown the shearing machine will be use.

Figure 3.6: Shearing Machine [9]

3.7.3 Rapid Prototyping/ 3D printer

Rapid Prototyping is use in order to fabricate the cam and yoke. In order to reduce the weight so the motor can run without heavy load. The plastic material was the best solution because it has a light weight. A part form that Rapid prototyping will reduce the time production because it faster than using machining that have a lot of steps. The design was draw with CATIA V5 software and the convert to STL format file in order to do rapid prototyping. Figure 3.7: shown the type of Rapid Prototyping machine use that is Makerbot Replicator 2.

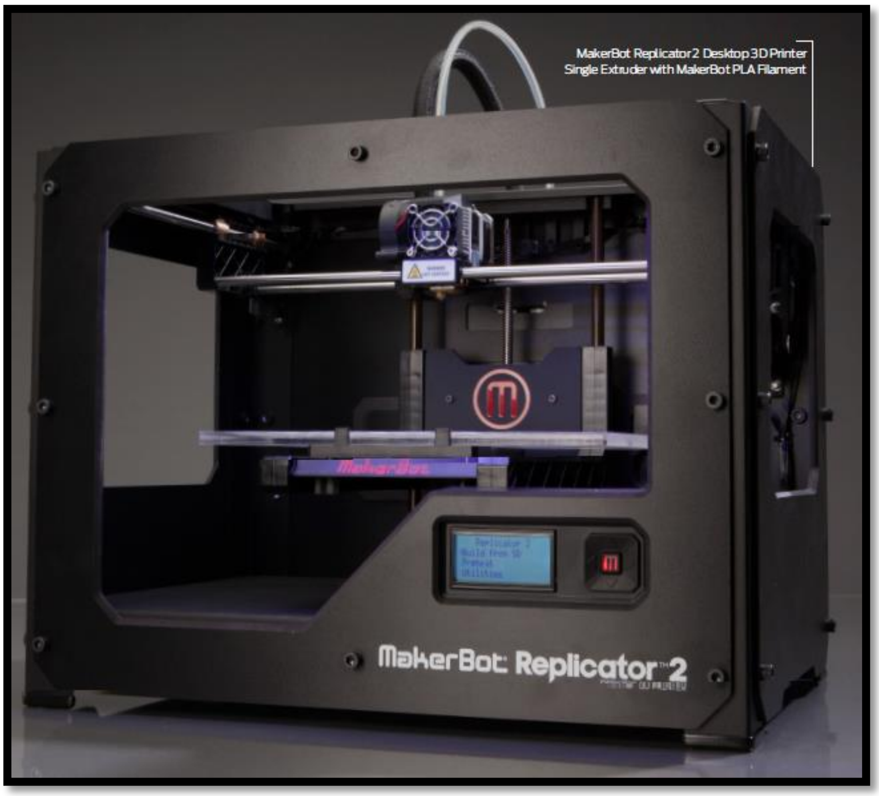


Figure 3.7: Makerbot Replicator 2 [10]

3.8 Process Flow Chart

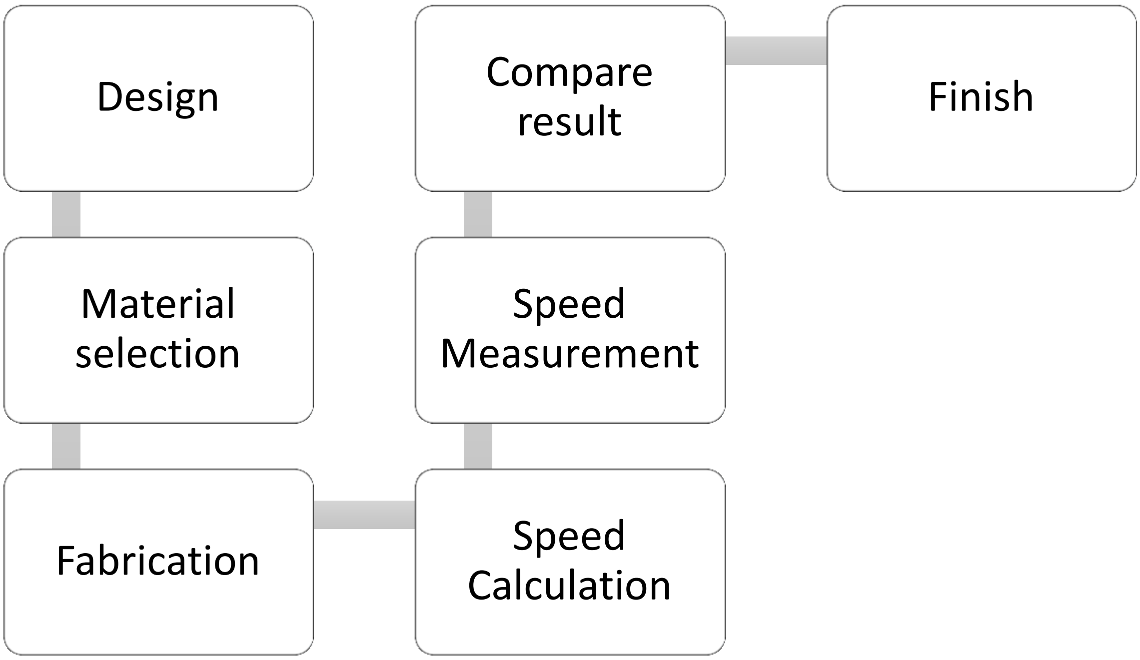


Figure 3.8: Process flow chart

3.9 Equation of motion

In every moving part, there will be a motion. The motion can be calculated by using an equation that is equation of motion. In this scotch yoke mechanism, the equation can be deriving for link 4 since there is some parameter that can we adjust by calculating the RPM using tachometer. Using the vector diagram in Figure 2.5 we can calculated the displacement, velocity and also acceleration of link 4.

The angular velocity of the Cam can be determined by using speed testing instrument that is Tachometer. The parameter that we can determine is $\theta_2 = 60^o$ since $\theta_1 = 0^o$ and $\theta_3 = 90^o$ as the given from the vector diagram. In this case we have been fixed the distance for that $r_2 = 5\ mm$. Where r_2 is the distance of the crank pin from the centre of the Cam.

By using the previous equation of motion in Chapter 2 that is shown below, we can calculated the displacement for Link 4 that mean the shaker movement that is r_1 and also the velocity, $\dot{r}$ and acceleration, $\ddot{r_1}$

Equation [2.1] to determine displacement

$$\begin{bmatrix} \cos\theta_1 & \cos\theta_3 \\ \sin\theta_1 & \sin\theta_3 \end{bmatrix} \begin{Bmatrix} r_1 \\ r_3 \end{Bmatrix} = \begin{Bmatrix} r_2\cos\theta_2 \\ r_2\sin\theta_2 \end{Bmatrix} \qquad \text{Eq [2.1]}$$

Equation [2.2] to determine speed

$$\begin{bmatrix} \cos\theta_1 & \cos\theta_3 \\ \sin\theta_1 & \sin\theta_3 \end{bmatrix} \begin{Bmatrix} \dot{r}_1 \\ \dot{r}_3 \end{Bmatrix} = \begin{Bmatrix} -r_2\dot{\theta}\sin\theta_2 \\ r_2\,\dot{\theta}\cos\theta_2 \end{Bmatrix} \qquad \text{Eq [2.2]}$$

Equation [2.3] to determine acceleration

$$\begin{bmatrix} \cos\theta_1 & \cos\theta_3 \\ \sin\theta_1 & \sin\theta_3 \end{bmatrix} \begin{Bmatrix} \ddot{r}_1 \\ \ddot{r}_3 \end{Bmatrix} = \begin{Bmatrix} -r_2\ddot{\theta}^2\sin\theta_2 - r_2\dot{\theta}^2\cos\theta_2 \\ r_2\,\ddot{\theta}^2\cos\theta_2 - r_2\,\dot{\theta}^2\sin\theta_2 \end{Bmatrix} \qquad \text{Eq [2.3]}$$

Chapter 4

4.0 Result and Discussions

4.1 Introduction

This chapter contains calculation of the shaker speed and acceleration and the hardware fabrication. The results that can be achieved at the end of this project by completed the fabrication and the calculation base on the equation of motion that have been discussed in chapter 3. This chapter also discussion on all the results obtained and the limitation of the project. All discussions are concentrating on the result and performance of the direct drive shaker.

4.2 Calculation of the shaker speed and acceleration

Figure 4.1: shown the vector diagram of the shaker mechanism that is scotch yoke. The parameter has been measure that is speed of the Cam using the tachometer. The Cam was mark with black permanent marker so the tachometer can read the speed because the tachometer has been used is using Digital Photo Sensor. From that result the speed max of the Cam, ω_2 is 3000rpm.

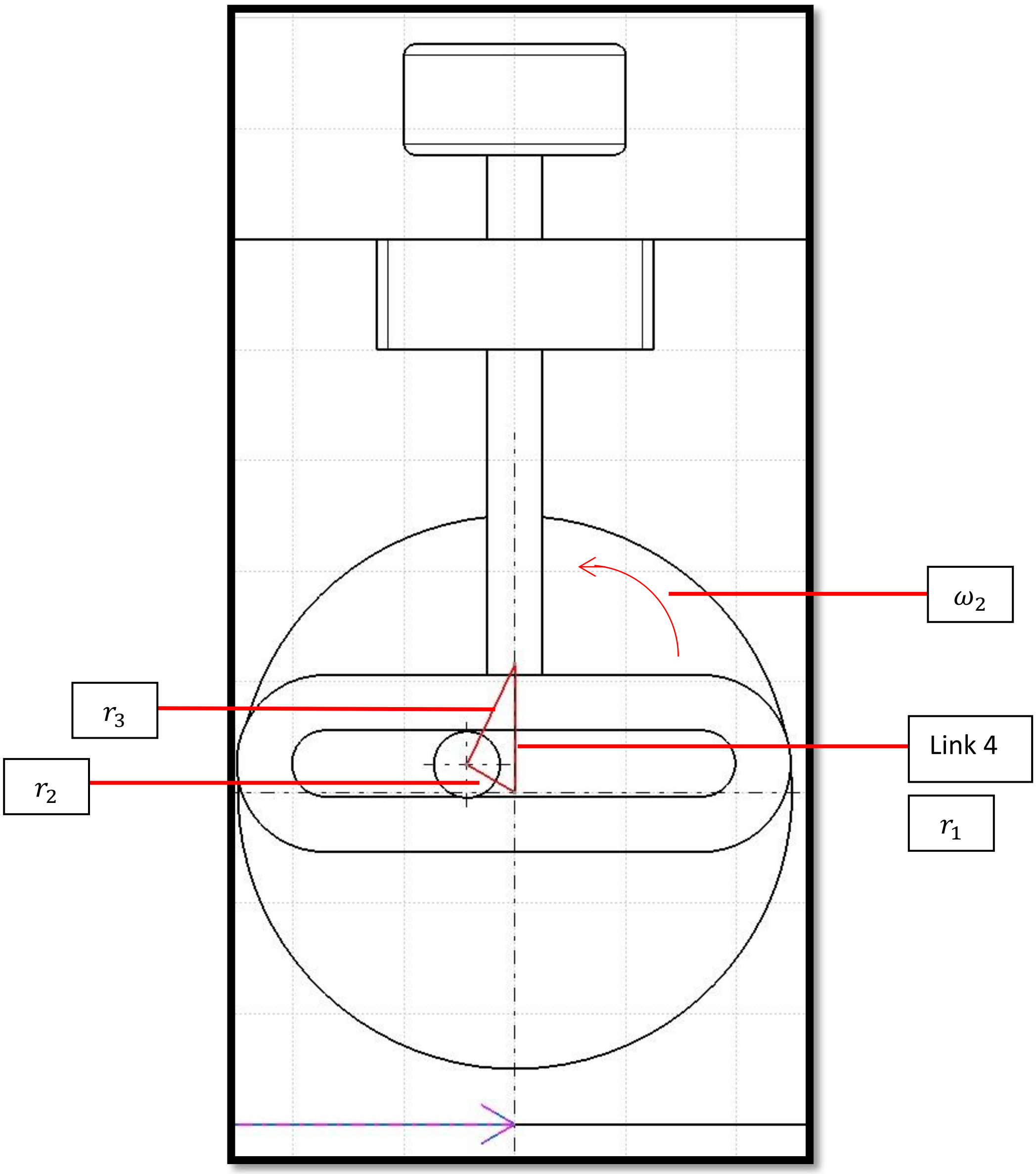


Figure 4.1: Free body diagram of scotch yoke

The value of link 2 from radius can be determined that is $r_2 = 5mm$. The value of r_1 and r_3 can be calculated. Given below the value ofθ_1, θ_2 and θ_3

$\theta_1 = 0^\circ$, $\theta_2 = 60^\circ$ and $\theta_3 = 90^\circ$

Hence that speed of the Cam is $\omega_2 = \dot{\theta}_2 = 3000\ rpm = 314\frac{rad}{s}$

The acceleration in Link 2, $\ddot{\theta}_2$ is 0 since ω_2 is constant.

Using equation [2.1] from chapter 2

Equation [2.1]is to determine displacement

$$\begin{bmatrix} \cos\theta_1 & \cos\theta_3 \\ \sin\theta_1 & \sin\theta_3 \end{bmatrix} \begin{Bmatrix} r_1 \\ r_3 \end{Bmatrix} = \begin{Bmatrix} r_2\cos\theta_2 \\ r_2\sin\theta_2 \end{Bmatrix}$$

$$\begin{bmatrix} \cos 0^\circ & \cos 90^\circ \\ \sin 0^\circ & \sin 90^\circ \end{bmatrix} \begin{Bmatrix} r_1 \\ r_3 \end{Bmatrix} = \begin{Bmatrix} 5\cos 60^\circ \\ 5\sin 60^\circ \end{Bmatrix}$$

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{Bmatrix} r_1 \\ r_3 \end{Bmatrix} = \begin{Bmatrix} 2.50 \\ 4.33 \end{Bmatrix}$$

Therefore the value of r_1 and r_3 are

$$r_1 = 2.50\ mm$$
$$r_3 = 4.33\ mm$$

From the result the distance between the link 4 and the radius of the cam is 2.50mm.

Using equation [2.2] from chapter 2

Equation [2.2] is to determine speed

$$\begin{bmatrix} \cos\theta_1 & \cos\theta_3 \\ \sin\theta_1 & \sin\theta_3 \end{bmatrix} \begin{Bmatrix} \dot{r}_1 \\ \dot{r}_3 \end{Bmatrix} = \begin{Bmatrix} -r_2\dot{\theta}\sin\theta_2 \\ r_2\,\dot{\theta}\cos\theta_2 \end{Bmatrix}$$

$$\begin{bmatrix} \cos 0^\circ & \cos 90^\circ \\ \sin 0^\circ & \sin 90^\circ \end{bmatrix} \begin{Bmatrix} \dot{r}_1 \\ \dot{r}_3 \end{Bmatrix} = \begin{Bmatrix} -5\dot{\theta}\sin 60^\circ \\ 5\,\dot{\theta}\cos 60^\circ \end{Bmatrix}$$

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{Bmatrix} \dot{r}_1 \\ \dot{r}_3 \end{Bmatrix} = \begin{Bmatrix} -5(314)\sin 60^\circ \\ 5(314)\cos 60^\circ \end{Bmatrix}$$

Therefore the value of $\dot{r}_1$ and $\dot{r}_3$ are

$$\dot{r}_1 = -1360\ \frac{mm}{s}$$

$$\dot{r}_3 = 785\frac{mm}{s}$$

From that result the speed for the Link 4 or the shaker is 1360mm/s or 1.36m/s. The negative sign mean the link 4 or the shaker is decreasing in length with increasing with time

Using equation [2.3] from chapter 2

Equation [2.3] is to determine acceleration

$$\begin{bmatrix} \cos\theta_1 & \cos\theta_3 \\ \sin\theta_1 & \sin\theta_3 \end{bmatrix} \begin{Bmatrix} \ddot{r}_1 \\ \ddot{r}_3 \end{Bmatrix} = \begin{Bmatrix} -r_2\ddot{\theta}^2 \sin\theta_2 - r_2\dot{\theta}^2 \cos\theta_2 \\ r_2\,\ddot{\theta}^2 \cos\theta_2 - r_2\,\dot{\theta}^2 \sin\theta_2 \end{Bmatrix}$$

$$\begin{bmatrix} \cos 0^\circ & \cos 90^\circ \\ \sin 0^\circ & \sin 90^\circ \end{bmatrix} \begin{Bmatrix} \ddot{r}_1 \\ \ddot{r}_3 \end{Bmatrix} = \begin{Bmatrix} -r_2\ddot{\theta}^2 \sin\theta_2 - r_2\dot{\theta}^2 \cos\theta_2 \\ r_2\,\ddot{\theta}^2 \cos\theta_2 - r_2\,\dot{\theta}^2 \sin\theta_2 \end{Bmatrix}$$

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{Bmatrix} \ddot{r}_1 \\ \ddot{r}_3 \end{Bmatrix} = \begin{Bmatrix} -5(0)(\sin 60^\circ) - 5(314^2)\,(\cos 60^\circ) \\ 5(0)(\cos 60^\circ) - 5\,(314^2)(\sin 60^\circ) \end{Bmatrix}$$

Therefore the value of $\ddot{r}_1$ and $\ddot{r}_3$ are

$$\ddot{r}_1 = 0.25\frac{m}{s^2}$$

$$\ddot{r}_3 = 42.7\frac{m}{s^2}$$

From that result the acceleration for the Link 4 or the shaker is 0.25m/s². The negative sign mean the link 4 or the shaker is decreasing in length with increasing with time.

In order to calculate the speed of the shaker in RPM, there is other formula to calculate the RPM. Given r= 5mm. So the speed for the shaker in RPM is by using equation [4.1];

$$v = r\omega \qquad [4.1]$$

Where $v = linear\ velocity\ (shaker\ speed)$

$r = radius\ (meter)$

$\omega = angular\ velocity$

So the velocity in RPM

$$v = r\omega$$

$$1.36 \quad = (0.005)(\omega)$$

$$\omega = \frac{1.36}{0.05} = 2720\ RPM$$

From the data above we can conclude there is a small different with the theory and the actual result that measure by using tachometer. This is because of the light intensity that pointing the marking is not too consistent. Table 4.1: shown the comparison or the speed and frequency for theory and actual data.

Table 4.1: Result

Shaker Speed (rpm) / frequency(Hz)	
Theory	Actual
2720/ 45.33	2580 / 43.00

4.3 Hardware Fabrication

The fabrication of the shaker consists 1 week in total. There is some problem when machining process start. The first problem is the vibration is too high and can make the shaker moving because it vibration is forcing it to move. For the solution, the bottom part of the shaker is cover with anti-slip that is a rubber type stand. This will reduce the shaker to move because of the vibration.

The second problem encounter the shaker is the vibration produces very high noise. This is due to the collision between the housing and the yoke. Since the yoke is independent mean there is no guide in between, the yoke is tend to touch the housing that make from steel plate. For the solution, the yoke was reducing in size, so it not touches the wall of the housing.

As the fabrication complete, the last part must be finishing part. The housing is polish using sandpaper to remove a scratch from the effect of machining. Figure 4.2; shown the mechanism and Figure 4.3 shown the complete product of the shaker.

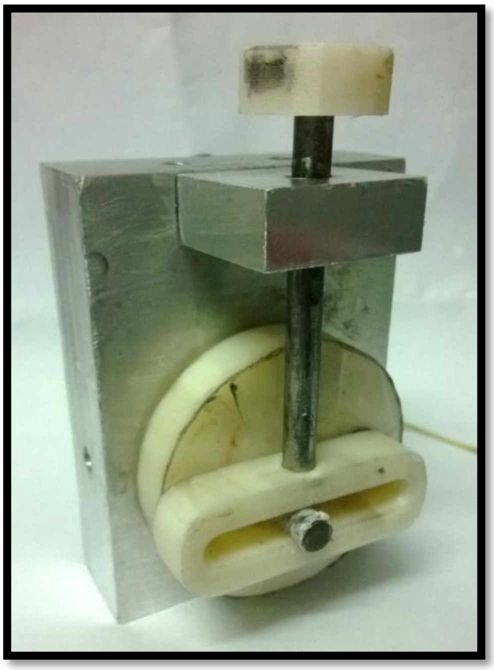


Figure 4.2: Mechanism fabrication

Figure 4.3: Complete shaker fabrication

4.4 Discussion

The shaker in this project was basically is a z-axis movement or in other word is is moving upward and downward. The type of this shaker is a direct drive shaker. Dc motor is the main part of movement for this shaker. The scotch yoke is the mechanism of movement for the shaker. It converts rotational motion (motor) to a linear motion (shaker).

This shaker has a maximum frequency that is about 50 Hz. This is below the targeted frequency that has been plan that is 100Hz. The problem is because of the DC motor did not reach its maximum no load speed that shown in datasheet in Appendix A. After giving different current to the motor, it only give a maximum RPM about 3000 Hz.

In my opinion, the motor efficiency is below than the datasheet given is because of the design of the motor bracket. Since the motor bracket for this shaker is holding the side of the motor, it may force the rotor and the stator to be move friction inside the motor itself. This has been happen since the screw compressing the motor stator and rotor.

For the solution is, when retighten the motor bracket screw, it must be not too tight, because it may influence the efficiency of the motor since there is stator and rotor move inside the motor.

As the conclusion, the higher RPM will give the higher frequency to the shaker since the frequency is speed divide by time that is 1 minute or 60 second.

Chapter 5

5.0 Conclusion and Recommendation

5.1 Conclusion

In this project, the objective was achieved successfully. The objective to design and to fabricate the direct drive shaker is completed. Every project have a limitation, one of the limitation for this project is high noise. High noise in this shaker is because of the collision between housing and the yoke. In order to reduce the noise is reduce the collision. By reduce collision the noise will be reduced.

The other limitation is motor speed and torque. Since the dc geared motor was modified that mean the gear is remove, the torque is motor is very low. Motor that still with its gear, the speed is very low. So for the solution, the higher torque and higher motor speed must be selected in order to increase the frequency for the shaker. The other solution is like what have been done in this project that is reducing the load by fabricating the scotch yoke mechanism using plastic rapid prototyping.

5.2 Recommendation

As mention before in limitation of project, the noise can be reduce by reducing the size of collision part. A part from that is by putting some lubricant so that the friction will be less. We cannot remove noise, we can only reduce it.

This type of shaker is very high in speed if we using a motor that have high rpm, but the problem is to find higher rpm motor with low cost is almost impossible. As for the recommendation, for getting higher frequency is to use electromagnetic shaker type. The electromagnetic shaker will have very low noise and almost not hearing any noise but the challenge is to the configuration of magnetic circuit. The frequency of the shaker can be higher by supplying more current to the circuit.

REFFERENCES

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APPENDIX –A

SPG30 Series

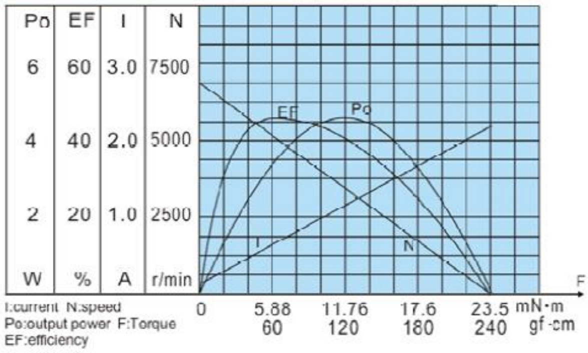
Cytron Technologies

Output Power: 1.1W

Weight: ~160g

Typical applications: Labal printers、auto shutter、welding machines、water meter IC card、grill、oven、cleaning machine、garbage disposers、household appliances、slot machines、money detector、automatic actuator、coffee machine、towel disposal、lighting、coin refund devices、peristaltic pump.

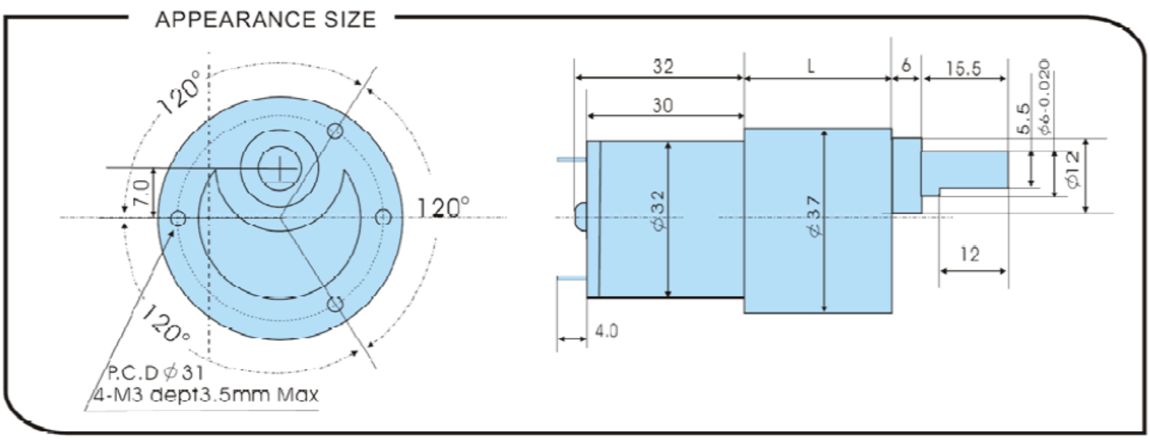
MOTOR CHARACTERISTICS



MOTOR TORQUE/SPEED/CURRENT

Rated voltage	12VDC
No load speed	7000r/min
No load current	70mA
Rated torque	60gf・cm 5.88mN・m
Rated current	410mA
Rated speed	5200r/min
Stall torque	240gf・cm 23.5mN・m
Stall current	1.8A

APPEARANCE SIZE



Order Option							
Order Code	Input Voltage	Rated		Weight (g)	Power (w)	Diameter (mm)	L (mm)
		Speed (RPM)	Torque (mN.m)				
SPG10-30K	6	440	29.4	10	-	12	24
SPG10-150K	6	85	107.9	10	-	12	24
SPG10-298K	6	45	176.5	10	-	12	24
SPG20-50K	12	130	58.8	60	0.6	27.2	-
SPG30-20K	12	185	78.4	160	1.1	37	22
SPG30-30K	12	103	127.4	160	1.1	37	22
SPG30-60K	12	58	254.8	160	1.1	37	25
SPG30-150K	12	26	588	160	1.1	37	27
SPG30-200K	12	17	784	160	1.1	37	27
SPG30-300K	12	12	1176	160	1.1	37	27
SPG50-20K	12	170	196	300	3.4	37	23
SPG50-60K	12	56	588	300	3.4	37	26
SPG50-100K	12	34	980	300	3.4	37	26
SPG50-180K	12	17	1960	300	3.4	37	28

Table A1: Motor Specification

APPENDIX – B

GANTT CHART

Table B1: GANTT CHART FOR FYP 1

Task/Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Briefing for FYP															
Introduction															
Literature review															
Mid-semester presentation															
Methodology															
Report writing															
Presentation of FYP1															

	Plan
	Actual

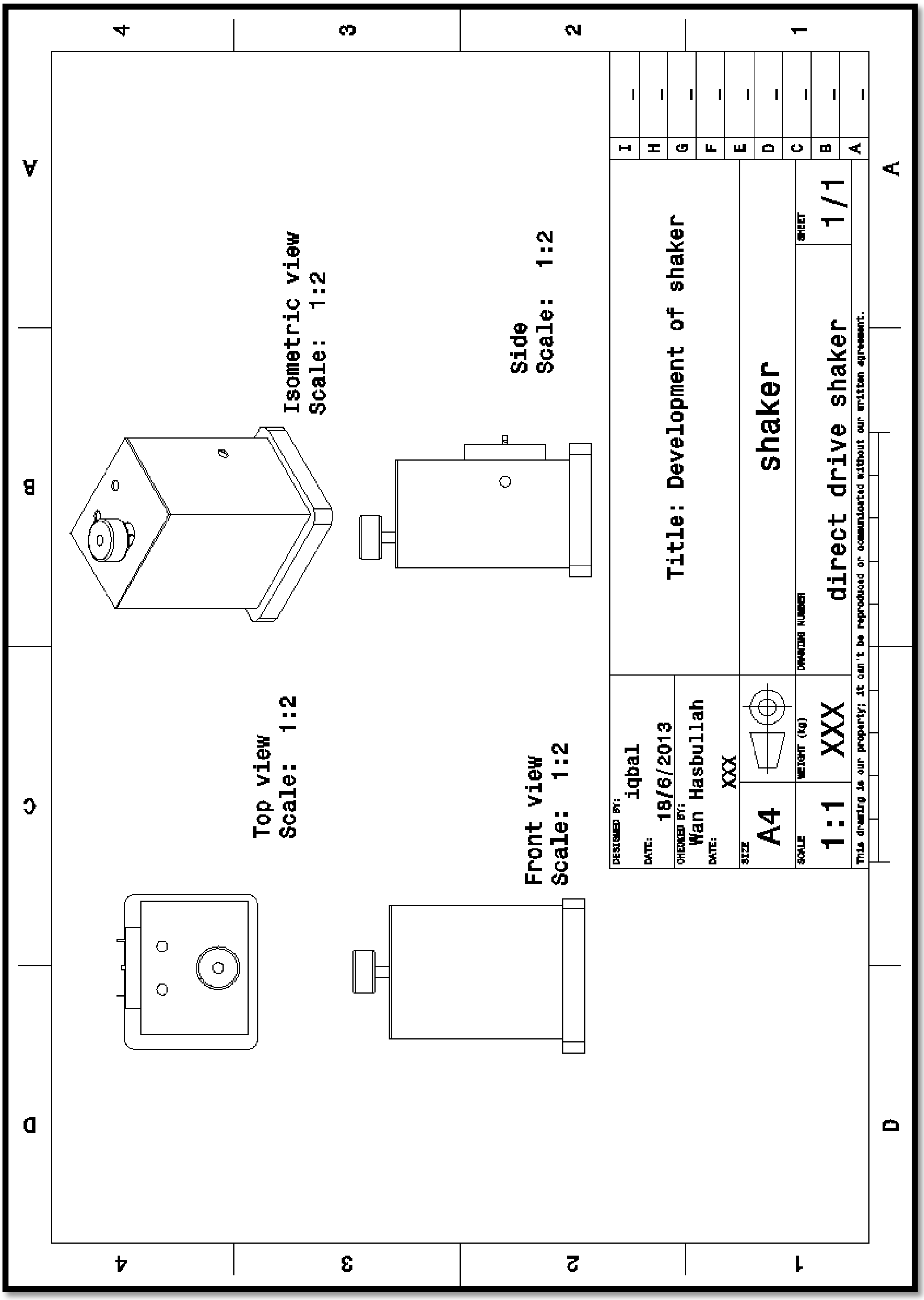
APPENDIX – B

Table B2: GANTT CHART FOR FYP 2

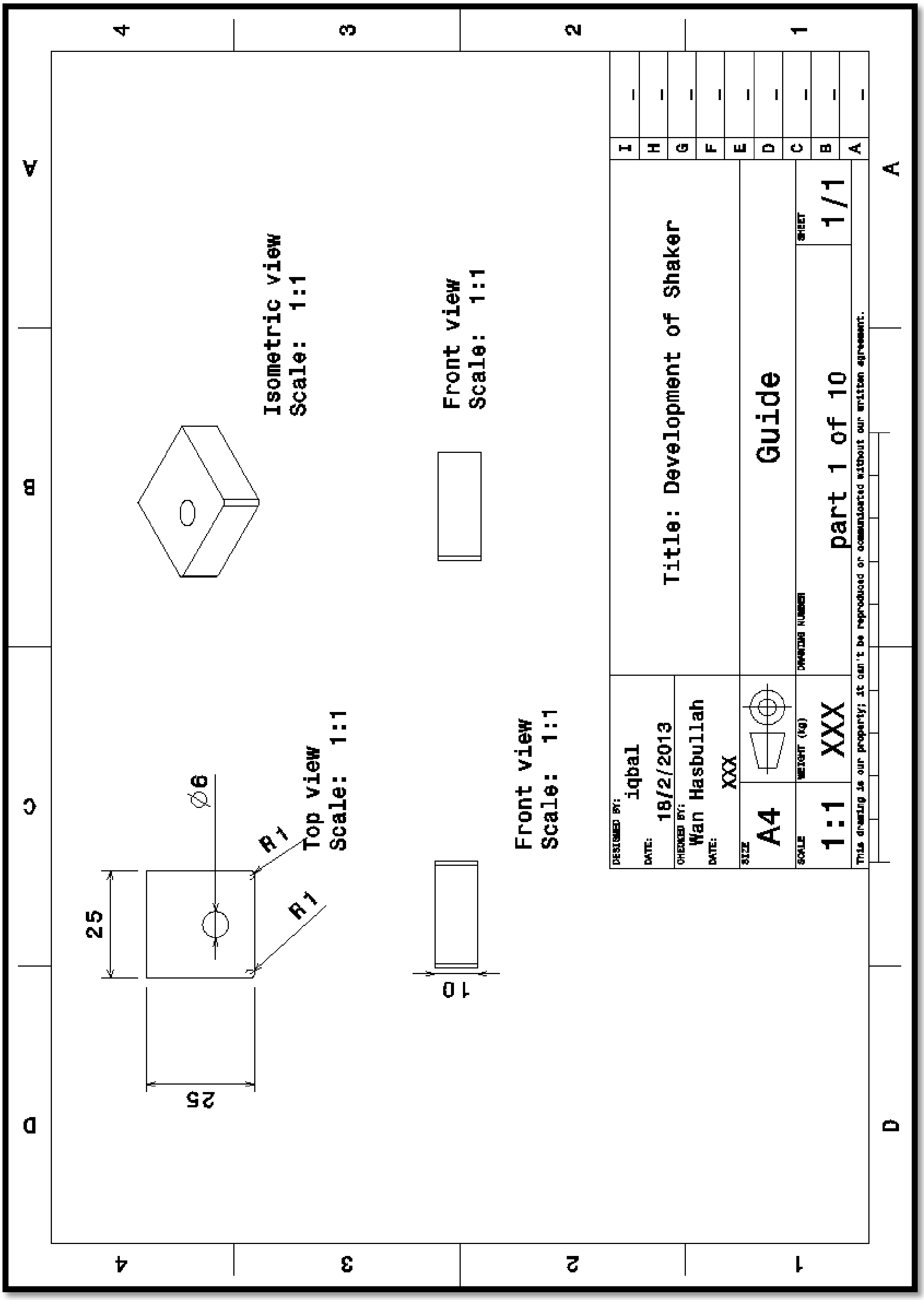
Task/Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Proceed fabrication of shaker																		
Report writing (Result and Conclusion)																		
Preparation of FYP Poster																		
Presentation of FYP 2 (Poster)																		
Record a video for video presentation																		
Report and Video submission																		

	Plan
	Actual

APPENDIX – C



Isometric view
Scale: 1:2
Side
Scale: 1:2
Top view
Scale: 1:2
Front view
Scale: 1:2
Title: Development of shaker
shaker
direct drive shaker
DESIGNED BY:
iqbal
DATE:
18/6/2013
CHECKED BY:
Wan Hasbullah
DATE:
XXX
SIZE
A4
SCALE
1:1
WEIGHT (kg)
XXX
DRAWING NUMBER
SHEET
1/1
This drawing is our property; it can't be reproduced or communicated without our written agreement.



Isometric view
Scale: 1:1
Front view
Scale: 1:1
Top view
Scale: 1:1
Front view
Scale: 1:1
25
25
Ø6
R1
R1
10
DESIGNED BY: iqbal
DATE: 18/2/2013
CHECKED BY: Wan Hasbullah
DATE: XXX
SIZE A4
SCALE 1:1
WEIGHT (kg) XXX
DRAWING NUMBER
SHEET 1/1
Title: Development of Shaker
Guide
part 1 of 10
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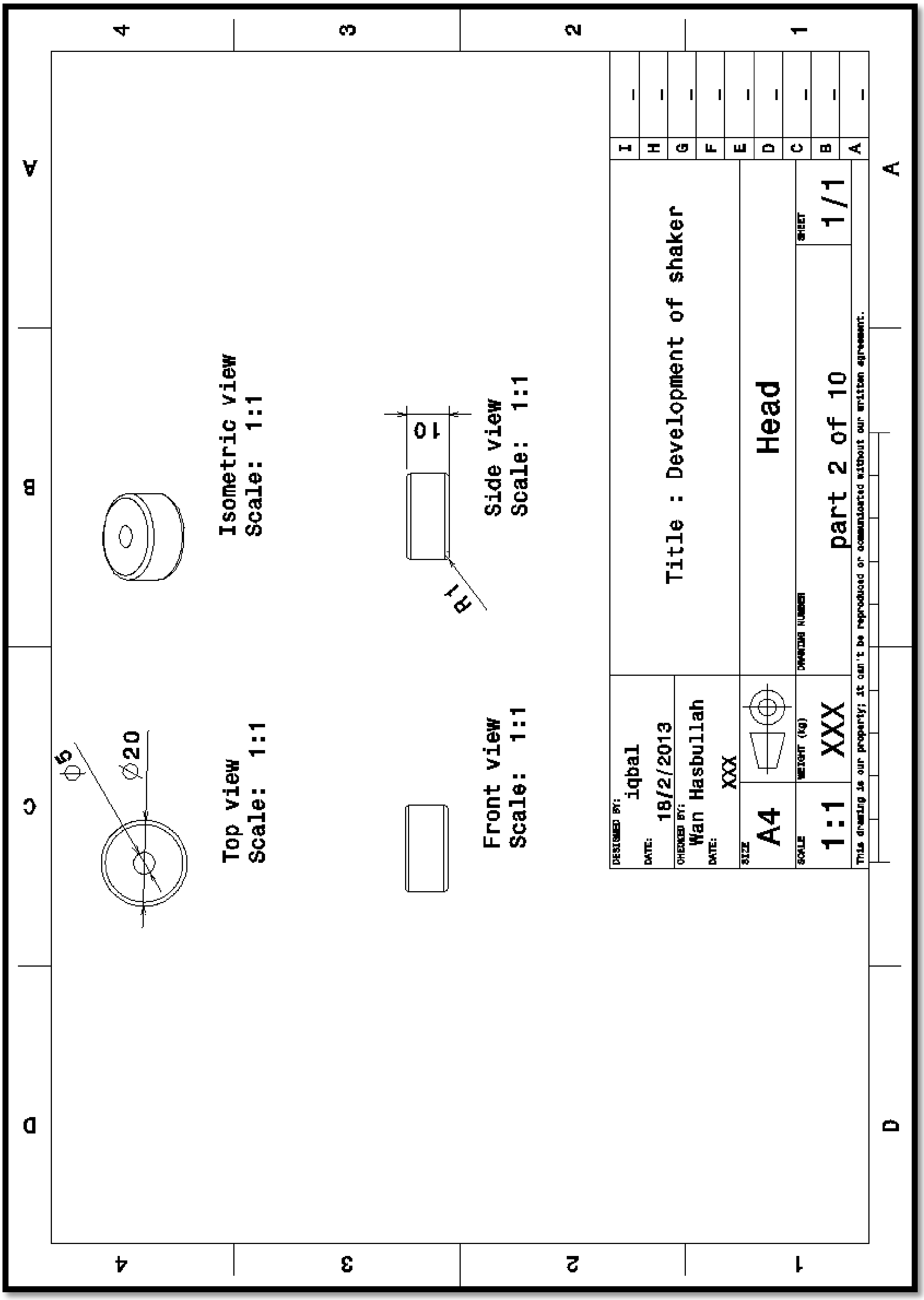
Isometric view
Scale: 1:1
Top view
Scale: 1:1
ϕ5
ϕ20
Front view
Scale: 1:1
Side view
Scale: 1:1
10
R1
Title : Development of shaker
Head
part 2 of 10
DESIGNED BY:
iqbal
DATE:
18/2/2013
CHECKED BY:
Wan Hasbullah
DATE:
XXX
SIZE
A4
SCALE
1:1
WEIGHT (kg)
XXX
DRAWING NUMBER
SHEET
1/1
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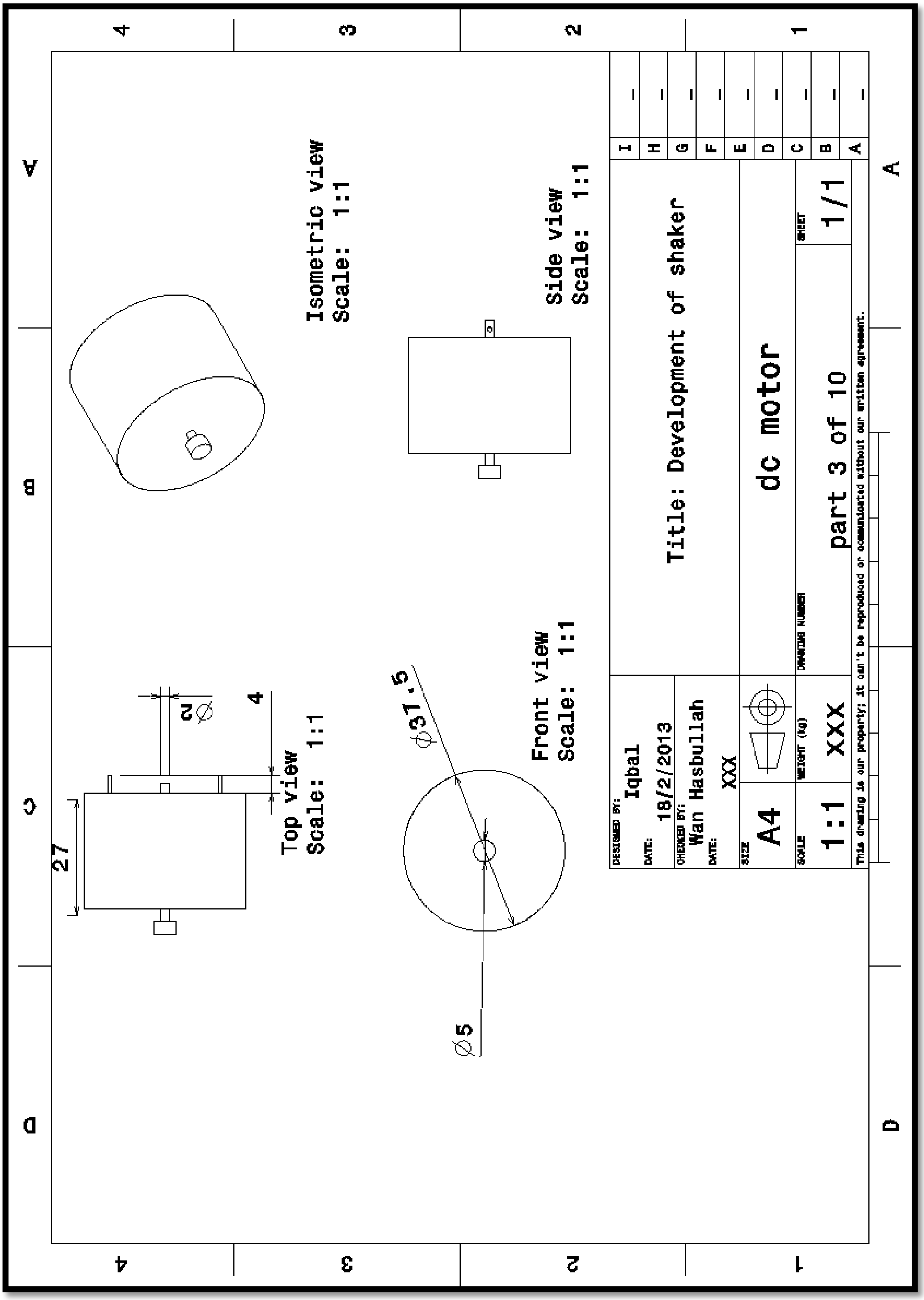
Isometric view
Scale: 1:1
Side view
Scale: 1:1
Top view
Scale: 1:1
Front view
Scale: 1:1
27
4
Ø2
Ø37.5
Ø5
Title: Development of shaker
dc motor
DESIGNED BY:
Iqbal
DATE:
18/2/2013
CHECKED BY:
Wan Hasbullah
DATE:
XXX
SIZE
A4
SCALE
1:1
WEIGHT (kg)
XXX
DRAWING NUMBER
part 3 of 10
SHEET
1/1
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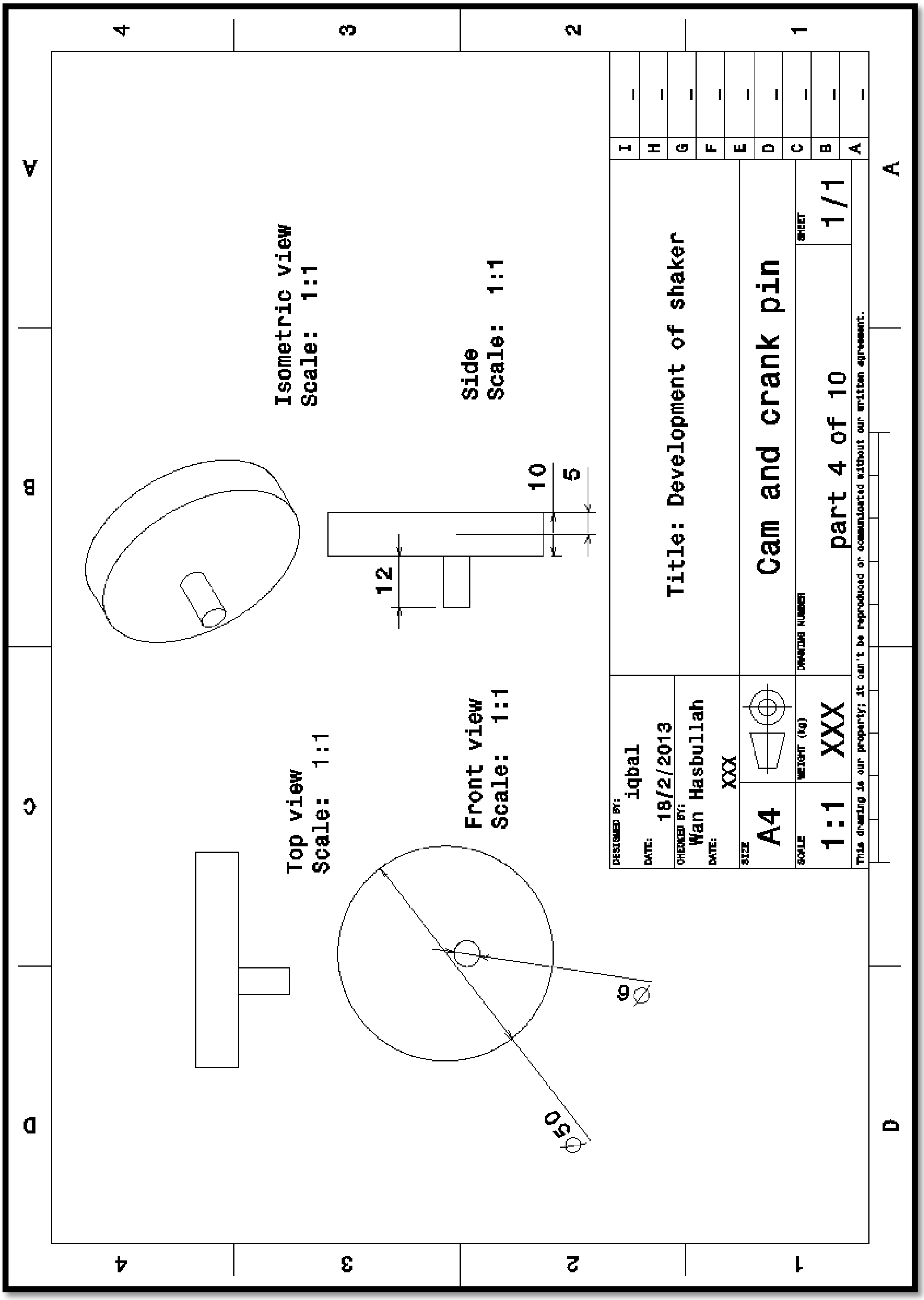
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Scale: 1:1
Side
Scale: 1:1
Top view
Scale: 1:1
Front view
Scale: 1:1
10
5
12
Ø6
Ø50
Title: Development of shaker
Cam and crank pin
part 4 of 10
DESIGNED BY:
iqbal
DATE:
18/2/2013
CHECKED BY:
Wan Hasbullah
DATE:
XXX
SIZE
A4
SCALE
1:1
WEIGHT (kg)
XXX
DRAWING NUMBER
SHEET
1/1
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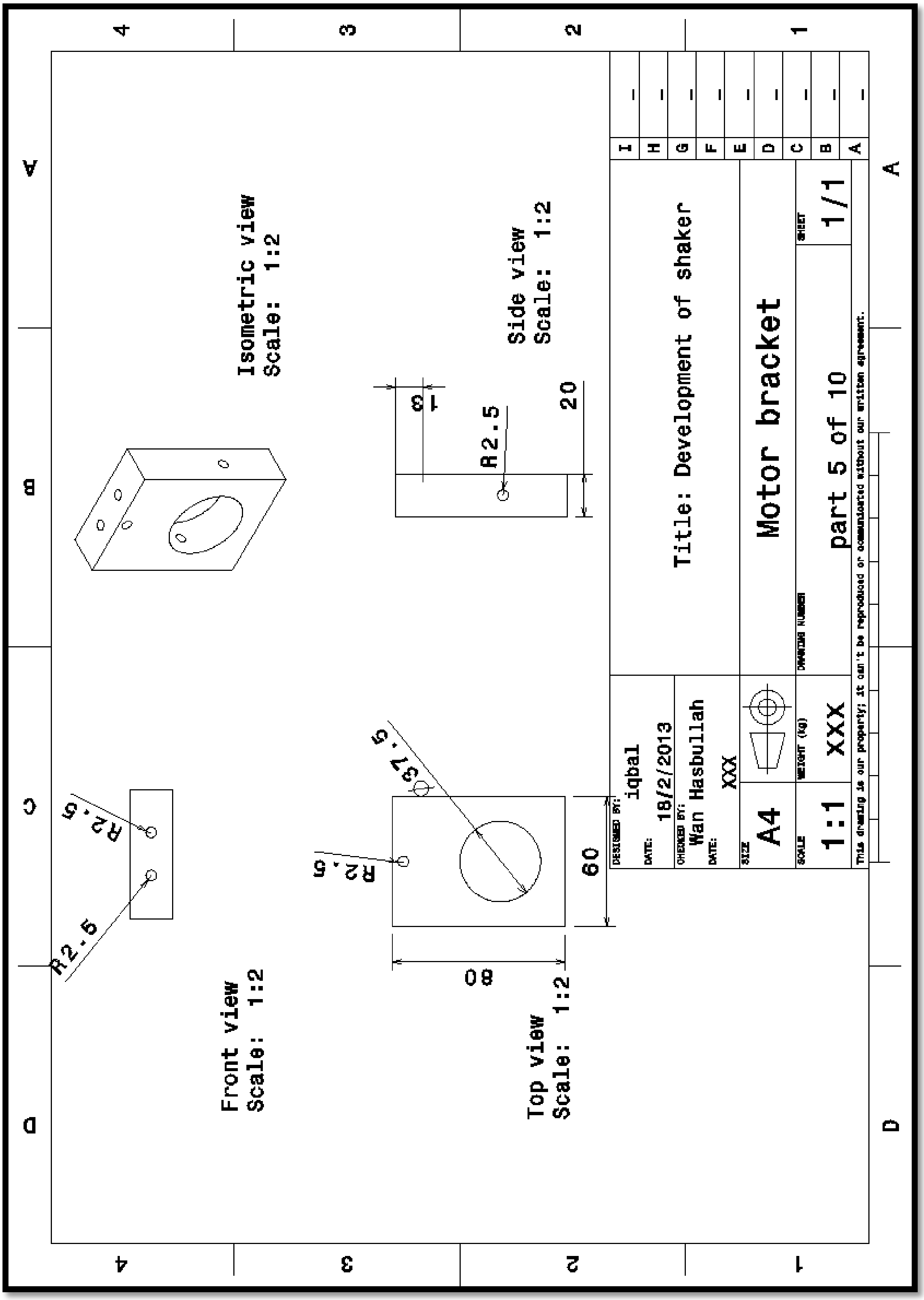
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Side view
Scale: 1:2
Front view
Scale: 1:2
Top view
Scale: 1:2
R2.5
37.5
80
60
20
Title: Development of shaker
Motor bracket
part 5 of 10
DESIGNED BY: iqbal
DATE: 18/2/2013
CHECKED BY: Wan Hasbullah
DATE: XXX
SIZE A4
SCALE 1:1
WEIGHT (kg) XXX
SHEET 1/1
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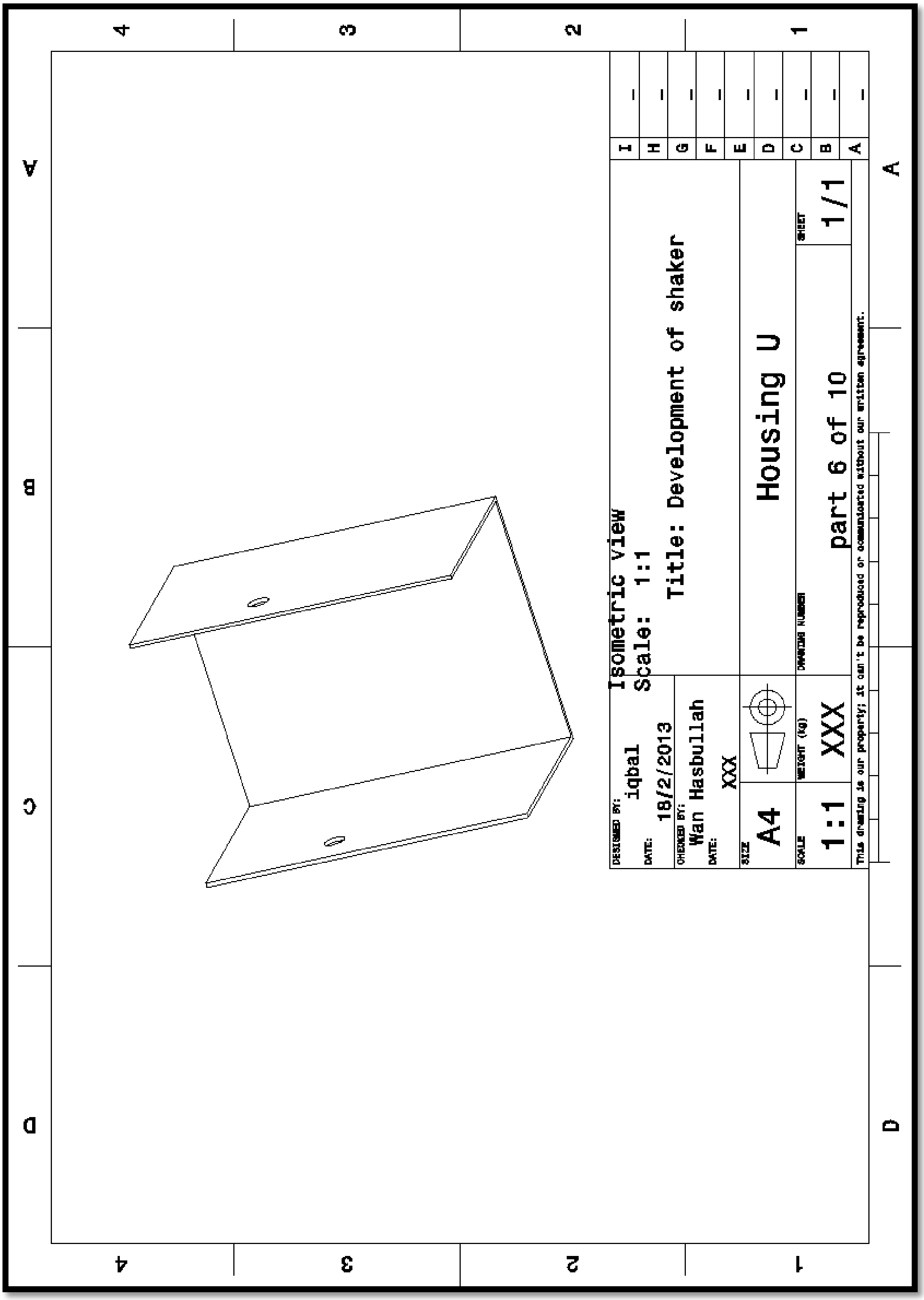
Isometric view
Scale: 1:1
Title: Development of shaker
DESIGNED BY: iqbal
DATE: 18/2/2013
CHECKED BY: Wan Hasbullah
DATE: XXX
SIZE A4
SCALE 1:1
WEIGHT (kg) XXX
DRAWING NUMBER
Housing U
part 6 of 10
SHEET 1/1
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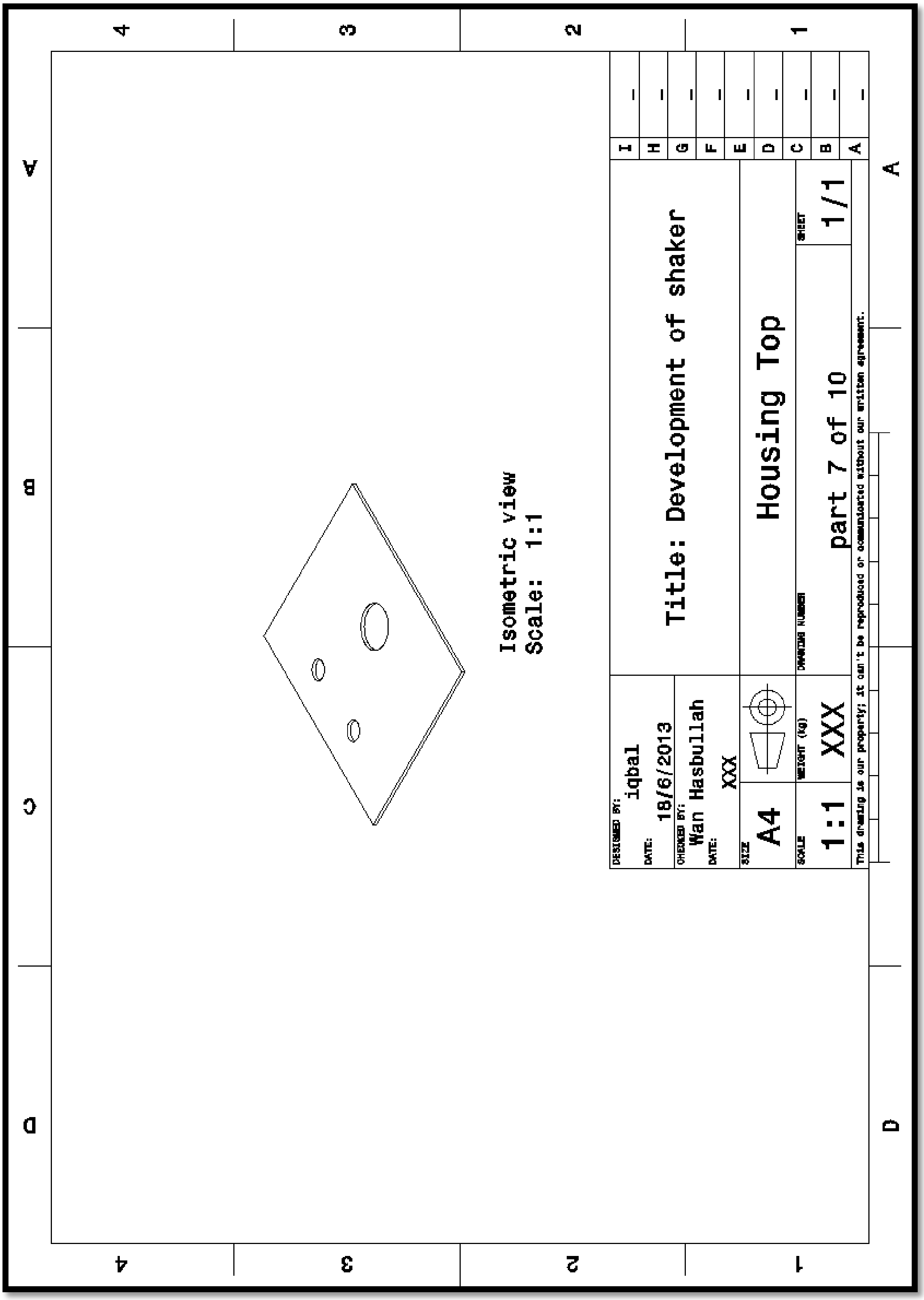
Isometric view
Scale: 1:1
DESIGNED BY:
iqbal
DATE:
18/6/2013
CHECKED BY:
Wan Hasbullah
DATE:
XXX
SIZE
A4
SCALE
1:1
WEIGHT (kg)
XXX
DRAWING NUMBER
part 7 of 10
SHEET
1/1
Title: Development of shaker
Housing Top
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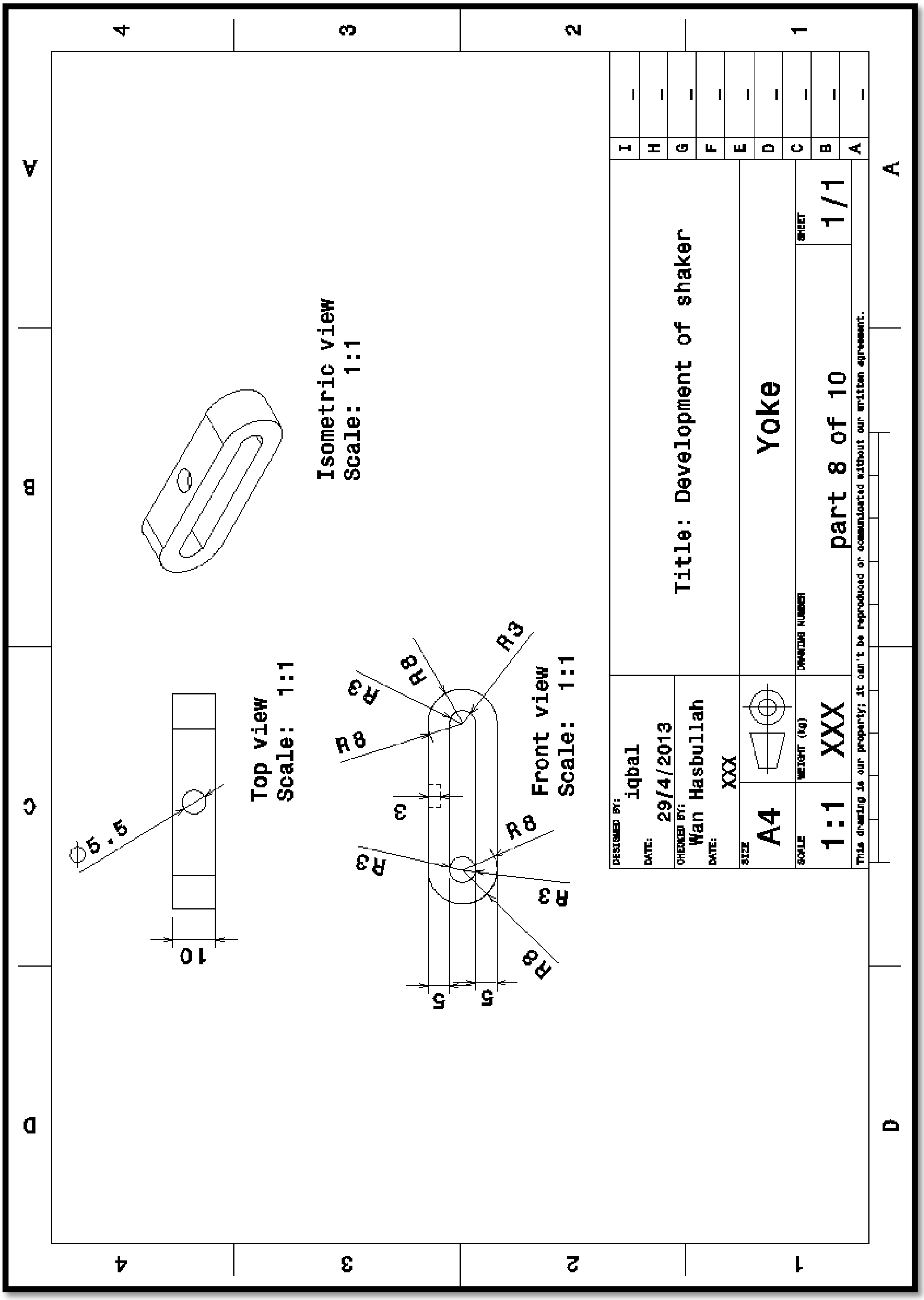
Isometric view
Scale: 1:1
Top view
Scale: 1:1
Front view
Scale: 1:1
⌀5.5
10
R8
R3
3
5
5
DESIGNED BY:
iqbal
DATE:
29/4/2013
CHECKED BY:
Wan Hasbullah
DATE:
XXX
SIZE
A4
SCALE
1:1
WEIGHT (kg)
XXX
DRAWING NUMBER
part 8 of 10
SHEET
1/1
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Yoke
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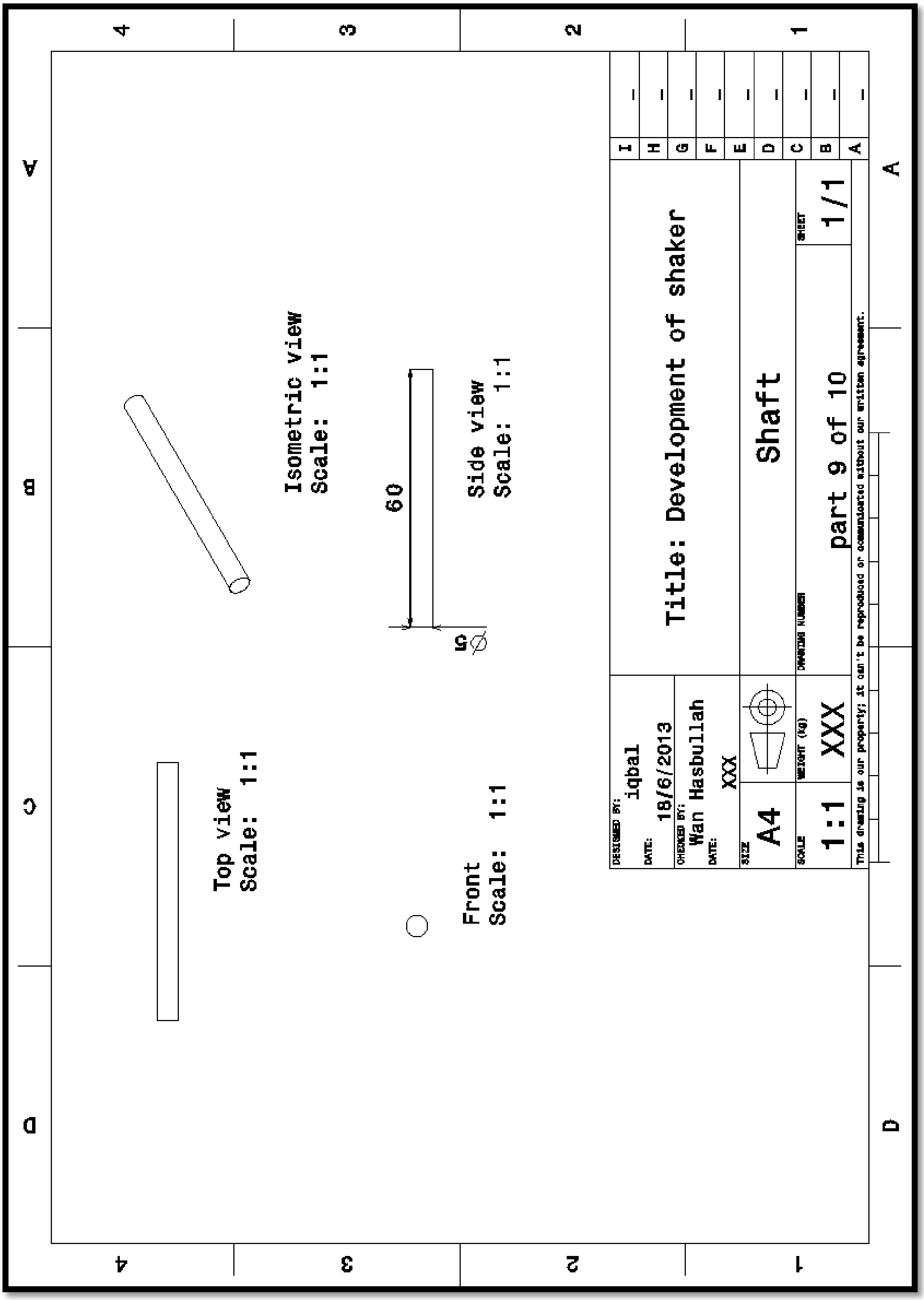
Isometric view
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Side view
Scale: 1:1
60
Ø5
Top view
Scale: 1:1
Front
Scale: 1:1
DESIGNED BY:
iqbal
DATE:
18/6/2013
CHECKED BY:
Wan Hasbullah
DATE:
XXX
SIZE
A4
SCALE
1:1
WEIGHT (kg)
XXX
DRAWING NUMBER
part 9 of 10
SHEET
1/1
Title: Development of shaker
Shaft
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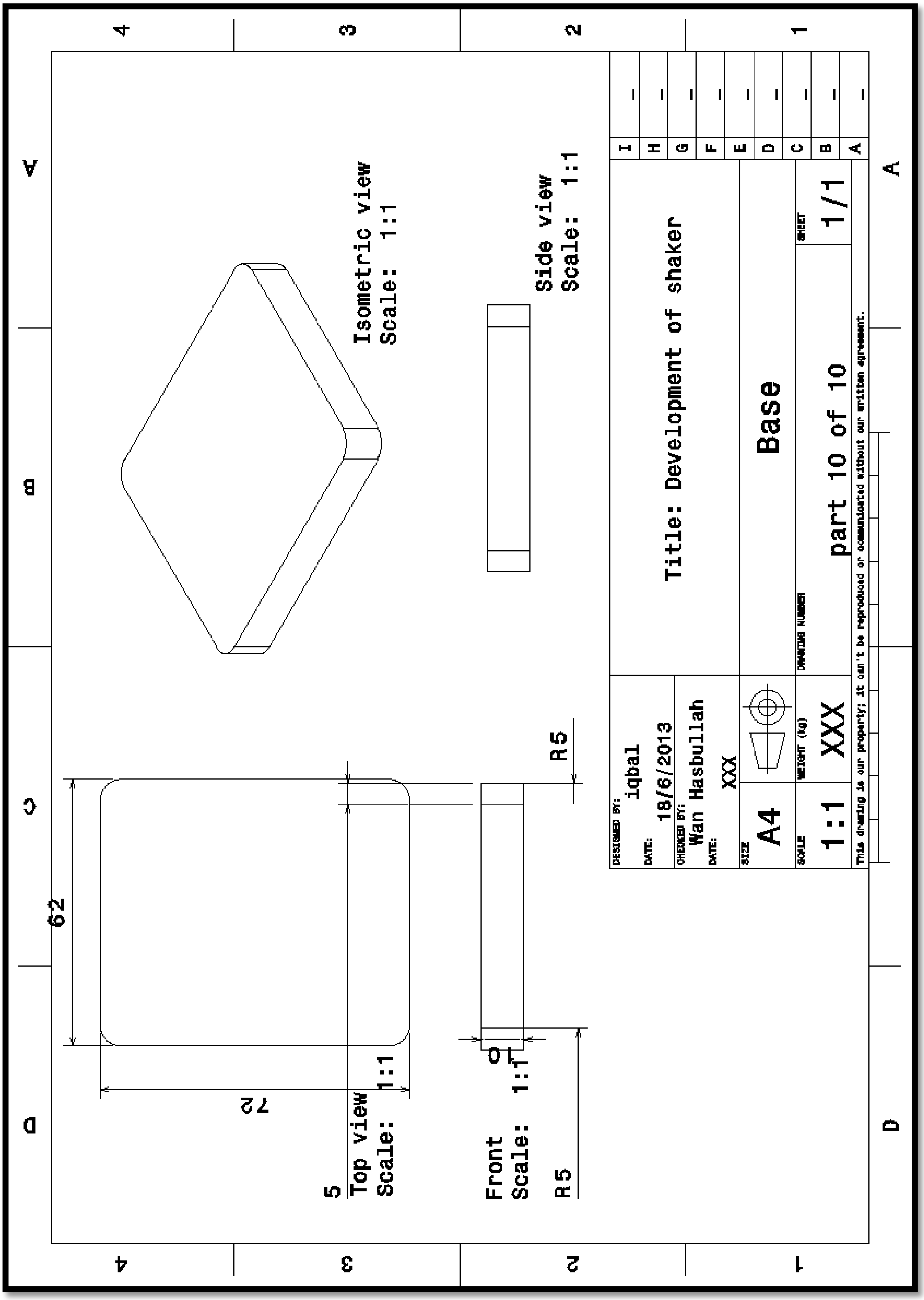
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Side view
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Top view
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Front
Scale: 1:1
62
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R5
R5
DESIGNED BY:
iqbal
DATE:
18/6/2013
CHECKED BY:
Wan Hasbullah
DATE:
XXX
SIZE
A4
SCALE
1:1
WEIGHT (kg)
XXX
DRAWING NUMBER
part 10 of 10
SHEET
1/1
Title: Development of shaker
Base
This drawing is our property; it can't be reproduced or communicated without our written agreement.