# DESIGN AND DEVELOP ROBOTIC ARM FOR AUTOMATIC GUIDED CONVEYOR


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# CHAPTER 1

# INTRODUCTION

## 1.1 PROJECT BACKGROUND

Automated guided conveyors (AGC) are commonly used in facilities such as manufacturing plants, house, distribution centres and transhipment terminals. AGC can be referred as a common piece of mechanical handling equipment that moves materials from one location to another. A variety of technology is currently available moves materials from one location to another location in the warehouses and other facilities. AGC also allow quick and efficient transportation for a wide variety of materials, which make them very popular in handling and packaging industries. It also involved the movement of tools, raw material and work in process between or into the storage.

The development of conveyor system is needed to achieve the highest efficiency so the warehouse will more profit from the development. The purpose of AGC is to help reduce the time cost of manufacturing process and increase in manufacturing system.

This project is the development of previous project that is about Automated Guided Vehicle System (AGV) to transport the acralyte during laser cutting process. The essential capability of this AGV is ability transfer loads to location through path under computer control by programming. The loading and unloading mechanism for this AGV includes the vacuum sucking unit for lifting the acralyte by vacuum sucking the corresponding to a position of working place, a loading mechanism for moving, move the sucking unit which has vacuum sucked the acralyte to the laser cut machine and an unload mechanism for carrying another acralyte.

This project is to design and development AGC involving a Robotic Arm Mechanism to transport an item. The essential capabilities of Robotic Arm is slightly same as Vacuum sucking unit which are ability to transfer load and unload an item to specific location through path under computer control by programming.

The loading and unloading mechanism of the Robotic Arm includes the arm mechanism which lifting an items corresponding to a position of working place, a loading mechanism for moving, move the lifting unit which is arm mechanism lift an item to the desire location.

## 1.2 PROBLEM STATEMENT

AGC is designed to reduce the time handling of manufacturing process. The time management for the process is really important for the improvement the product efficiency. Material handling is an integral part of any manufacturing activity. Given the high costs involved in manufacturing process, many industries cannot afford to high production rate. It is imperative to design a good loading and unloading mechanism to handle material. The Robotic Arm functions as the loading and unloading mechanism slightly increase the production rate which is able to transfer an item to specific location systematically. The AGC system is an important element in computer integrated manufacturing facility. AGC provide considerable advantages as compared to other material loading equipment.

The problem statement of this project is size, material selection, torque, and motor rpm which affect the characteristic of Robotic Arm performances. Thus, the problems regarding to Robotic Arm should be care of to achieve the desire performances.

## 1.3 PROJECT OBJECTIVES

i. To design Robotic Arm of loading and unloading mechanism for AGC application
ii. To fabricate Robotic Arm of loading and unloading mechanism for AGC application.
iii. To assemble Robotic Arm into AGC main body
iv. To perform Stress analysis of the Robotic Arm.

## 1.4 SCOPE OF PROJECT

i. Design Robotic Arm cad model using SOLIDWORKS.
ii. Analysis the design using ALGOR.
iii. Fabricate prototype of Robotic Arm.
iv. Assemble the Robotic Arm into AGC main body.
v. Transport an item.

# CHAPTER 2

# LITERATURE REVIEW

## 2.0 INTRODUCTION

The aim of this chapter is to give information about the AGC and Robotic Arm in term of its design and development. The history, previous research and findings, and theories made on Robotic Arm System are explained in detail in this chapter. Various research including journals; thesis, reference books, and literature reviews have been carried out and revised in writing this chapter.

This chapter also explain about mechanical component and electric component used for this project. Mechanical component includes arm link, robotic arm base, servo motor holder, joint and mechanical gripper. Electric components include servo motor, servo controller, gripper, regulator and connector for computer to servo controller.

## 2.1 OVERVIEW OF AUTOMATIC GUIDED CONVEYOR

Conveyors are widely used for handling bulk material over short to medium conveying distance because of their efficiency of transportation is high compared to other transport methods. Energy cost forms a large part of the material cost up to 40% (according to Marais J, Mathews E and Pelzer R, 2008) of belt conveyor systems. Conveyor systems allow quick and efficient transportation for a wide variety of materials, which make very popular in the material handling and packaging industries. Many kinds of conveying systems are available, and are used according to the various needs of different industries.

There are many benefits of using AGC as a material handling equipment, such as it can reduce product damage because the main function of AGC is to transport the product safely by following the programmable path and it also a user friendly because the path and the system can be modified or expand easily. Besides that, AGC also improve plant logistic by delivering the product upon demand and improve response time, and last but not least, by using AG aisle traffic will reduce and this will improve the plant safety.

Conveyor systems are used widespread across range of industries due to the numerous benefits they provide such as conveyors are able to safely transport materials from one level to another, which when done by human labour would be strenuous and expensive, they can be installed almost anywhere, and are much safer than using a forklift or other machine to move materials, they can move loads of all shapes, sizes and weights. Also, many have advanced safely features that help prevent accidents, and there are a variety of options available for running conveying systems, including the hydraulic, mechanical and fully automated systems, which are equipped to fit individual needs.

Conveyor systems are commonly used in many industries, including the automotive, agricultural, computer, electronic, food processing, aerospace, pharmaceutical, chemical, bottling and canning, print finishing and packaging. Although a wide variety of materials can be conveyed, some of the most common including food items such as beans and nuts, bottles and cans, automotive components, scrap metal, pill and powders, wood and furniture and grain and animal feed. Many factors are important in selection of the accurate conveyor system. It is important to know how the conveyor system will be used beforehand. Some individual areas that are helpful to consider are the required conveyor operations, such as transportation, accumulation and sorting, the material sizes, weights and shapes and where the loading and pickup points need to be.

## 2.2 ROBOTIC ARM

Productivity and product quality of an automated manufacturing process rely on accuracy of the individual manufacturing tasks such as parts transfer, assembly, welding, and inspection. Nowadays, all of these tasks are carried out by robotic manipulators. The performances of a robotic manipulator depend on considerably on the way the manipulator is controlled, and this has a direct impact on the overall performance of the manufacturing system. (De Silva, 1989, MacFarlane, 1989)

## 2.3 LOW-COST TELEOPERABLE ROBOTIC ARM

A low-cost robotic arm and controller system is a desktop model of the robotic arm with the same degrees of freedom whose joints are equipped with sensors. Robotic arm system can save lives by enabling human to do dangerous task at safe distances. Teleoperative systems have been used in a range of applications. In earth-space systems the communication time delay is a significant consideration. This robotic arm system has two components; a robotic arm and a controller that serves as an operator interface. The controller functions as a desktop model of the robotic arm with the same degrees of freedom. (Rogers, 2009)

## 2.4 FORCE CONTROL

The equations of motion of the planar manipulator are derived using the extended Hamilton's Principle with only structurally flexibility effects included in the dynamic model. The using of feed forward and feedback control torques solved the control problem of the manipulator of robotic. The feed forward torques maneuvers the flexible manipulator along a nominal trajectory and feed torques (obtained using LQR theory) minimize the deviation from the nominal trajectory. (Su, Choi, and Krishnamurthy, 1990)

## 2.5 ROBOTIC ARM GRIPPER

Gripper function used to grip an item. The Cooperation with human should be based on the human control system enable it to most effectively cooperate with humans and also to make it human friendly. The function of gripper decrease time management for certain process in factory. Besides that, gripper also help grip any object that will cause any harm to human while holding the object. Figure 2.1 show the Multifingered robot sketch.

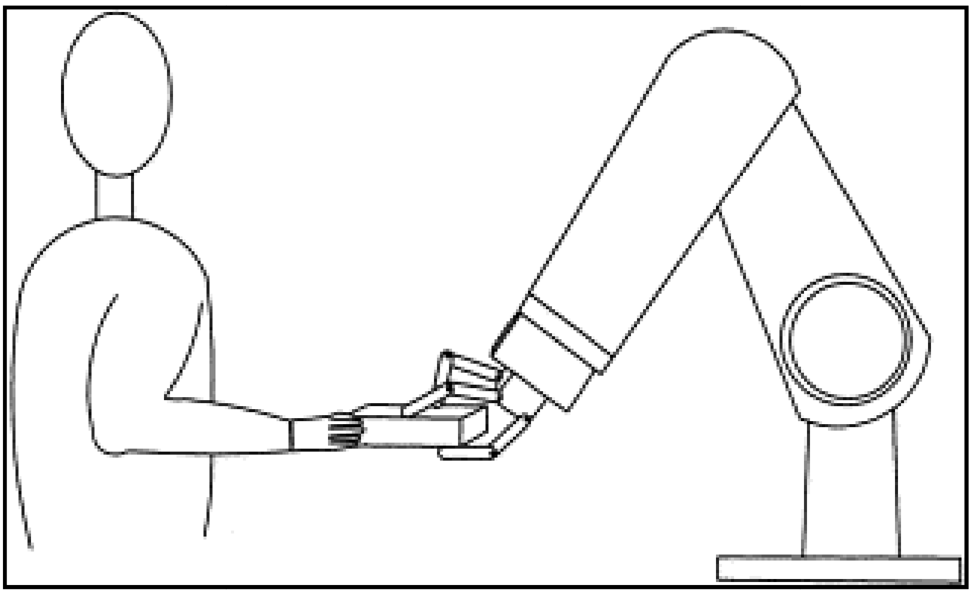

**Figure 2.1**: Multifingered robot – human cooperation (Ashish Duta and Goro Obinata, 2002)

## 2.6 GRIPPER

Gripper model is the important part and critical part in designing the robotic arm. Gripper used in the application of the robotic arm as an end effecter. Nowadays, gripper is the most important part in robotic arm because of its function to pick or hold an item for transferring process in factory. Thus, gripper basically used to pick up and place objects to specific places controlled by remote or computer. The performances of robot to grasp on the object are depending on the weight of the object, friction between the object and the gripper, movement speed of the robot, and relation between the direction of movement and the gripper position. There are varieties of gripper model depending on the use of the gripper such gripper move both side and gripper only moves one side. Basically, gripper designed based on the purpose of the gripper. Figure 2.2 show the picture of the big gripper.

**Figure 2.2**: The Big Gripper

## 2.7 PARAMETER REQUIREMENT

There are several parameters requirement should be consider including torque, stress analysis and weight. For the real system the physical characteristics of the electric hardware are modelled and then the actuator and mechanical transmission effect determined. Complex friction parameters of the system are then estimated; these allow the development of friction models and make possible friction compensation for control. (G.Dodds and N.Glover, 1995)

## 2.8 TORQUE

The calculation of torque is depending on the link length of the robotic arm and the weight of an object. Torque is defined as turning or twisting force and is calculated using the following relation:

$$Torque\ (\tau) = Force\ (F) \times Length\ (L)$$

$$\tau = F \times L \tag{2.1}$$

$$F = m \times g \tag{2.2}$$

$$W = m \times g \tag{2.3}$$

$$\tau = m \times g \times L \tag{2.4}$$

Speed of the motor depends on the model of the servo motor. The more power used will be able to lift an item quickly. Different model of servo motor has different torque and the ability to lift heavy weight is depending on it. Result from the torque calculation will help on choosing suitable servo motor to lift an item within specific weight.

## 2.9 SERVO MOTOR

Motor is a device that creates motion; it usually refers to either an electrical motor or an internal combustion engine. It may also refer to electric motor includes DC motor for an electric motor that is driven by alternating current and AC motor; an electric motor that runs on direct current electricity. The selection of motor for this project is depending on the three degree of freedom of the robotic arm includes weight, arm link length and power or current.

Radio Control (RC) servo is used for this project. RC servo is small actuators designed remotely operating model vehicles such as cars, airplanes, and boats. Today, RC servos are become popular in robotic arm, creating humanoid robot, biologically inspired robot, and robotic arm. This is because its ability to rotate and maintain and certain location, position or angle according to control pulse from a single wire. Inside a typical RC servo contains a small motor and gearbox to do the work, a potentiometer to measure the position of the output gear, and an electric circuit that control the motor to make the output gear move to the desired position. Because all of these components are packed into a compact, low-cost unit, RC servos are great actuator for this robotic arm project. Figure 2.3 show the picture of the RC servo motor.

**Figure 2.3:** RC Servo Motor

Servos are controlled by sending them a pulse of variable width. The signal wire is used to send this pulse. The parameters for this pulse are that it has a minimum pulse, a maximum pulse, and repetition rate. Given the rotation constraints of the servo, neutral is defined to be the position where the servo exactly the same amount of potential rotation in the clockwise direction as it does in the counter clockwise direction. It is important to note that different servos will have different constraints on their rotation.

## 2.10 SERVO CONTROLLER

Servos controller is used to control the position of the pulse of servo motor. Servo controller is the electronic part which functions as the program language to sending pulse to servo motor. Servo controller usually comes with required program which can be controlled by computer or PIC circuit. Figure 2.4 show the picture of the servo controller, SC080A.

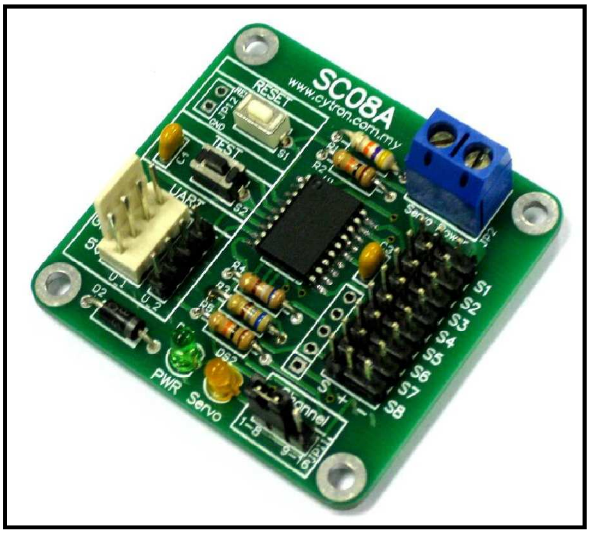


**Figure 2.4**: Servo Controller

# CHAPTER 3

# METHODOLOGY

## 3.1 INTRODUCTION

This chapter is focused on the methodology process which is the sets of methods to fabricate and design that been used. The design that been implement are need to specify certain criteria to achieve project objectives. The information in the literature review is interpreted to select the suitable design for the Robotic Arm. The design need to be specified in CAD software model. The steps that involve in fabricating and programming of the model are stated.

## 3.2 FLOW CHART

To achieve the objectives, the methodology has been constructed (Figure 3.1). The function of the flow chart is to give guideline and direction to accomplish the main goal of the project. The following paragraph is the summary of the flow chart.

First of all, the project start with the review about related topic on Robotic Arm and Automatic Guided Conveyor. After reviewing on related topic, the design of Robotic Arm is sketched on the paperwork. If the design characteristic is still not good, the sketching process will be continue until meet the desire design of Robotic Arm. Then, based on the design sketch, the CAD MODEL of Robotic arm using solidwork is made. The final process are fabricating and finishing.

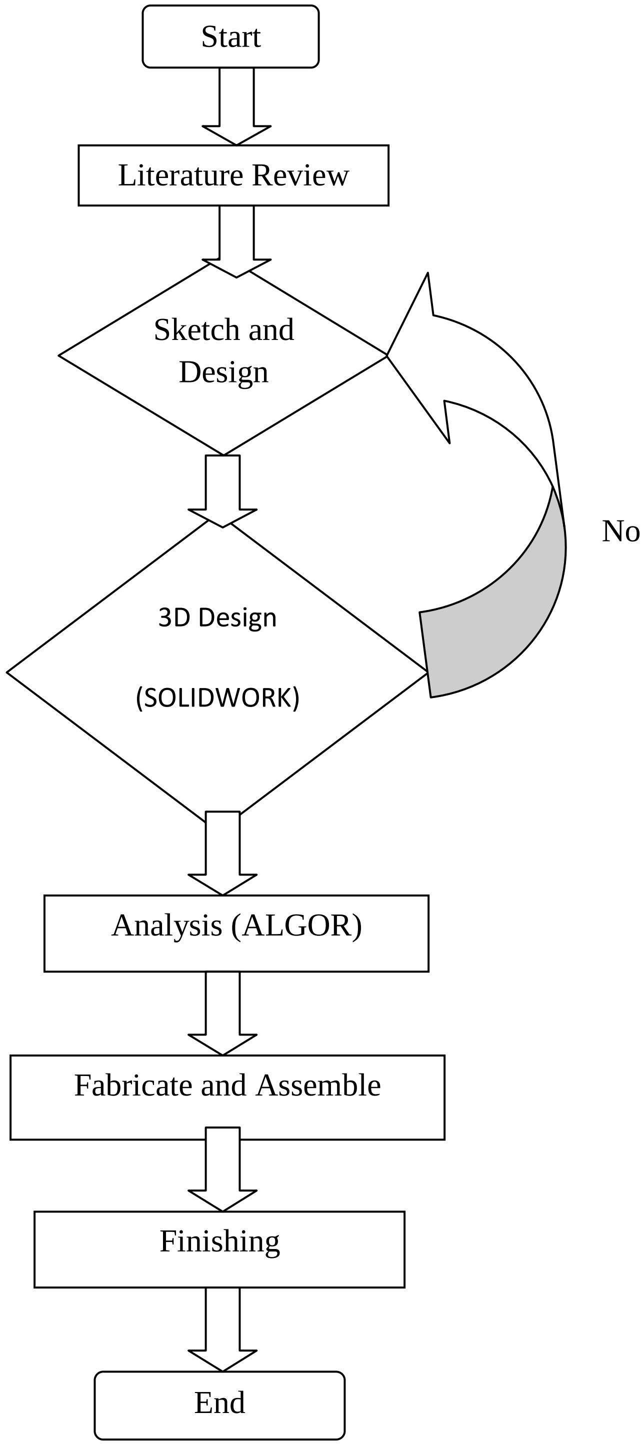


**Figure 3.1**: Flow Chart

## 3.3 PROPOSED ROBOTIC ARM DESIGN

There are several consideration should be known when designing the Robotic Arm including mechanical parts and electrical components to sensor technology, computer programming system and artificial technology that influenced the overall robotic arm performance. The mechanical and electrical components include grippers and the body of the robot, while the electrical components consist of microcontroller or servo controller, voltage regulator, and sensing system.

The overall design of robotic arm can be categorized into two parts, which are the mechanical design and the electrical components. The mechanical design such as gripper and the robotic arm or body must be designed as accurate as possible to keep away from any problem when the robot starts its movement. The electrical components also must be chosen wisely to make sure the electronic can be performing perfectly and easy to attach to mechanical part of the robotic arm.

The robotic arm design consists of the gripper and the body part. The gripper should be lightweight and the body of the robot must be able to support the weight of the object to be lifted. The material used for mechanical parts must be considered because the weight is an important factor to make sure the robot can move smoothly or can operate.

The mechanical parts is designed by choosing aluminium because it strong and light material compare to Perspex or other material. Aluminium is difficult to break due to its quality. On the other hand, Aluminium material also easily to find and the price is cheap.

## 3.4 DRAWING CONSIDERATION

The drawing of the Robotic Arm must achieve the entire desired objective. The drawings must be complete as fast as possible and then it can be fabricated perfectly without making any mistake in the middle of the fabrication process. The consideration for the drawing is for it firstly to be moveable, in sketching; the measurement of the robotic arm link length must be taken to get the suitable size for the robotic arm. This is to make sure the loading and unloading mechanism can lift and move the load. The robotic arm depends on degree of freedom angle or translation limitation, and the arm link, the angle. The configuration of the robotic arm should be considered. Besides that, all the motors used for the robotic arm must achieve the required motor torque.

In this project, the software used to draw the model is Solid Works. Solid Works software is mechanical design automation as a computer added software (CAD). This software was chosen as it is possible to sketch idea of the design, experiment with features and dimensions and produce models. Solid works able to draw 3D design based on the component. There are some steps that must be follow which is:

(i). **Sketches:** Draw some design sketches, dimensioning, where to apply the objectives needed and so on

(ii). **Features:** Select the appropriate features, determine the best features to be applied and so on.

(iii). **Assemblies:** Select the components to be mate, what types of mate to apply in the drawing and so on. Mate is the mating process in Solidwork.

After the overall design finish, the next step which is fabricating process can be continuing. All the components to be fabricated must be label first to avoid repetition process.

## 3.5 ROBOTIC ARM DESIGN

Robotic arm design is the mechanical component sketch before fabricating process. Overall design of the robotic arm use simple arm link, base and servo motor holder. The important thing about the robotic arm design is the dimension. The design must achieve the required dimension to match with the servo motor torque.

Basically, mechanical part of robotic arm can be bought at fabricating company which allowing any design from Solidwork to be fabricated. Figure 3.2 show the dimension of the servo holder. Figure 3.3 show the dimension of the arm joint.

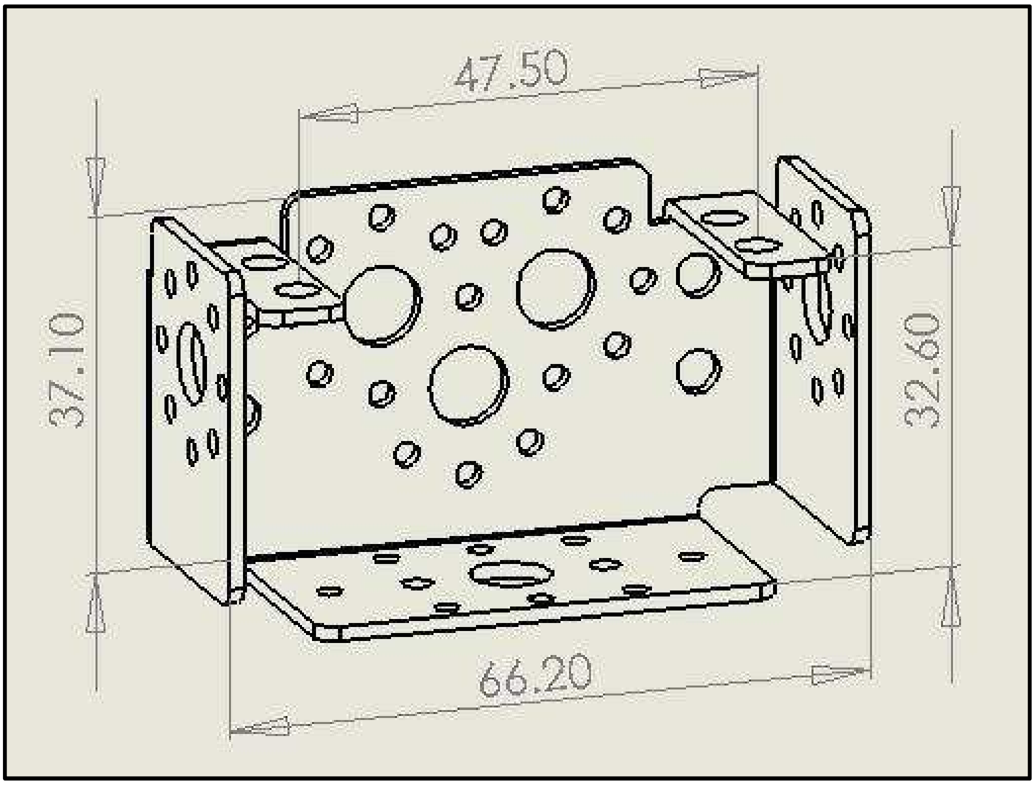


**Figure 3.2:** Servo Holder

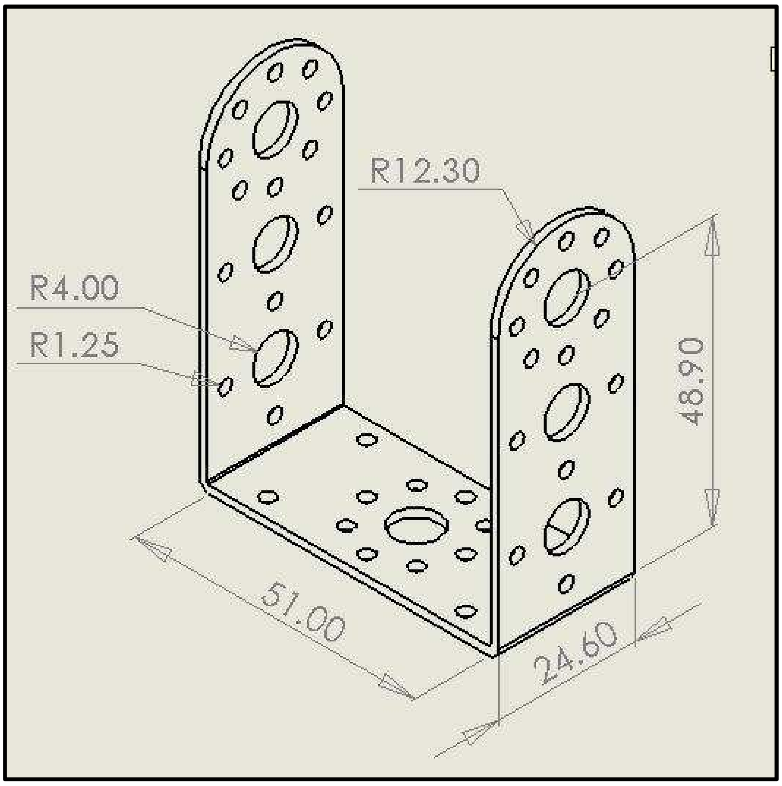


**Figure 3.3:** Arm Link or U Joint

## 3.6 ROBOTIC ARM DEGREE OF FREEDOM

Robotic arm includes a drive assembly and an articulated arm assembly pivotally connected to the drive assembly. The articulated arm includes a pivoting base link system, a wrist link system, and a first elbow link system rotatable connected to the base link system by a pair of upper arms and connected to the wrist link system by a pair of forearms, a second elbow link system rotatable connected to the base link system by another at least one upper arm and connected to the wrist link system by another at least one forearm, wherein the drive assembly is connected to at least one of the upper arms and the base link system to provide three degrees of freedom by driving the at least one of the upper arms and pivoting the pivoting base link system to position the wrist link system at a given location with a predetermined skew relative to an axis of translation.

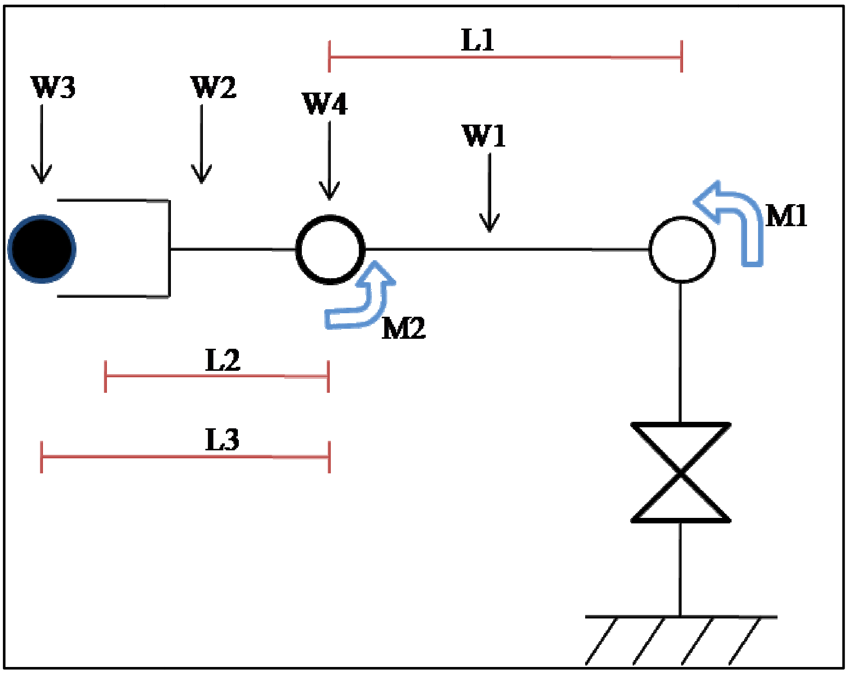


**Figure 3.4:** Force Calculation of Joint

Based on Figure 3.4, the desire force calculation of joint at can be calculated by using moment of Inertia formula.

(i). Torque about Joint 1

$$M_1 = \left(\frac{L_1}{2}\right)(W_1) + L_1(W_4) + \left(L_1 + \frac{L_2}{2}\right)(W_2) + (L_1 + L_3)(W_3) \quad (3.1)$$

(ii). Torque about Joint 2

$$M_2 = \left(\frac{L_2}{2}\right)(W_2) + (L_3)(W_3) \quad (3.2)$$

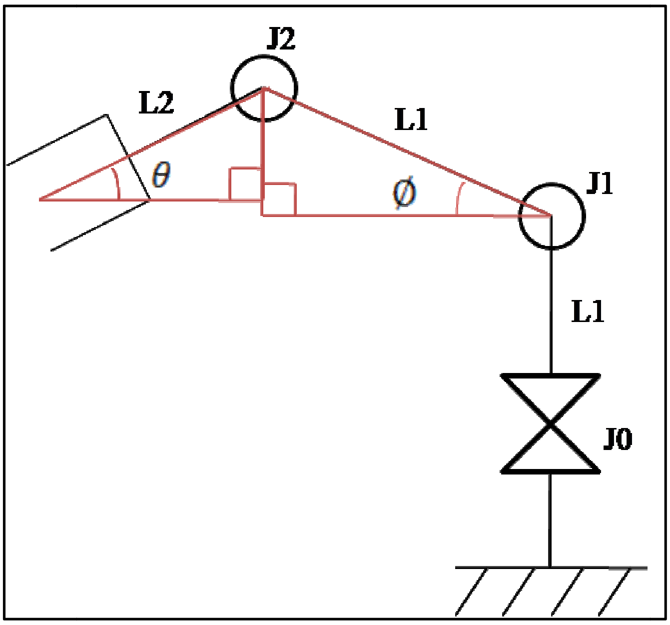


**Figure 3.5:** Forward Kinematics

Based on Figure 3.5, forward kinematic of the robotic arm can be calculated. Forward kinematic is the method to solve the orientation and position of the end effectors, given the joint angles and link lengths of the robotic arm. To calculate forward kinematics, the knowledge about trigonometry and algebra can be refer to. Refer to Figure 3.5, assume the base is located at $x = 0$ and $y = 0$. The first step is to locate $x$ and $y$ of each joint.

Joint 0 (with $x$ and $y$ at base equaling 0):

$$x_0 = 0 \tag{3.3}$$

$$y_o = 0 \tag{3.4}$$

Joint 1 (with $x$ and $y$ at J1 equaling 0):

$$\cos \emptyset = \frac{x_1}{L_1} \tag{3.5}$$

$$x_1 = L_1(\cos \emptyset) \tag{3.6}$$

$$\sin \emptyset = \frac{y_1}{L_1} \tag{3.7}$$

$$y_1 = L_1(\sin \emptyset) \tag{3.8}$$

Joint 2 (with $x$ and $y$ at J2 equaling 0):

$$\sin \theta = \frac{x_2}{L_2} \tag{3.9}$$

$$x_2 = L_2(\sin \theta) \tag{3.10}$$

$$\cos \theta = \frac{y_2}{L_2} \tag{3.11}$$

$$y_2 = L_2(\cos \theta) \tag{3.12}$$

End effectors location:

$$x_0 + x_1 + x_2 \tag{3.13}$$

Or

$$0 + L_1(\cos \emptyset) + L_2(\sin \theta) \tag{3.14}$$

$$y_0 + y_1 + y_2 \tag{3.15}$$

Or

$$L_0 + L_1(\sin \emptyset) + L_2(\cos \theta) \tag{3.16}$$

$z$ Equals alpha, in cylindrical coordinates

## 3.7 ANALYSIS

The purpose of linear static stress analysis of robotic is to determine the displacement and stress resulting under loads representing normal operating conditions. The analysis of linear static stress will be done by using. ALGOR software is a general-purpose metaphysics finite element analysis software package develops by ALGOR. After analysis is completed using the software, we will got the information if the aluminium profile which is used to carry the object is strong enough or not. The capabilities of robotic arm are rely on these results whether the element can carry on the project or to withstand the object to be loaded.

## 3.8 TESTING PROCESS

To assemble mechanical components of this robotic arm, the method of fabricating parts must be sure first because the part to be assembled has different dimensions and usage. Gripper is used to hold an object. The gripper is assembling along with the RC Servo using coupling to give the movement. The suitable lift mechanism is important in robotic arm because it's function as an affecter to hold the object. The methods that have been used to lift the object are robotic arm mechanism which gripper functions as the holder.

Besides assembling mechanical components, electric components used for this project must be considered. There are many electronic for robotic arm out there such as servo controller, regulator, microcontroller and computer. Servo controller used to control many servos simultaneously by using computer as a host. Host of the servo controller can be computer or microcontroller. For this project, computer functions as the operation system to control all servos using software provided by the manufacturer.

## 3.9 EXPECTED OUTCOME

The expected outcome after the project is completed, Robotic arm able to:

i. Load and unload the object
ii. The movement of the robotic arm
iii. Electric components decided

## 3.10 CONCLUSION

The whole procedures in this chapter are important to build the robotic arm. Start with design concept, analysis and fabrication process. The design concept is to set the robotic arm mechanism to load and unload the object. With the entire design concept, continue to the next level that is analysis based on the design concepts. Analysis includes weight consideration, material consideration and size consideration. The purpose of analysis is to get the result which slightly affected the performances of the robotic arm. After completing the all processes, fabrication process can take place.

# CHAPTER 4

# RESULT AND DISCUSSION

## 4.1 INTRODUCTION

This chapter is mainly about the result, analysis and discussion from the finish product. The result is mean by the robotic arm ability to perform the task by the given input. Analysis can be obtained by the performance of the robotic arm to load or unload the object to specific place. In the discussion section, the problem occurs related to the robotic arm performance being analyzed to get the real factor affecting robotic arm performance.

## 4.2 MODELS OF ROBOTIC ARM

Robotic arm depends on the efficiency of the various parameters that can be investigated through analysis. From the result of analysis, decisions that affect the selection of the best models can be made. This analysis includes the investigation of degree of freedom, robot workspace, force calculations, forward kinematics, inverse kinematics, motion planning, velocity, and sensing and end effectors design.

Degree of freedom is a joint on the arm where it can bend or rotate. The number of degree of freedom can be identified by the number of actuators on the robotic arm. Each of degree requires a motor, often an encoder, and exponential algorithms calculation.

Robot workspace is the reachable space that the end effectors can reach. It is depends on the degree of freedom angle or translation limitations, the arm link lengths, the angle at which something must be picked up.

The purpose of the force calculations of joints is to choose the suitable motor for the robotic arm. The selected motor must support all the weight of the robotic arm includes the weight of the object that being picked up.

Forward kinematics is the method for determining the orientation and position of the end effectors, given the joint angles and link lengths of the robotic arm. Inverse kinematic also affect robotic arm performances and it is opposite of the forward kinematics mechanism.

### 4.2.1 ROBOTIC ARM MODEL 1

Figure 4.1, Figure 4.2 and Figure 4.3 show 3 different view of the robotic arm that is front view, top view and side view.

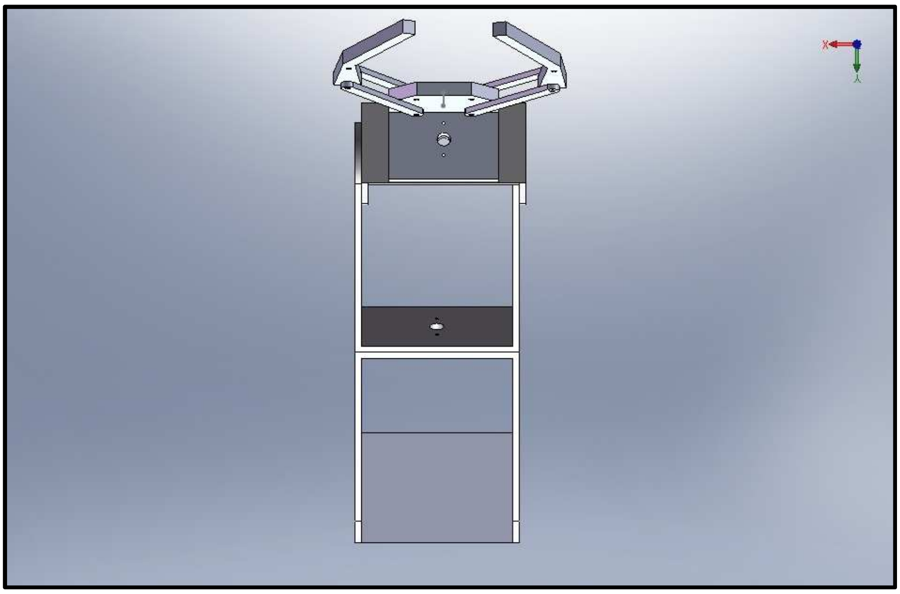

Figure 4.1: Front View of Model 1

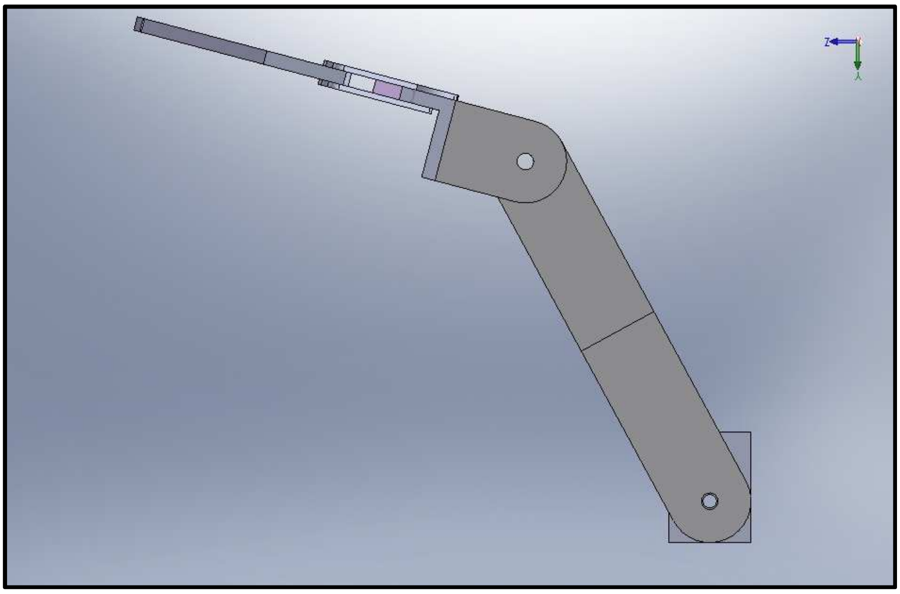

Figure 4.2: Side View of Model 1

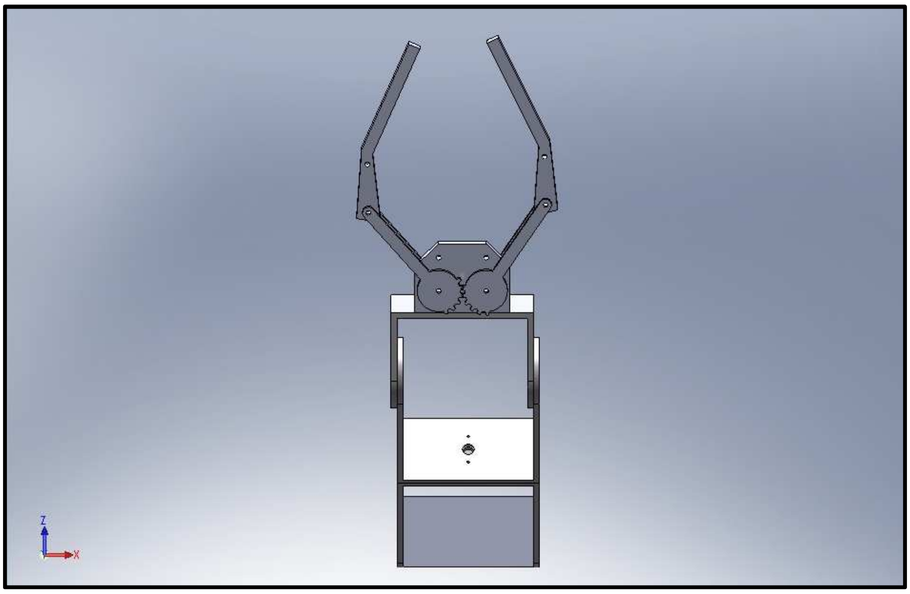

Figure 4.3: Top View of Model 1

Robotic arm model 1 is the two degrees of freedom which only have two motor at each joint. For this project, robotic arm model 1 had been chosen by investigated various parameters involved.

Two degrees of freedom had been chosen because it only has two joint and each joint have one motor. Thus, only two motor will be used that attached at each joint.

Based on the servo motor specification, servo motor only can rotate 180 degrees which mean the robotic workspace is not wide compared to more degrees of freedom.

Figure 4.4 show the free body diagram of the joint model arm.

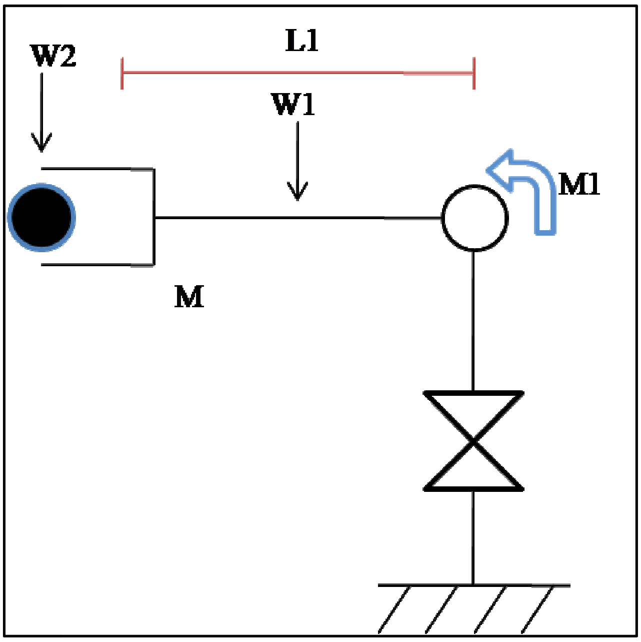


**Figure 4.4:** Force Calculation of Joint Model 1

Below are the force calculations of robotic arm model 1:

Torque calculation of joint 1, where:

$L_1 = 0.09m$

$W_1 = 0.035kg$

$W_2 = 0.08kg$

$$L_0 + L_1(\sin \emptyset) + L_2(\cos \theta)$$

$$= \frac{0.09m}{2}(0.035kg) + 0.09m(0.08kg)$$

$$= 8.775 \times 10^{-3} kg.m$$

Based on the Figure 4.4, the number of joint of the robotic arm is reduced to ensure the stability of the robotic arm. Therefore, there are only one moment was calculated. This calculation must be done for each lifting actuators but for this particular design has just one degree of freedom that require lifting, and the center of mass of linkage is assumed to be length divide by two. The increasing of degree of freedom of robotic arm make the mathematic calculation gets more complicated. These conclude that shorter arm lengths allow smaller torque requirement.

Forward kinematics calculations:

$\emptyset = 25°$

Joint 0 (with $x$ and $y$ at base equaling 0):

$$x_0 = 0$$

$$y_o = 0$$

Joint 1 (with $x$ and $y$ at J1 equaling 0):

$$\cos \emptyset = \frac{x_1}{L_1}$$

$$x_1 = 0.09m(\cos 25\,°)$$
$$= 0.08157m$$

$$\sin \emptyset = \frac{y_1}{L_1}$$

$$y_1 = 0.09m(\sin 25)$$
$$= 0.0380m$$

End effectors location:

$$(x_0 + x_1, y_0 + y_1) = (0.08157, 0.0380)m$$

$z$ Equals alpha, in cylindrical coordinates

### 4.2.2 ROBOTIC ARM MODEL 2

Figure 4.5 and Figure 4.6 show the views from top view and side view of the robotic arm.

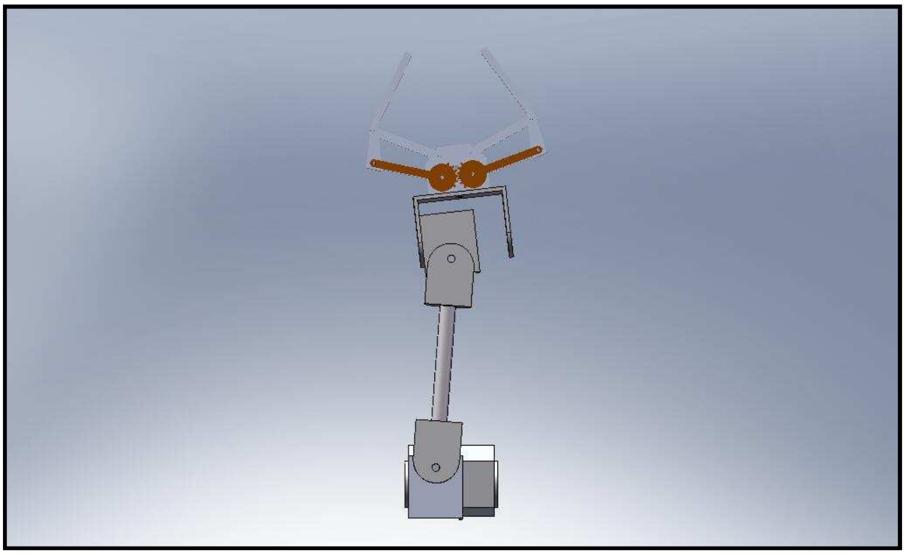

**Figure 4.5:** Top View of Model 2

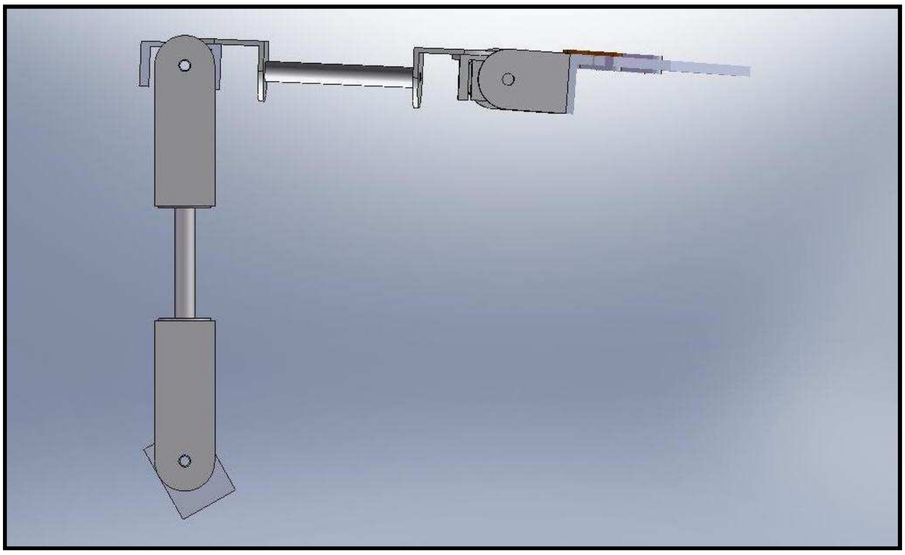

**Figure 4.6:** Side View of Model 2

Robotic arm model 2 is the three degrees of freedom which mean has 3 joint. Three degrees of freedom explain there are 3 servo motor needed to attach at each joint. The function of the motor is to rotate the joint either forward or backward. The increasing of degree of freedom of robotic arm increase the total weight that exerted on the robotic arm.

Three degrees of freedom of the robotic arm increase the robotic workspace where the robotic arm can reach much area compared to the two degrees of freedom robotic arm. Figure 4.7 shows the free body diagram of the joint model 2.

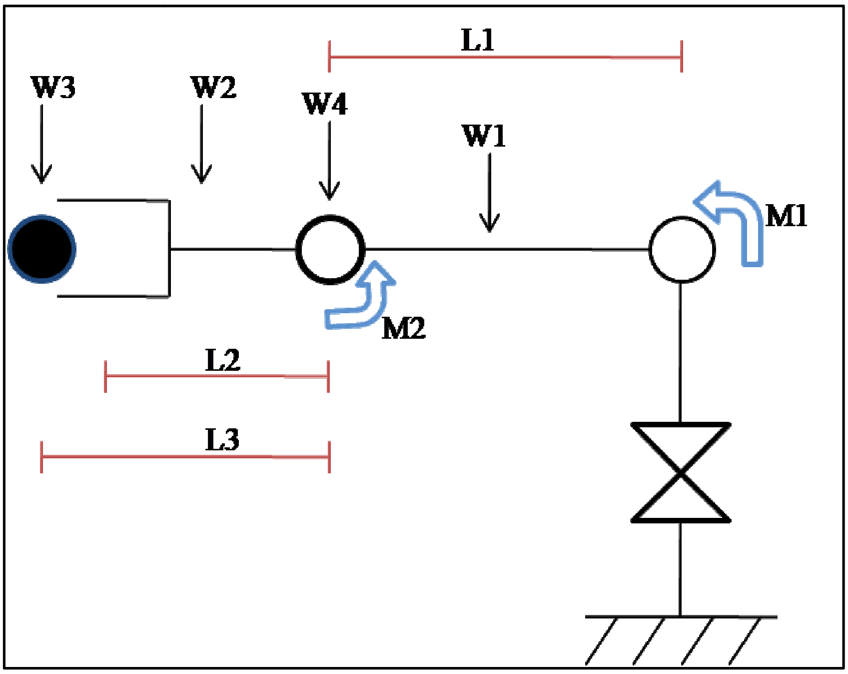


**Figure 4.7:** Force Calculation of Joint Model 2

Torque calculation of joint 1, where:

$Length\ 1, L_1 = 0.09m$

$Length\ 2, L_2 = 0.05m$

$Length\ 3, L_3 = 0.06m$

$Weight\ 1, W_1 = 0.035kg$

$Weight\ 4, W_4 = 0.035kg$

$Weight\ 2, W_2 = 0.015kg$

$Weight\ 3, W_3 = 0.08kg$

$$M_1 = \left(\frac{L_1}{2}\right)(W_1) + (L_1)(W_4) + \left(L_1 + \frac{L_2}{2}\right)(W_2) + (L_1 + L_3)(W_3)$$

$$= \frac{0.09m}{2}(0.035kg) + 0.09m(0.035kg) + (0.09m + 0.05m)(0.015kg) + (0.09m + 0.06m)(0.08kg)$$

$$= 0.018825kg.m$$

Torque calculation of joint 2:

$$M_2 = \frac{L_2}{2}(W_2) + L_3(W_3)$$

$$= \frac{0.05m}{2}(0.015kg) + 0.06m(0.08kg)$$

$$= 5.175 \times 10^{-3} kg.m$$

Based on the Figure 4.7, the number joint are 3 which mean that the weight of the robotic arm is heavy compare to model 1. The increasing of weight of robotic arm increase the torque required for the servo motor.

There is various ways to stabilize the robotic arm such as by putting heaviest part near to the base of the robotic arm. By doing this, the stability of the robotic arm can be maximize and decrease the probability to fall.

Forward kinematic calculations of model 2, refer to Figure 3.5:

$\emptyset = 25°$

$\theta = 40°$

Joint 0 (with $x$ and $y$ at base equaling 0):

$$x_0 = 0$$

$$y_o = 0$$

Joint 1 (with $x$ and $y$ at J1 equaling 0):

$$\cos \emptyset = \frac{x_1}{L_1}$$

$$x_1 = 0.09m(\cos 25)$$
$$= 0.08157m$$

$$\sin \emptyset = \frac{y_1}{L_1}$$

$$y_1 = 0.09m(\sin 25)$$
$$= 0.03803m$$

Joint 2 (with $x$ and $y$ at J2 equaling 0):

$$\sin \theta = \frac{x_2}{L_2}$$

$$x_2 = 0.05m(\sin 40)$$
$$= 0.03214m$$

$$\cos \theta = \frac{y_2}{L_2}$$

$$y_2 = 0.05m(\cos 40)$$
$$= 0.03830m$$

End effectors location:

$$(x_0 + x_1 + x_2, y_0 + y_1 + y_3) = (0.11371\ , 0.07633)$$

$z$ Equals alpha, in cylindrical coordinates

## 4.3 SPECIFICATIONS

The robotic arm dimension detail is based on the CAD design and physical condition which slightly affect the robotic arm performance. The specification of the robotic arm is obtained by the component that has been used in the fabrication process. Overall specification (Table 4.1) including the entire component involving the operating system of the robotic arm.

**Table 4.1**: Overall Specifications of Robotic Arm

| **Item** | **Specifications** |
|---|---|
| Body Material | Aluminium |
| Components | Arm Links, Arm Stand and Gripper |
| Dimensions | $(32 \times 5.5)$ cm |
| Mass | 0.5Kg |
| Power Supply | 5-6V |
| Servo motor | 3 units |
| Servo Controller | 1 unit |

During lifting process, gripper holds an item and lifts it up. Motor is used to control the gripper along with arm links and arm stand. The movement of the loading and unloading mechanism, four RC servo motor connected at each link to control the left and right movement of the robotic. The servo motors are hold by the aluminium holder. The detail description of the servo motor of the servo motor is in the Table 4.2 below.

**Table 4.2**: RC Servo Motor Specifications

| **Descriptions** | **Specifications** |
|---|---|
| Supplier | Cytron Technologies |
| Model | RC Hobby Servo C40S |
| Weight (g) | 38 |
| Voltage (V) | 4.8 ~ 7 |
| Torque (kg.cm) | 6 ~7 |
| $Speed/60°$ | 0.16 ~ 0.19 |

**Table 4.3:** Servo Controller SC16A

| **Parameter** | **Voltage** |
|---|---|
| Operating Voltage (V) | 4.8 - 6 |
| Operating System / Program | Servo32Ch |

The power supply of this robotic arm is 9V battery but the servo motor can only receive 5V to 6V of power supply, thus regulator to decrease the power supply to 5V is made. Regulator may refer to a device that maintains a designated characteristic, this explain why regulator used to control the power supply so the servo motor can function well. The program or operating system used to operate robotic arm is Servo32Ch. Servo32Ch is window application used to control each servo.

## 4.4 MECHANICAL COMPONENT ANALYSIS

The main objective of analysis is to identify all relevant parameters of already designed and fabricated components. The mechanical structures of the robotic arm, the drive system, and as well as the materials being used is analyzed. Maximum configuration in terms of geometry and mass distribution is obtained. For example in Figure 4.8, the linear stress analysis of the robotic arm shoulder holder, based on the Figure 4.8, the maximum load to be stand can be known. If the shoulder holder is being loaded with excess load, it will fracture.

Based on Figure 4.9, the shoulder arm link analysis, the value of load used is 0.46Kg and pressured at coordinate-z. The Figure 4.9 shows that the shoulder arm link able to hold more than 0.46kg load and then fractured when reach maximum load.

The purpose of these analyses is to determine the suitable material by the use of finite element stress analysis by giving 0.45Kg load to the mechanical components of the robotic arm. Since the stress within each link is low, there is no gravitational load in lateral direction. Focusing on sidewall of the robotic arm link, the two plates are equally loaded, thus reduce to a single plate with an equivalent load equal to the half of the total load at the end effectors being able to reduce the analysis to a planar problem was very beneficial in terms of computing time.

The material selected is AI 6061 T6 similar, the safety factor is extremely large and is between 3 and 4, still yielding very low mass of about 0.088Kg per plate. The estimated total weight is less than 1Kg.

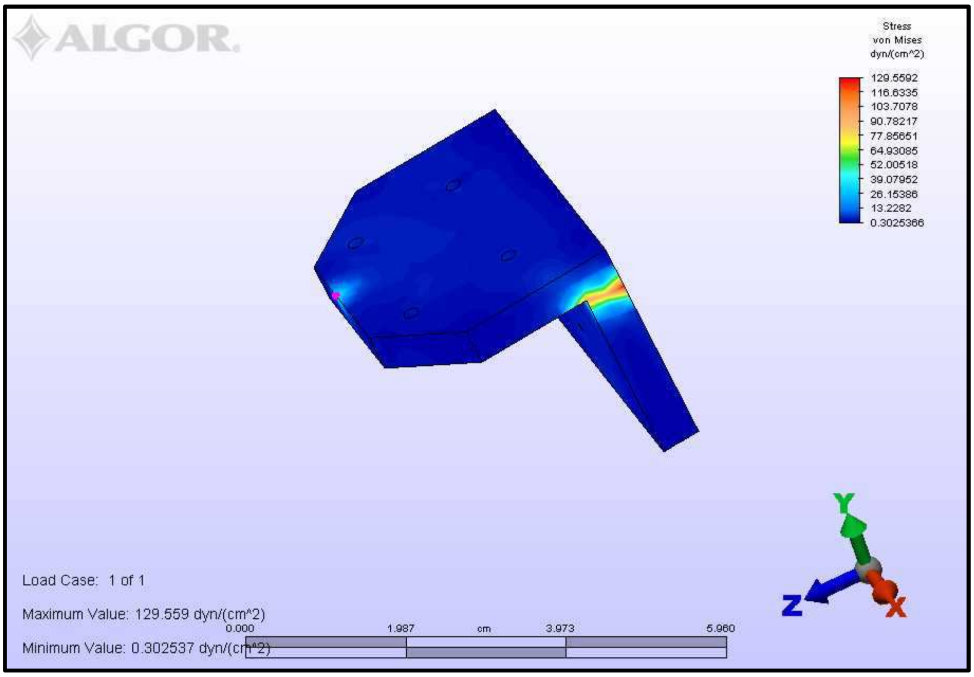


**Figure 4.8:** Linear Stress of Gripper Holder

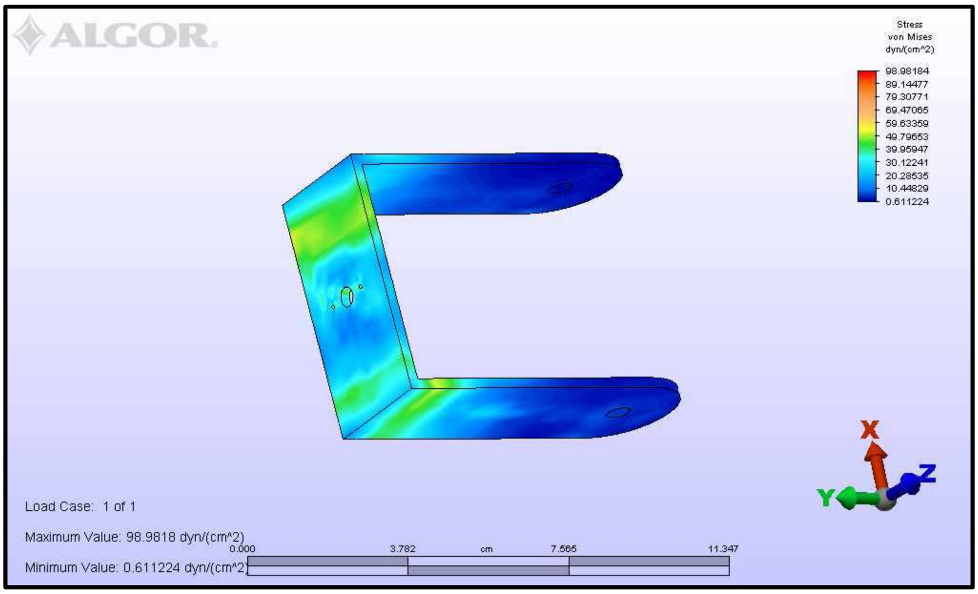


**Figure 4.9:** Linear Stress of Shoulder Arm Link

## 4.5 FINISHING PRODUCT OF ROBOTIC ARM

Figure 4.10, Figure 4.11 and Figure 4.12 shows the 3 different views of the finishing product of the robotic arm.

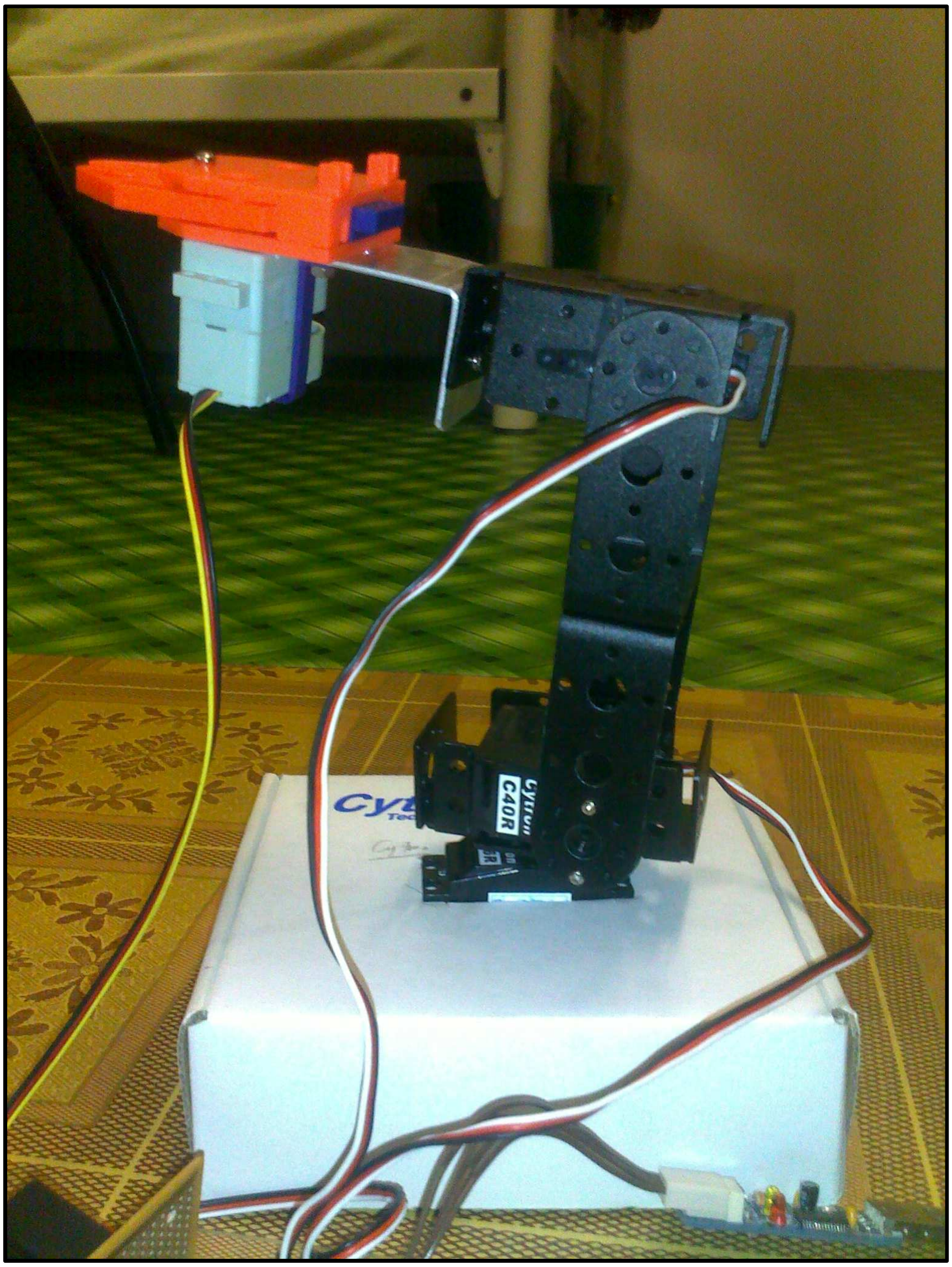


**Figure 4.10:** Side View of Robotic Arm

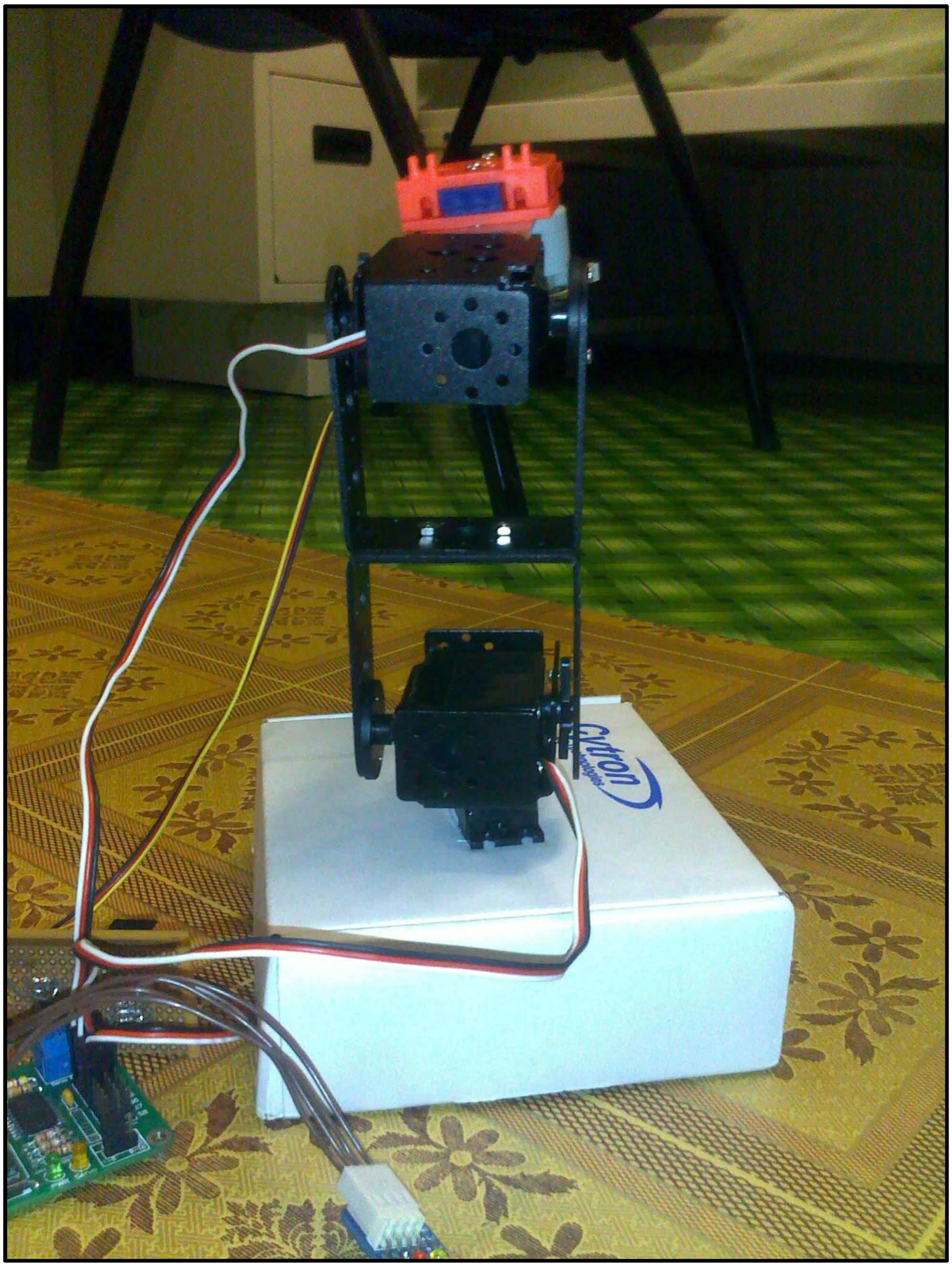


**Figure 4.11:** Back View of Robotic Arm

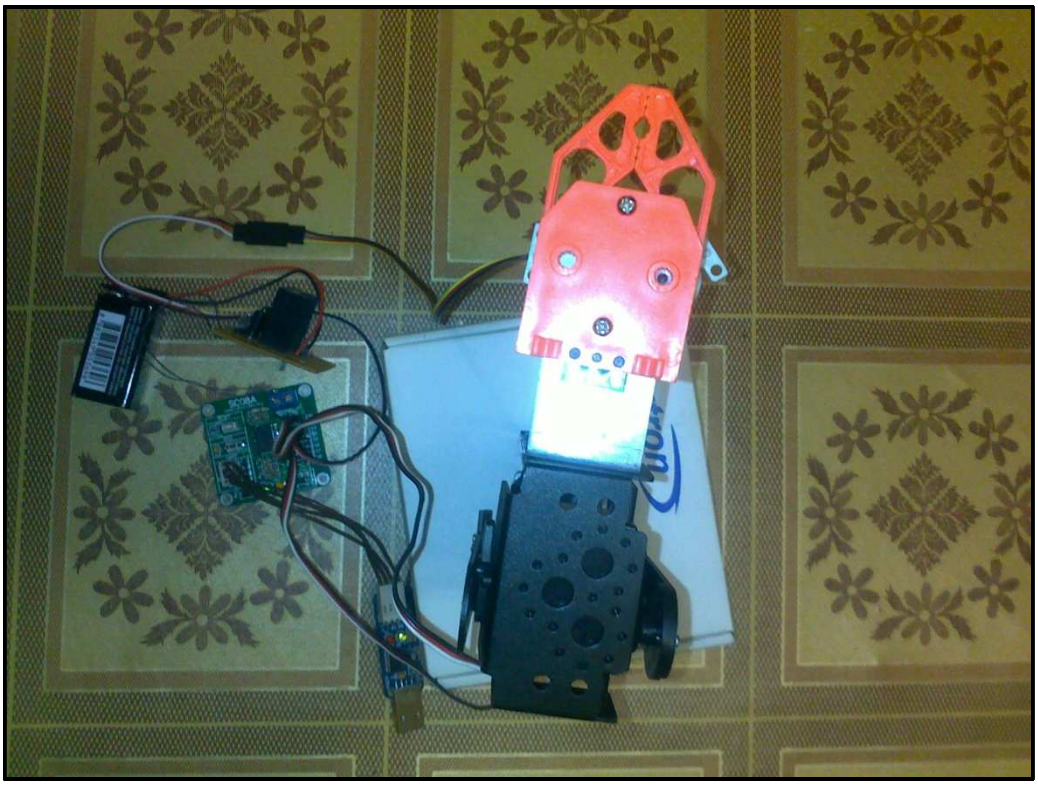

**Figure 4.12:** Top View of Robotic Arm

# CHAPTER 5

# CONCLUSION AND RECOMMENDATION

## 5.1 CONCLUSION

The development stage of the product started with the background knowledge of the certain product. All the method related to robotic arm, previous research that had been accomplished and robotic arm mechanism is discussed. The second step is about design concept; which is how the robotic arm looks like, dimension of the robotic arm, calculation related to achieve the perfect design although it is hard to fabricate the most perfect robotic arm. This step includes detail drawing fabrication process. Detail drawing is the drawing sketch of robotic arm in solidworks and then dimensioning process is carried out. The third step is analyzing the finish product. The important of the third step is to make sure the robotic arm is able to move perfectly by choosing the most suitable servo motor and servo controller. The servo motor used for robotic arm affect the performance of the robotic arm, this explain how power of the motor considered as the main mechanism in robotic arm.

The present study successfully indicated that the main objective of the project is achievable. The development of the Robotic Arm to lift an item gives more advantages for the factory because it is the mechanism to ease factory work. Besides that, it can save work power, time and money. The efficiency of the gripper still needed to be improved, by improving this mechanism, the power source to move the gripper can be reduced. All additional features can be added for more practical usage for example sensors at the gripper.

## 5.2 RECOMMENDATION FOR THE FUTURE RESEARCH

This topic explains how robotic arm can be upgraded with variety of design, analysis and motor. The performances of the robotic arm rely on it design, the perfect design enhance the perfect performance of the robotic arm. It can be upgraded with putting ball joint at each arm link joint. This ball joint functions as a two degree of freedom modular wrist which capable to reduce the friction of the working motor.

Robot kinematic is the main important thing related to the movement of the robotic arm either in static and dynamic condition. The geometry and the kinematics of robotic arm link must be carefully studied to obtain much iteration. The iteration of kinematic of robotic arm then can be analysis to improve the movement of the robotic arm link. The robotic arm kinematics also determine the versatility of the robotic arm perform a variety of task indoor and outdoor environment. The optimization of robot kinematic is needed to maximize the working area and to minimize the robot in stability.

Minimum weight design also can be improved by selection of two main links of robotic arm which is robotic arm link 1 and robotic arm link 2. This analysis can be performed by using finite element stress analysis by analyze each material used for the robotic arm. The element of the link must be considered first either quadratic tubes, brick, plate or many more. The perfect selection of this material will improve the performances and the stability of the robotic arm to stand any load without reaching maximum load.

As a conclusion, the future research of robotic arm is needed to maximize the performances. The system analysis of the robotic arm includes the study of engineering drawing of the robotic arm chasis and drive system. Drive system is the operating system which functions as the controller of the robotic arm. The conceptual design involves the study of the geometry of the robotic arm, kinematic parameters, disposition, and type of actuators, finite element stress analyses of links to minimize the masses and inertias, and selection of the material.

# REFERENCES

This guide is prepared based on the following references:

Marais J, Mathews E, Pelzer R., Analyzing DSM opportunities on mine conveyor systems in Industrial and commercial use of energy conference; Cape Town, South Africa; 28-30 May 2008.

C.W de Silva and A.G.J MacFarlane, Knowledge-based control approach for robotic manipulators, Internat J. Control 50 (1989) 249-273.

John R. Rogers, Low-cost teleoperable robotic arm, 2008.

H.J. Su, B. O CHoi and K Krishnamurthy, Force control of high-speed, lightweight robot (manipulators), Mathematical and Computer Modeling, Volume 14, 1990, Pages 474-479.

G. Dodds and N. Glover, Detailed modeling and estimation of practical robotic parameters; for precision control, Control Engineering Practice, Volume 3, Issue 10, October 1995, Pages 1401-1408.

## SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project report and in our opinion this project is satisfactory in terms of scope and quality for the award of the Degree of Bachelor of Mechanical Engineering.

Signature :
Name of Supervisor : DR. HAJAH YUSNITA RAHAYU
Position : SENIOR LECTURER
Date : 30 MAY 2011

## STUDENT'S DECLARATION

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

Signature :
Name : FRANCIS GIANG ANAK JAPAR
ID Number : MA07031
Date : 30 MAY 2011

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## ABSTRACT

This thesis is related to the mechanism of a robotic arm that serves as a tool to lift an object from one place to another where it is widely used in the factory. The study of this material was analyzed using computer software that can calculate the finite element of linear stress analysis of each mechanical components of robotic arm. Results of this analysis will be a reference to select suitable material. In this project, the aluminium 6061 was used. In addition, the selection of electrical components used in the robotic arm is also taken into account by calculating the inverse kinematic and forward kinematic of this robotic arm movement. Besides that, the forces exerted on the robotic arm are also calculated to ensure the mechanical components of the robotic arm is not easily broken or damaged. Referring to the result obtained, a robotic arm resistance depends on the motor used. Therefore, the compatibility of motor torque with the robotic arm design is made is important because it affects the stability of the robotic arm.

**ABSTRAK**

Tesis ini berkaitan dengan mekanisma lengan robot yang berfungsi sebagai alat untuk mengangkat barang dari satu tempat ke tempat yang lain dimana ia banyak digunakan di dalam kilang. Kajian tentang bahan ini di analisis menggunakan perisian komputer yang mampu mengira "finite element linear stress analysis" setiap komponen lengan robot. Keputusan analisis ini akan menjadi rujukan untuk memilih bahan yang sesuai. Dalam projek ini, aluminium 6061 telah digunakan. Selain itu, pemilihan komponen elektrik yang digunakan dalam lengan robot ini juga diambil kira dengan mengira kinematik terbalik dan kinematik depan pergerakan robot ini. Di samping itu daya yang dikenakan terhadap lengan robot ini juga dikira untuk memastikan robot komponen mekanikal robot ini tidak mudah patah ataupun rosak. Merujuk kepada keputusan yang diperolehi, daya ketahanan sesebuah lengan robot bergantung dengan motor yang digunakan. Kekuatan torque motor yang tinggi mampu menambahkan lagi kecekapan lengan robot tersebut. Oleh itu, keserasian torque motor dengan reka bentuk lengan robot yang dibuat amat penting kerana ia mempengaruhi kestabilan robot tersebut.

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# LIST OF SYMBOLS

| | |
|---|---|
| cm | Centimetre |
| $F$ | Force |
| Kg | Kilogram |
| $L$ | Length |
| M | metre |
| $M$ | Moment |
| $\emptyset$ | Phi |
| $\theta$ | Theta |
| $T$ | Torque |
| V | Voltage |
| $W$ | Weight |

# LIST OF ABBREVIATIONS

| | |
|---|---|
| AGC | Automated Guided Conveyor |
| AGV | Automated Guided Vehicle |
| RC | Radio Control |

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**SESI PENGAJIAN**: **2010/2011**

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I certify that the project entitled *"Design and Develop Robotic Arm for Automatic Guided Conveyor"* is written by *Francis Giang Anak Japar*. I have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering.

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