Design Consideration of Gripper Control for Mine Detector Robot (MDR)

W.H.Hong, H.Mansor, N.S.Khalid, A.Z.A.Firdaus, I.I.Ismail, S.N.A.M.Kanafiah and H.Ali
School of Mechatronic Engineering, Universiti Malaysia Perlis (UniMAP), Kampus Pauh Putra, 02600 Arau, Perlis
humairah@unimap.edu.my

***Abstract*—Landmine is an explosive device designed as a military weapon and poses a great threat to humanity. The metal detector robot is designed to detect the location of the landmine to increase the efficiency in the demining process. Most of the mine detector robot does not have the mechanism for the application of pick and place the landmine from the ground. Human still has to manually dispose of the landmine even with the assist of the mine detector robot. This situation still threatens the safety of human during the demining process. This situation can be overcome if the mine detector robot is equipped with a robot arm with gripper control to pick up a landmine. Hence, in this paper, the arm with gripper control is designed for pick and place of landmine which can be implanted on the mine detector robot. This robot arm can be controlled wirelessly within a safety range to perform pick and place of the landmine. Some of the simulations of static analysis has been done to test the ability of this gripper. As a result, this gripper can pick up the load up to 500g.**

***Index Terms*— Gripper Control; Landmine; Mine Detector Robot (MDR); Pick and Place.**

I. INTRODUCTION

There are two types of landmines which are anti-tank mines and anti-personnel mines. The anti-personnel mines are more dangerous compared with anti-tank mines because anti-tank mines need high pressure about 100- 300kg to detonate while the anti-personnel mine only required the pressure about 5-50kg to activate it [1]. The metal detector robot is designed to detect mines, and it has increased the efficiency of the demining process because the mine detector robot helps to detect the location of a landmine. The Mine Detector Robot (MDR) also reduces the risk of injury caused by the false detection of a landmine during the demining process. There are some limitations with most of the mine detector robot where the Mine Detector Robot (MDR) only perform on detection of landmines, and it cannot help people to dispose of the mines. Therefore, the process of demining is still dangerous to people even though with the assist of the mine detector robot because people still have to either detonate or disarm the landmine which is still active manually.

This paper describes the mechanical design, static analysis and the moment calculation for the robot arm which designed for the Mine Detector Robot. The static analysis can help determine whether the design structure of robot arm can withstand a given load condition. The moment calculation is used for the selection of motor for the robot arm.

II. MECHANICAL DESIGN OF THE ROBOT ARM

A. Design of Robot Arm

The mechanic of the robot arm is based on a robot manipulator with similar functions to a human arm [1-3]. The robotic arm is designed by using the Catia V5 CAD software. The complete design of the robot arm has been assembled by using various parts of the robot. The assembly includes parts such as the base, body arm and gripper for the robot arm.

Figure 1 shows the Free Body Diagram (FBD) of the robot arm. The workspace of a robot arm with four degree of freedom (4DOF) provided enough movement to perform the application of the pick and place for Mine Detector Robot. This robot arm is an articulated robot arm and all the joint in this robot arm is the revolute joint. The electric servo motor actuates the robot arm joints. Table 1 shows the specification of the robot arm.

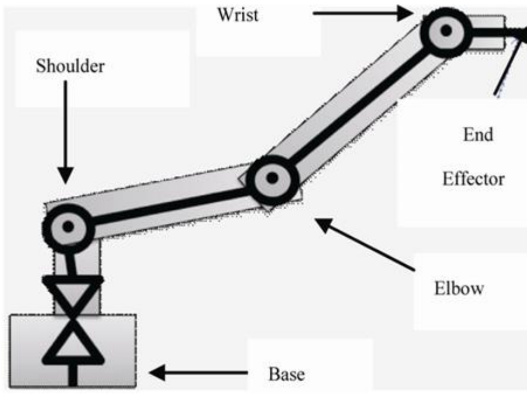

Figure 1: Free body diagram of the 4DOF robot arm

Table 1
The Specification of the Robot Arm

Specification	Value
Number of axis	4
Horizontal reach	249mm
Vertical reach	454mm
Actuators	5 servos motor
Material	Aluminum
	Density: 2710kg/m"
	Poisson Ratio: 0.3

Figure 2 shows the full robot arm which is designed in the Catia V5 CAD software. The design of the robot arm has to perform the static analysis to ensure the design of robot arm is successful, and it can withstand the target load without the deformation.

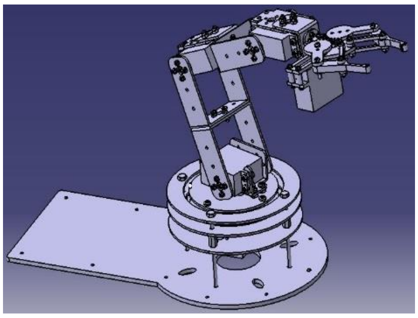

Figure 2: Robot arm design on Catia software

B. Design of Gripper

Figure 3 shows the design of the gripper in the Catia software. This gripper design is based on the two-jaw gripper mechanism. The gripper only requires one motor to operate. The gripper is developed to be able to grip square and the round-shaped target object. The material for the gripper used is aluminium material. This can make the gripper lighter and more rigid.

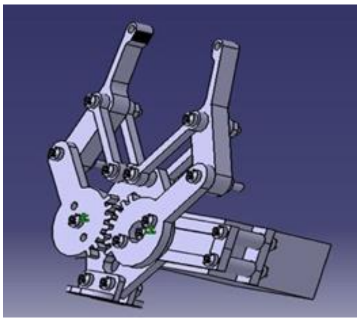

Figure 3: Design of gripper in CAD software

III. METHODOLOGY

A. Simulation of Static Analysis on Robot Arm and Gripper

The robot arm and gripper model have been performed the static analysis which by using FEA method in Catia. Catia can show the result of Von Mises stress on the effect of the applied force for the robot arm. The maximum of Von Mises stresses able to determine the critical stress and critical point of the design model. By comparing the critical stress with the yield strength of the material, it can determine whether the design of robot arm and gripper can withstand a given load condition. Table 2 shows the material properties of aluminium.

Table 2
Material Properties of Aluminium

Material	Aluminium
Young modulus	$70GNm^{-2}$
Poisson ratio	0.346
Density	$2710kgm^{-3}$
Thermal Expansion	$23.6\mu K^{-1}deg^{-1}$
Yield strength	$310MNm^{-2}$

Figure 4 shows the result of static analysis on the robot arm body and the load application on the robot arm body is 500g. From the Figure 4, the critical point for the robot arm body model is on the first joint of a motor shaft, and the critical stress is $0.218GNm^{-2}$. In this case, the critical stress is less than the yield strength of the aluminum material. In conclusion, the robot arm body is rigid and will not break under 500g load.

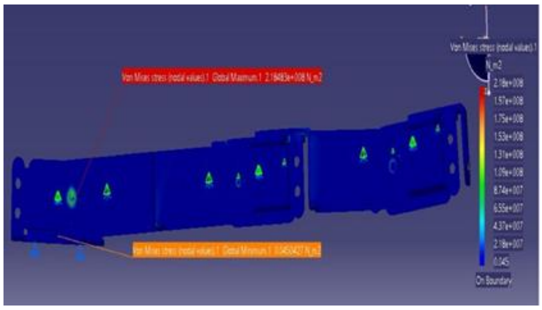

Figure 4: Result of Von Mises stress on the robot arm

Figure 5 shows the result of static analysis on the gripper. From the Figure 5, the critical point for the gripper model is at the end of the body part of the gripper, and the critical stress is $0.0237GNm^{-2}$. The critical stress is less than the yield strength of the aluminium material. In conclusion, the gripper is rigid when gripping the 500g load.

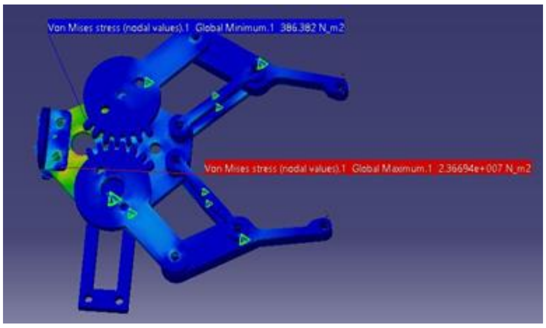

Figure 5: Result of Von Mises stress on the robot arm

B. Moment Calculation on Robot Arm and Gripper

The moment calculation for the robot arm and gripper will be shown in detailed. Figure 6 shows the free body diagram of the robot arm which is fully stretched out. Table 3 shows the detail of parameter which is the length of the link, the weight of the joint and weight of the link.

Table 3
Parameter of Robot Arm and Load

Parameter	Weight(kg)
Weight of the link 1, W1	0.0422
Weight of the link 2, W2	0.0417
Weight of the link 3, W3	0.1457
Weigh of the servo motor	0.0662
The target load	0.500
Length of the link 1	10.5
Length of the link 2	9.8
Length of the link 3	15.1

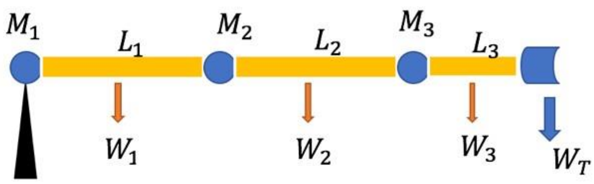

Figure 6: Free body diagram of the robot arm

The moment equation can be derived for each joint of robot arm where W_i= weight of the link and joint, L_i= length of the link and W_T= load.

Moment at joint 1:

$$M_1 = W_1\frac{L_1}{2} + W_2(L_1 + \frac{L_2}{2}) + W_3(L_1 + L_2 + \frac{L_3}{2}) + W_T(L_1 + L_2 + L_3) \quad (1)$$

Moment at joint 2:

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

Moment at joint 3:

$$M_3 = \frac{L_3}{2}W_3 + L_3W_T \quad (3)$$

Moment for joint 1 to 3 have been obtained after input all the parameter. M_1 = 24.5 kg.cm, M_2= 14.3 kg.cm, M_3 =8.65 kg.cm

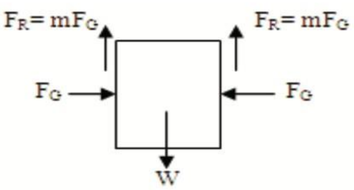

Figure 7: Free body diagram of the target object in the gripper

Figure 7 shows the Free Body Diagram (FBD) for the target object in the gripper. The designed gripper which use two jaws to grip the object. Therefore, two forces is acting on the target object. The equation for minimum grip force for the gripper to grip target object without a slip is:

$$F = \frac{mg}{2\mu} \quad (4)$$

whereas the m=0.500kg and μ= 2.5 which is the static frictional coefficient and g=9.81m/s^2. Minimum required grip force, F=1.635N. The gripper torque can be approximately calculated by multiplying the jaw length with the grip force of the gripper as shown in Equation (5).

$$\text{Gripper torque, } T = 1.635 * 0.8 \quad (5)$$

The minimum torque required by the gripper to grip a 500g object, it required motor has the minimum of 13.34 kg.cm to enable the gripper to grip the object without slip.

IV. RESULTS AND DISCUSSIONS

A. Result on Hardware

Figure 8 shows the hardware gripper. The material that used is of aluminium material.

Figure 8: Hardware of gripper

B. Circuit Design for the Robot Arm

Figure 9 shows the schematic diagram for the circuit connection of the robot arm and gripper. The component in the circuit design has five servos motor, Arduino Uno R3 microcontroller, HC-05 Bluetooth module and battery to act as the power supply.

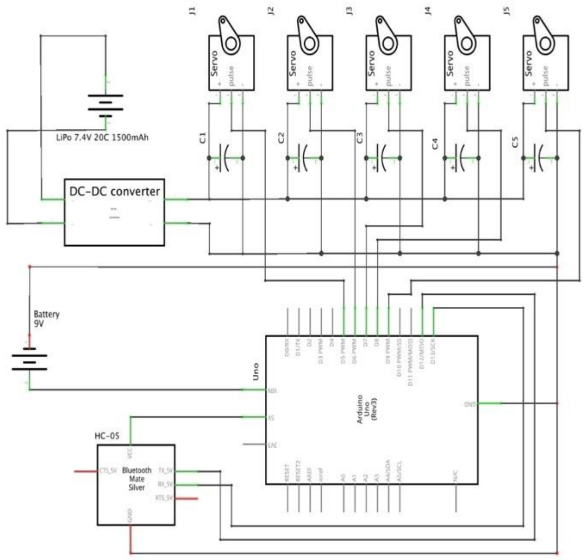

Figure 9: Schematic diagram of the robot arm

There is two power supply in the circuit to ensure the circuit can function adequately. The servo motor needed more power when compared to the Arduino Uno board. The Li-Po battery has been chosen because it has the high discharging rate up to 30A which is required to supply the servo when the motor is stalling. However, the voltage rating for the servo motor is 6V. A DC buck converter is applied into the circuit to step down the voltage of the battery to 6V. The output current of DC buck converter is up to 15A which enough for the application in this project. The capacitor used in the circuit to filter the noise of servo motor.

C. Result of Robot Arm on Various Load

After the prototype of robot arm has been assembled out, the various load, shape and size of the target object have been tested to determine the maximum payload of the robot arm. The flow of robot arm to perform the pick and place of the target object which shown in Figure 10 to Figure 12.

Figure 10: Initial position of the gripper

Figure 11: The gripper move to the target position

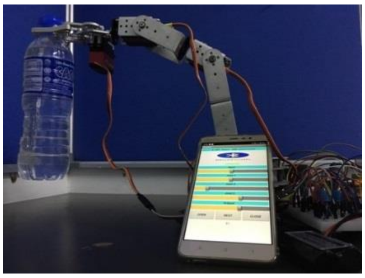

Figure 12: Target object lifted and gripped

Table 4 shows the result of robot arm on various load. For the result in the category to pass, the gripper should grip the object firmly without slipping with addition ability to lift the object. Otherwise, it will consider as failed.

Table 4
The Result on Various Target Load

Load(g)	Result
50	Pass
100	Pass
150	Pass
200	Pass
250	Pass
300	Pass
350	Pass
400	Pass
450	Pass
500	Pass
550	Fail

V. CONCLUSION

The robot arm is designed to help the people who in the process of a demining landmine. The robot arm which can be controlled wirelessly through the HC-05 Bluetooth module. With the aid of phone application to control the robot arm, there is no need extra hardware controller to the robot arm which can reduce the cost of the Mine Detector Robot (MDR). The weight of the full robot arm is only 1.2kg, and it is light to be installed on the Mine Detector Robot. The Arduino microcontroller controls the robot arm and gripper. The robot arm also can be reprogrammed to achieve the requirement of the customer. The GUI of phone application is user-friendly and allowed the user can control the robot arm smoothly. There is not much button to control the robot arm, the GUI of phone application provides the slider button control which allows user can enjoy more precise control of the robot arm.

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