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Design and implement of welding machine for circular welding process

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Submitted to the College of Engineering
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Design and implement of welding machine for circular welding process

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Abstract

Welding process is associated with many factors, these factors affect the rate of production and cost in addition to profit margin. In the manual welding system, welding was done manually using welding pistols, so the weld is not produced with the precision and quality required. The objective of this project is to produce circular welding for cylindrical work pieces more efficiently, higher accuracy, better quality, less running time, fewer workers and better consideration of worker safety. The welding process is achieved by "PLC". This project is about the number of inputs and outputs that have been introduced into the program using control systems. The system is controlled by a programmable logic controller. Automatic welding system produces circular welds independently of workers' skills.

ترتبط عملية اللحام بالعديد من العوامل ، تؤثر هذه العوامل على معدل الإنتاج والتكلفة بالإضافة إلى هامش الربح. في نظام اللحام اليدوي ، كان اللحام يتم يدويًا باستخدام مسدسات اللحام ، لذلك لا يتم انتاج اللحام بالدقة و الجودة المطلوبة . الهدف من هذا المشروع هو إنتاج لحام دائري لقطع الشغل الأسطوانية بكفاءة أكبر ودقة أعلى وجودة أفضل ووقت تشغيل أقل وعدد أقل من العمال ومراعاة أفضل لسلامة العمال. يتم تحقيق عملية اللحام عن طريق "PLC". هذا المشروع حول عدد المدخلات والمخرجات التي تم إدخالها إلى البرنامج باستخدام أنظمة التحكم. يتم التحكم في النظام بواسطة جهاز تحكم منطقي قابل للبرمجة. النظام الآلي للحام ينتج اللحامات الدائرية بشكل مستقل عن مهارات العمال .

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Chapter 1 : Introduction

1.1. Overview

1.2. Project objectives

1.3. Motivation

1.4. Problem definition

1.5. Solution

1.6. Time plan

1.7. Total cost

Chapter 1 : Introduction

1.1. Overview :

Welding is the process of material joining, where two parts are connected at their contacting surfaces by suitable heat and pressure. Welding processes are accomplished by heat alone, by heat and pressure, and with pressure only. The factories and companies suffer from the process of circular welding of cylindrical shapes such as a barrel. So the work on the production of circular welding machine which can be adjusted for different diameters of circular welding is significant . Automatic welding machines are very precise and the welding processes is very reproducible. Consequently, with ever increasing demand for both high production rates and high precision, automated welding processes have taken a prominent place in the welding field. The most important characteristics of this machine are safer , reduce the risk to the human element in the company and eliminate the defects and errors produced during the welding process**.**

1.2. Project Objectives :

The main objective is to design and implement an welding machine for circular welding process. It can produce circular parts in different positions with more accuracy, the machine operates automatically. All the operator has to do is place the barrel in its proper place, press the power button and control the welding speed with custom buttons**.** This machine are that it is safer and reduce the risk to the human element in the company and eliminate the defects and errors produced during the welding process**.**

1.3. Motivation :

The motivation behind this project is the need for a method or system that perform circular and linear welding forms. Which is one of the most important needs of the market (factories and companies) because of the difficulty of welding circular ring, and this machine is not produced in our country. So we decided to produce this machine with some improvement's.

1.4. Problem definition :

Factories suffer from the difficulty of circular welding and the lack of suitable machines for circular welding in the labor market, due to the high price of imported machine, and the absence of machines produced locally.

Due to the difficulty of standard welding process , the factories need circular welding machines that work better with higher quality and safer technology.

1.5. Solution :

We designed and implemented a local machine to circular and linear welding, thus reduce the cost of importing the machine and the cost of maintenance, to add modifications for them more safety ease of operation in terms of operation and maintenance of the machine. In addition, high speed welding, high quality, a large proportion of slag is recoverable, recycled and reused, high deposition rate.

1.6. Time Plan :

The project was implemented in two semesters . And the stages were divided into sixteen weeks for each semester . As shown in the tables (1 – 1 , 1 – 2) .

Table 1- 1 : Schedule time-first semester

Task \ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Identifying the project idea	■	■														
General study of the project			■	■												
State of the art				■	■	■										
Draw the Machine							■	■								
Design of the mechanical part									■	■	■	■				
Writing and documentation									■	■	■	■	■	■	■	■

Table 1- 2 : Schedule time-second semester

Task \ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Identifying the control system of the machine	■	■	■	■												
Purchase of machine parts					■	■	■	■	■							
Assembly of machine parts										■	■	■	■	■	■	
Design of control system						■	■	■	■							
Testing machine																■
Writing results						■	■	■	■	■	■	■	■	■	■	■

1.7. Expected Budget

The following table 1-3 shows the expected cost of the machine, which was determined after work on the study of the mechanical and electronic parts of the machine.

Table 1-3 : Budget

Tools and Device	**Item**	**Item price $**	**Total price $**
Motor	2	150	300
PLC	1	200	200
Piston	1	100	100
Inverter	1	200	200
Structure	1	300	300
Welding Machine	1	300	300
Total cost			**1400$**

Chapter 2 : State of the art

2.1. Introduction

2.2. Welding type

2.2.1. Arc welding process

2.2.2. MIG Welding

2.2.3. MAG Welding

2.2.4. TIG Welding

2.3. Comparison between CO_2 gas and SAW welding

2.4. Conclusion

Chapter 2 : state of the art

2.1. Introduction

This chapter will contain some machines used in the local market and international markets (containing the specifications and the type of welding used in each machine), each machine will be discussed and the advantages and disadvantages of the machine, to come out with the best design of the welding machine.

2.2. Welding type

2.2.1. Arc Welding :

- The process of joining metal to metal with the help of an electric arc is called arc welding.
- In the arc welding, the arc is used to create intense heat and this heat is used to join the metals together. the arc is brought in between two metal pieces and due to the heat generated, the arc melt and when the metals cools a strong welded joint is formed.**[1]**, as shown in figure 2-1.

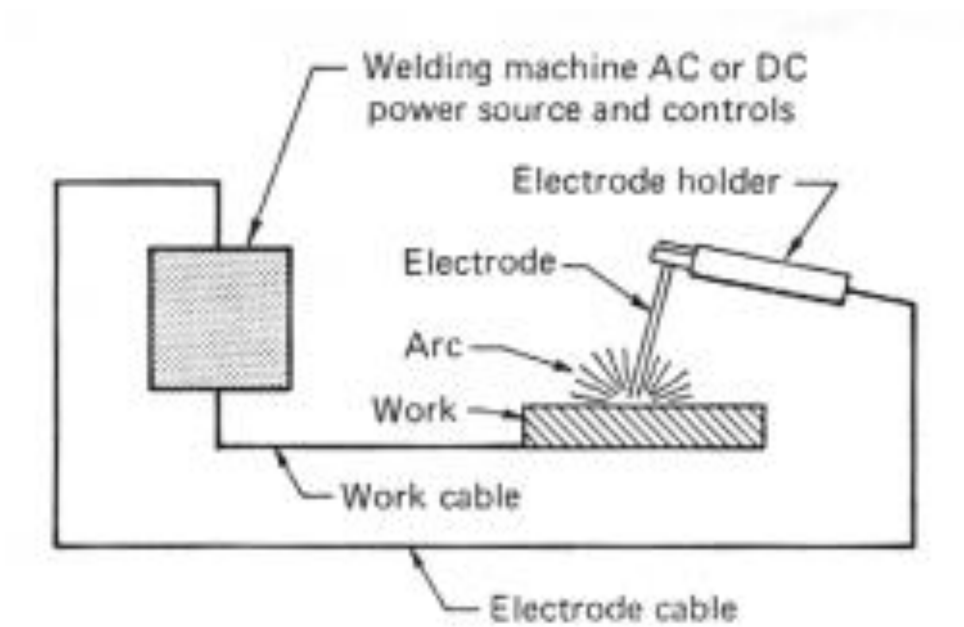

Figure 2- 1 : Arc welding [1]

- **There are number of advantages of using arc welding compared with many other formats[1]:**
  - Cost – equipment for arc welding is well-priced and affordable, and the process often requires less equipment in the first place because of the lack of gas.
  - Portability – these machines are very easy to transport.

- Works on dirty metal.
- Shielding gas isn't necessary – processes can be completed during wind or rain, and spatter isn't a major concern.

- **There are a few reasons why some people look to other options beyond arc welding for certain kinds of projects. These disadvantages include [1]:**
  - Lower efficiency
  - High skill level – operators of arc welding projects need a high level of skill and training, and not all professionals have this.
  - Thin materials – it can be tough to use arc welding on certain thin metals.

2.2.2. Metal Inert Gas (MIG) welding :

- MIG stands for Metal Inert Gas. This type of welding refers to the use of electricity to melt and fuse pieces of metal together. Out of the various welding styles MIG is probably the most basic of all. With this technique, a wire electrode is used to create a flaming arc that generates heat and creates filler material. While this is happening, an inert gas is released around the area of the weld to keep out external contamination**[2]**, as shown in figure 2-2 .
- MIG welding can be used for common household projects such as repairing a metal fence, swing set, or automobile.

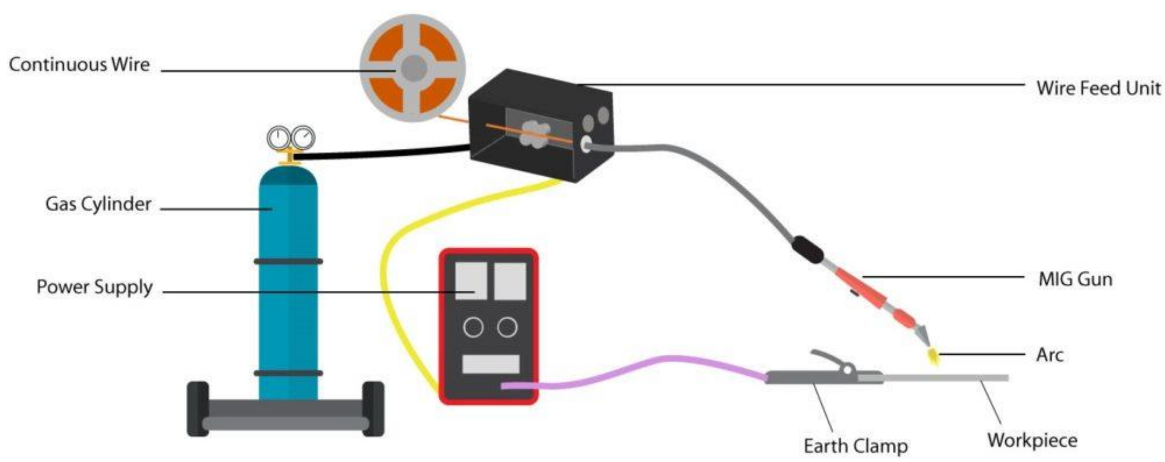

Figure 2- 2 : MIG welding [2]

- **Advantages :**
  - Higher productivity – many welders will enjoy higher productivity due to time saved by not having to constantly change rods or chip away slag, as well as not having to brush the weld repeatedly. They're able to work faster and cleaner**[2]**.
  - Simple of learn – one of the top advantages of MIG welding is its simplicity. Welders can learn how to MIG weld in a few hours**[2]**.

- Simple and great welds – MIG provides better weld pool visibility. Add this to the simplicity of the process and better control offered by the auto-feed wire, and MIG makes it simple to produce a great looking weld**[2]**.
- Clean and efficiency .
- Faster welding speed .

- **Disadvantages :**
  - Cost
  - Unsuitable for thick metals .
  - Unsuitable for outdoor welding .
  - Metal preparation time – before welding with a MIG welder, the material has to be free of rust or dirt in order to get a good weld and for safety's sake**[2]**.

2.2.3. Metal Arc Gas (MAG) Welding

- For MAG welding (with active gases) a gas mixture of Argon, Carbon dioxide and Oxygen is used. The proportions of the individual gases can be adjusted to the requirements of the material to be welded. In this way, secondary phenomena or side effects such as burn-in and spatter can be reduced. MAG welding is mainly used for unalloyed steels. As shown in figure 2-3 [3] .

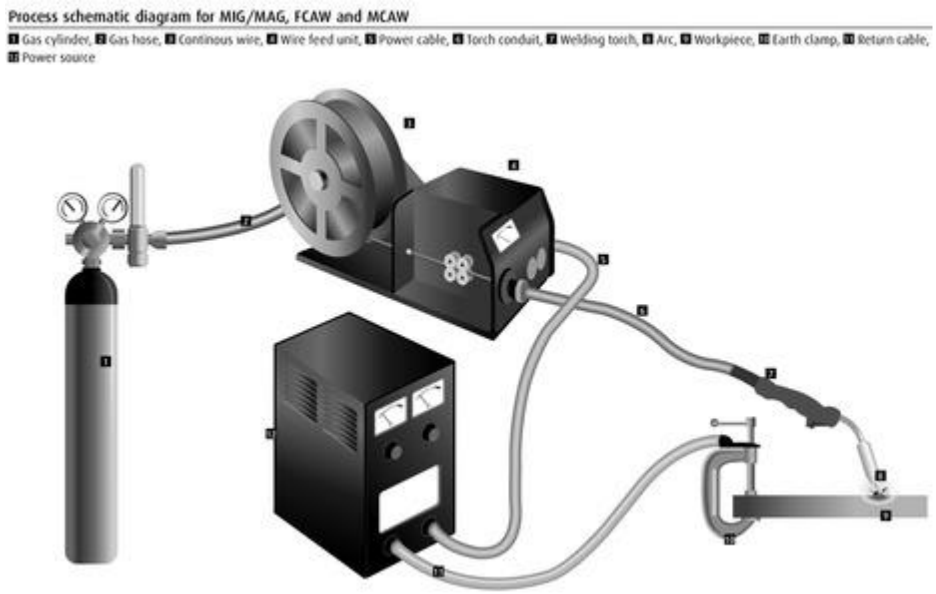

Figure 2-3 : MAG Welding [3]

- **Advantages[3]**
  1. The weld is protected against oxidation.
  2. No slag is produced.
  3. The working speed is very high.
  4. This procedure can be used in all Welding positions.

- **Disadvantages[3]**
  1. Wind susceptibility – metal shielding gas welding cannot take place outdoors.

2. MAG welding requires a great deal of experience and is not easy to control.
3. All rust must be removed from the weld area beforehand.
4. Protective clothing.

2.2.4. Tungsten Inert Gas (TIG) Welding

- The TIG process uses the heat generated by an electric arc between the metals to be joined and an infusible Tungsten-based electrode, located in the welding torch. The arc area is shrouded in an inert or reducing gas shield to protect the weld pool and the Tungsten electrode.[4]
- TIG welding is especially suited to sheet materials with thicknesses up to about 8 or 10 mm.[4]

- TIG welding offers a solution for welding critical joints, and for situations where small or exceptionally precise welds are required. It can be performed with a wide variety of metals, and, when done correctly, it produces a high-quality and high-purity weld compared with other joining processes, which is crucial in many applications. The price of TIG welding services is also usually quite affordable. However, costs will vary depending upon the materials being welded, and the scope of the project. Overall, it is one of the most efficient ways to join two metals.[4]

2.3. Comparison between CO_2 gas and SAW welding

1. CO_2 gas

- In CO_2 welding, the welding wire wound in coil is fed into the welding torch by the feeding motor automatically. The welding wire that is electrified through the contact tip becomes the electrode to strike an arc between itself and the base metal. The arc heat melts the wire and the base metal to join two pieces of base metal. In this case, in order that the weld metal will not be affected by Oxygen and Nitrogen in the atmosphere, CO_2 gas is supplied from the nozzle of the welding torch to shield the weld pool**[5]** , as shown in figure 2 – 4 .

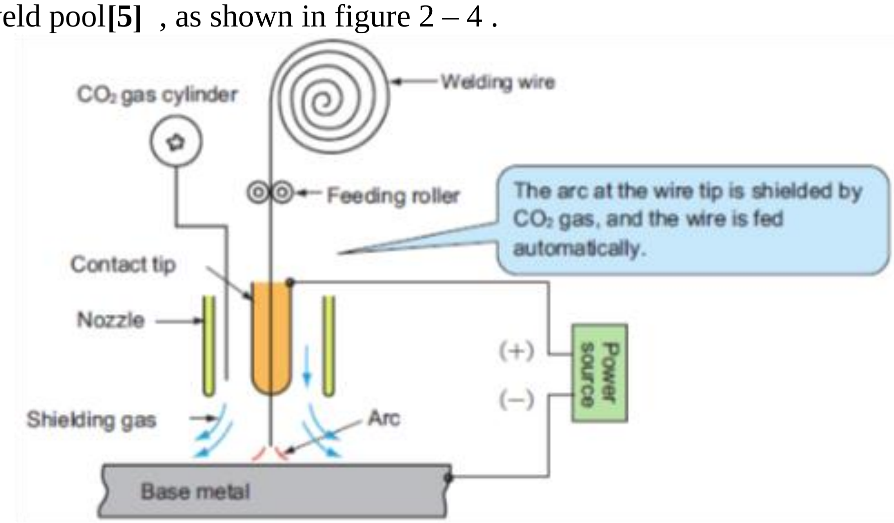

Figure 2- 4 : Schematic diagram of CO_2 arc welding[5]

- **Advantages :[5]**
  - As the diameter of the wire is small, the welding current density is high and thus the deposition rate is big.
  - Good concentration of the arc realizes deep penetration.
  - The arc generation rate is high, thereby lowering the welding cost and making the process to be more economical.
- **Disadvantages :[5]**
  - The price of the power source is high**.**
  - Loss in CO_2 gas**.**

2. Submerged Arc Welding (SAW)

- is a common welding process that is often used in industries such as structural and vessel construction. Also known as Sub-Arc or SAW, this process uses a blanket of granular fusible flux, beneath which both the weld and the arc zone are protected or "submerged." This flux blanket guards against atmospheric contamination, stabilizes the arc during welding, prevents splatter and sparks from flying about, and suppresses radiation and fumes that are typical of the shielded metal arc welding process. As shown in figure 2 – 5 .

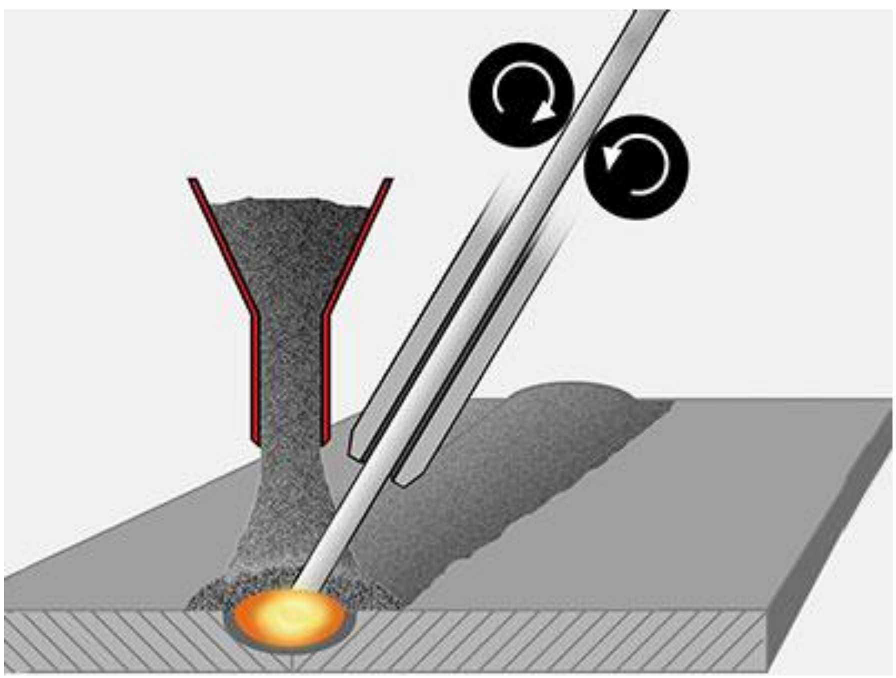

Figure 2- 5 : Submerged arc welding[6]

- **Advantages :**
  - Strong welds are readily made
  - Minimal welding fume is emitted

- Minimal arc light is emitted
- SAW is suitable for both indoor and outdoor works
- Less distortion
- Deep weld penetration
- High deposition rates are possible
- Thick materials may be welded
- At least half or more of the flux is recoverable

- **Disadvantages :**
  - Limited to ferrous (steel or stainless steels) and some Nickel-based alloys.
  - Normally limited to long straight seams or rotated pipes or vessels.
  - Import price of powder**[6].**
  - Limited to high thickness materials**[6]**.

2.4. Conclusion

After comparing welding types and techniques used in welding machines, and knowing the advantages and disadvantages of each type. The type of welding is specified in the machine to be designed.

MIG welding type was chosen because of its high efficiency and accuracy in welding, suitable for fine materials, increased safety, ease of operation

Chapter 3 : Market Study

3.1. Introduction

3.2. Neroukh factory

3.3. Oerlikon factory

3.4. International market

3.5. Conclusion

Chapter 3 : Market Study

3.1. Introduction

In this chapter, a study is conducted on some of the companies and factories producing the circular welding machine which we are working on designing and implementing. Through the knowledge of specifications , prices of machinery and economic quality of the machine.

These companies and factories design machines and sell them in international stores, or use them in the same factory.

3.2. Neroukh factory

Neroukh factory is one of the most important factories in the city of Hebron. It works on producing water boilers, welding operations and other products. The factory uses many mechanical and hydraulic machines, some of which are produced inside the factory. Circular and linear welding machine is designed and implemented by factory workers under the supervision of the Engineer Samir Sider, to get rid of the difficulty of the process of welding and defects resulting in welding. This machine works with MIG welding technology, as shown in figure 3-1 .

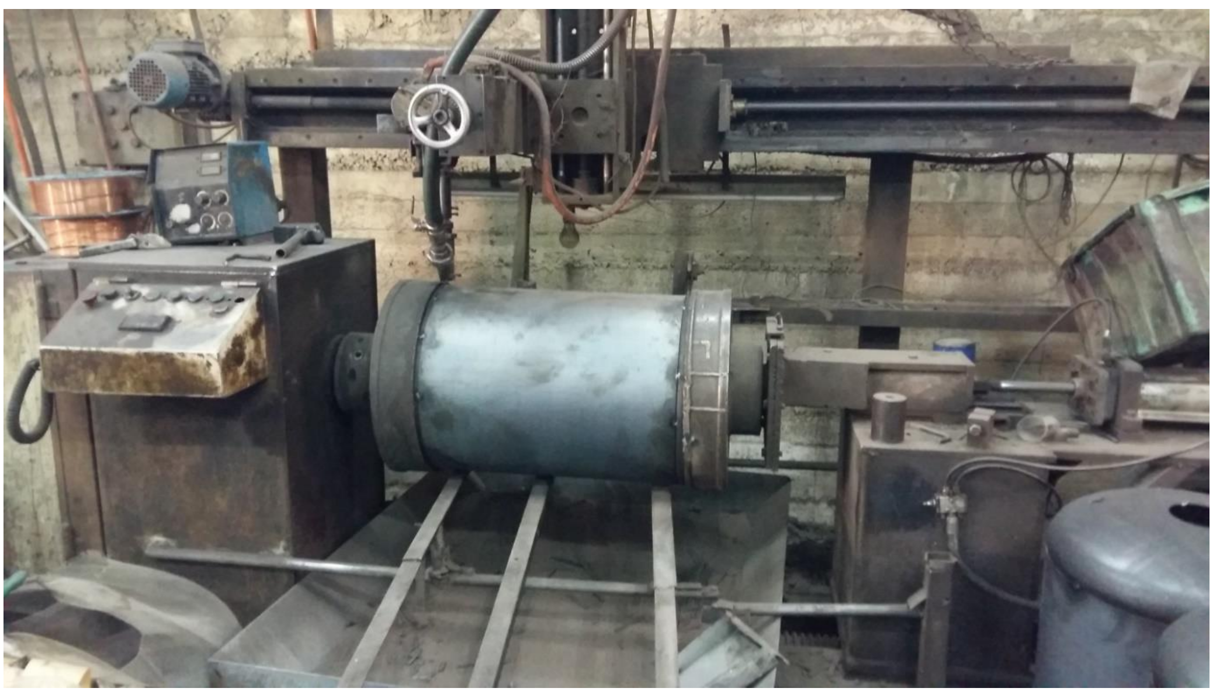

Figure 3-1 : Circular and linear welding machine in Neroukh factory

So that the engineers made the design of the machine to be specification as shown in the following table 3-1 :

Table 3-1 : Specification of machine

Rotating speed	(0.5 – 1.5) rpm
Length of barrel	100 cm
Radius of barrel	(48 , 37 , 27.5) cm
Maximum weight of barrel	150 kg
Current of welding	300 A
Type of welding	Submerged Arc Welding / (MIG welding)

The cost of implementing the machine was $ 15,000. Due to errors resulting in the design of the machine and unsuitable needed materials .

3.3. Oerlikon factory

The most famous Arab factories in the field of welding, located in Egypt, manufactures circular and linear welding machines using various welding techniques (MIG, MAG, Arc and TIG). The machine features the possibility of welding the work piece in seven different angles , as shown in figure 3-1 , with specification in table 3-2 [7]

Figure 3-2 : Welding Machine

Table 3-2 : Specifications for Welding Machine[7]

Rotating speed	(0.15 – 1.5) rpm
Length of barrel	100 cm
Radius of barrel	35 cm (maximum)
Maximum weight of barrel	130 kg
Current of welding	300 A
Angle	0 – 90 º

The factory exports and sells the machine for $ 8000 - $ 12000 , depending on the specifications and standards required.

3.4. International market

Automatic welding machines are one of the goods displayed in the online store, so that displays pictures, specifications and prices of machines. All machines have the same specifications, the difference between them is the type of welding and the used technique, and the prices of machines between ($8,000 – $25,000).[8]

Examples of the most famous machines sold in the world markets

A. **Solar Water Tank automatic Stainless Steel TIG Circular Seam Welding Machine.**

1) Ring seam welding machine is a kind of automatic welding equipment for ring seam. It can be equipped with a TIG Argon arc welding machine (filled or unfilled), a gas shielded gas welding machine (CO_2/MAG/MIG), plasma and other welding power sources to form a ring seam automatic welding system.

2) Consisting of bed body, rotary positioner, belt and screw mechanism, pneumatic mechanism and automatic welding controller.

3) The product adopts a combined structure, which is convenient for assembly and disassembly, and has good maneuverability. Therefore, with the appropriate welding power supply, it can be applied to the automatic welding of all kinds of ring welds.

4) The equipment is mainly used for high quality circumferential seam welding of work pieces of different materials, different sizes and shapes.

5) Similar work pieces such as air reservoirs, fire tubes, drive shafts, shock absorbers, mufflers, pipe flanges, etc. Two welding torches are mounted on the horizontal double-ring seam welder and can be welded at the same time. As shown in figure 3-3 .

6) The cost of building was $ 3500.

7) Specifications as shown in the following table 3-3 .

Figure 3-3 : Welding Machine [8]

Table 3-3 : Specifications for welding machine

Rotating speed	(0.5 – 1.5) rpm
Length of barrel	170.6 cm
Radius of barrel	40 cm
Maximum weight of barrel	500 kg
Current of welding	300 A
Type of welding	TIG Welding
Motor	Stepper motor and servo motor

B. Automatic Arc Welding Machine for Aluminum Tank

This machine is mainly used for automatic welding of various specifications of the tank butt end. Because of the circumferential seam is irregular, so it requires welding torch to track the seam, and can guarantee welding specification and uniform formation. Weld appearance is good, convenient in use, reliable; the welding quality can meet the requirements. As shown in figure (3-4) , and specification in table 3-4.

Figure 3-4 : Automatic arc welding machine[8]

Table 3-4 : Specifications for automatic arc welding machine

Rotating speed	1.5 rpm
Linear Welding	15 mm/s
Length of barrel	500 – 2000 mm
Radius of barrel	500 – 1500 mm
Maximum weight of barrel	150 kg
Current of welding	300 A
Welding Type	Gas CO_2
Cost	$ 8,000 - $20,000

The factory exports and sells the machine for $ 8000 - $ 20000 , depending on the specifications and standards required.

3.5. Conclusion

Through a study of the local and global market, it becomes easy to determine the specifications of the machine we are working to design, to produce the process of welding efficiently and low cost. These specifications are described in the mechanical design chapter.

Chapter 4 : Mechatronics Approach

4.1. Introduction

4.2. Requirements

4.3. Conceptual design

4.4. Functional specification

4.5. PLC connection

4.6. Comparison between PLC and microcontroller

4.7. Modeling the system

4.8. Controlling

Chapter 4 :Mechatronics Approach

4.1 Introduction:

This section describes the architecture of the project, including the system components (subsystems), and the function of each component and demonstrates also the relation between the elements**.**

Mechatronics engineering is interfacing systems, saving time and effort and reducing the inexperienced workforce, so the main idea is to be produce an automatic welding machine instead of manual welding.

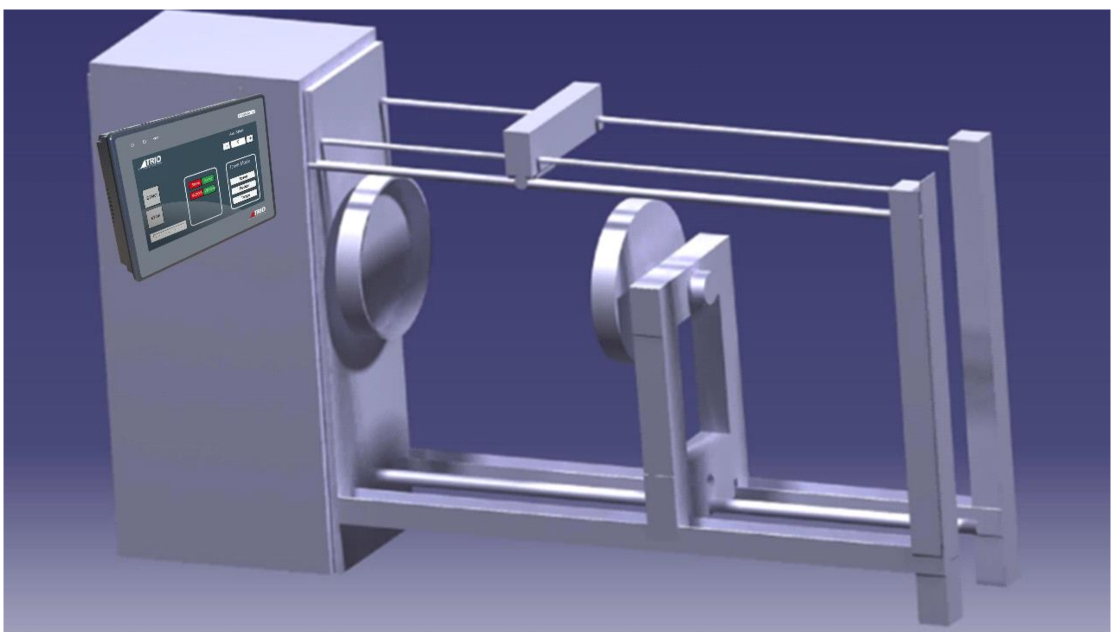

Figure 4.1 :System architecture

As shown in Figure 4.1, the system consists of seven integrated subsystems performs together to justify the goal, the seven subsystems are: power converter, user interface, programmable controller, two motors , welding unit, welding torch and the barrel for circulation process.

4.2 Requirements:

R1- Safety at all times and conditions.

R3-The shape of the system is appropriate.

R4-The possibility of maintenance and replacement parts.

R5-The costs do not exceed $ 2500 .

R6- Maximum mass of barrel is 30 kg.

R7- The radius of barrel 25 cm.

R8- Maximum length of barrel is 30 cm.

R9- Current of welding is 200A.

.

4.3 Conceptual design: idea for solution or (ideation) .

Conceptual design :-

1-components (subsystems) .

2-fuctions of components (subsystems) .

3-Relation among the components .

As shown in Figure 4.2 , main supply feeds power converter. power converter (rectifier) converts 220v ac to 24v dc to feed two motors . Relays and contactors are called control elements, they connected with motors and welding unit. The two subsystems (user interface and programmable controller) are communicate with each other and called controlling unit.

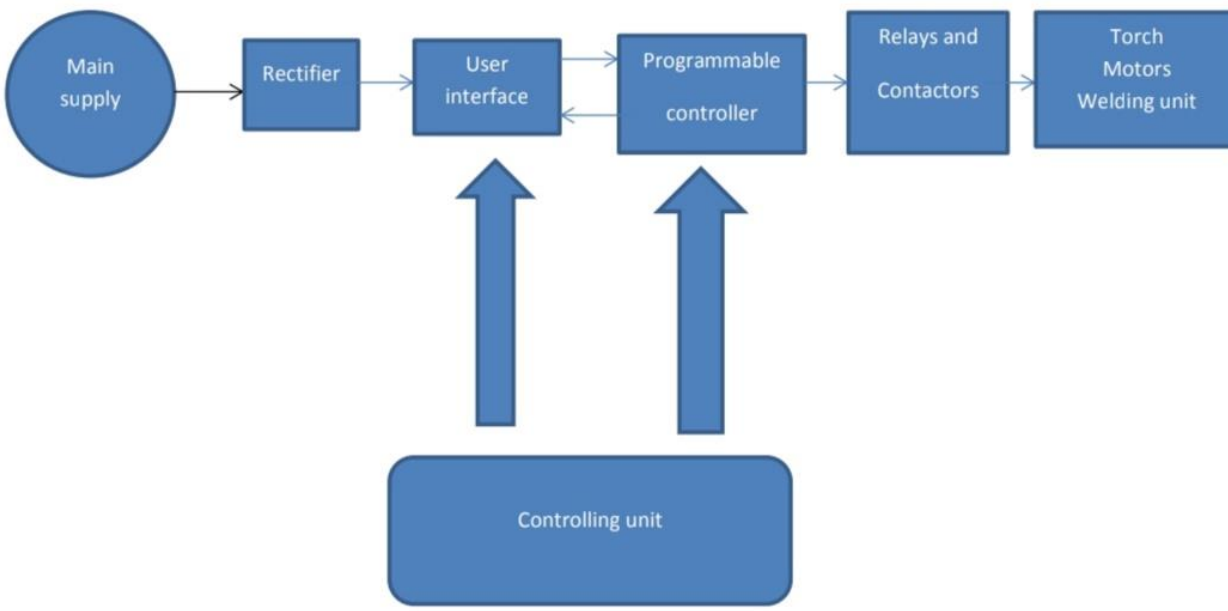

Figure 4.2 :Block diagram shows components of welding process.

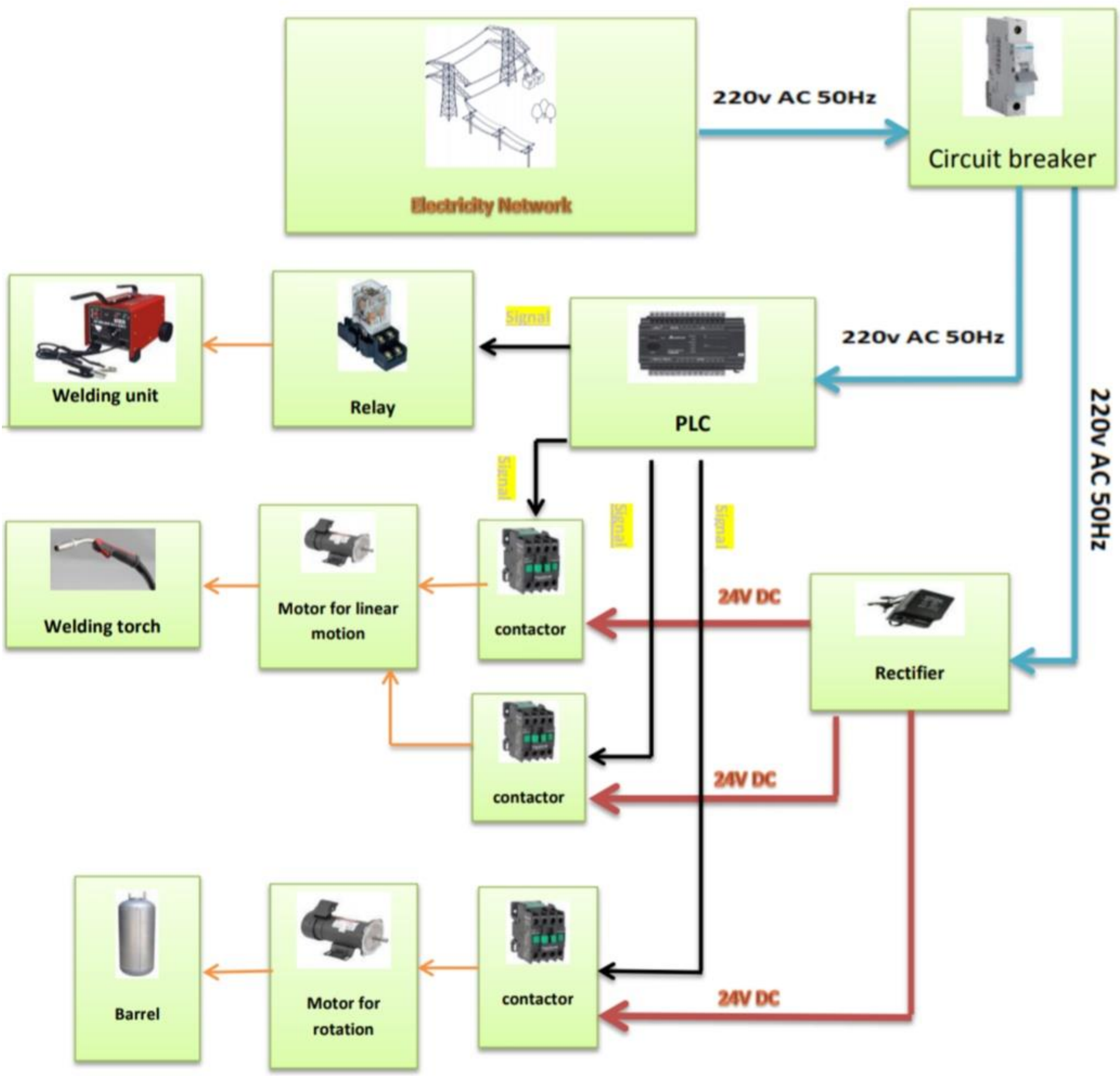

Figure 4.3 :conceptual design of the system.

4.4 Functional specification:

1-Power converter(rectifier): converts 220v ac to 24v dc in order to feed two motors, There is no limitation on its existence in the system.

- converts 220v (ac) to 24v (dc).
- 50HZ .

.

Figure 4.4 : Power converter.

2-Programmable controller (PLC): The selected controller is delta (DVP-16ES2) plc, because the number of input is (8) and the number of output pins is (8) . This is enough to connect all components used in our project, the frequency is good, there are no limitations of this component in the system.

- Compact(DVP-16ES2).
- 220 V (AC).
- .8 input pins
- 8 output pins.

Figure 4.5 : Plc

3-Motors: The system has two motors, one for linear motion and the second for the circular motion ,these two motors satisfy R1 (production of precise and accurate linear and circular welding).

A-Motor for linear motion: This motor is connected with contactor and the contactor connected directly to plc, the main goal of this motor is to move the welding torch along the horizontal line of barrel at a constant speed in order to have a fixed thickness of welding line.

B-Motor for circular motion: This motor is connected with contactor and the contactor connected directly to plc the main goal of this motor is to move the barrel in a circular way with a constant speed in order to have a fixed welding line .

Figure 4.6 : Motor

4- *Welding unit: it works on 220v ac, connected with relay, this component satisfy R11(*Current of welding is 300A*).*

** Input Voltage 220V ac*

** Welding Current : 200A*

Figure 4.7 : Welding unit.

There are some requirements satisfied by machine design in chapter 5 :

*R3(The shape of the system is appropriate):The system is designed with the following dimensions:

220cm L x 60cm W x 70cm H .So we can place the machine in an area of 1.32 square meters, which is suitable for the factory so that does not take much space.

*R7(Maximum mass of barrel is 30 kg), R7(The radius of barrel 25 cm) and R8(Maximum length of barrel is 30 cm): These requirements satisfied with calculation in chapter 5 .

*R4(The possibility of maintenance and replacement parts): The components are arranged in the design so that they are easily accessible without dismantling the entire machine.

*R5(The costs do not exceed $ 2500) : Table (1.3) shows the cost of components.

4.5 PLC connection:

The figure (4.8) shows the connection. PLC has 8 inputs and 8 outputs , that enough for the project and its type (DVP-16ES2) series .Two circuit breakers are used before rectifier and PLC .The main function of a circuit breaker is to detect any faulty condition in the electrical system and discontinue the flow of electricity to ensure safety. A 220V Ac feeds PLC and rectifier. The rectifier(convert 220V AC to 12V DC) also feeds the motors with 12V Dc through contactors (control elements).

As shown in the figure (4.8), the S/S terminal is used to configure the unit inputs for sinking or sourcing signals (all at once).
When the S/S is connected to the logic ground, the inputs react on sourcing signals .When it is connected to the logic power (typically 24V DC) the inputs react on sinking signals . Emergency and stop bush buttons are normally closed, but (On bush button) is normally open. Relay is connected with welding unit (control high voltage through low voltage).

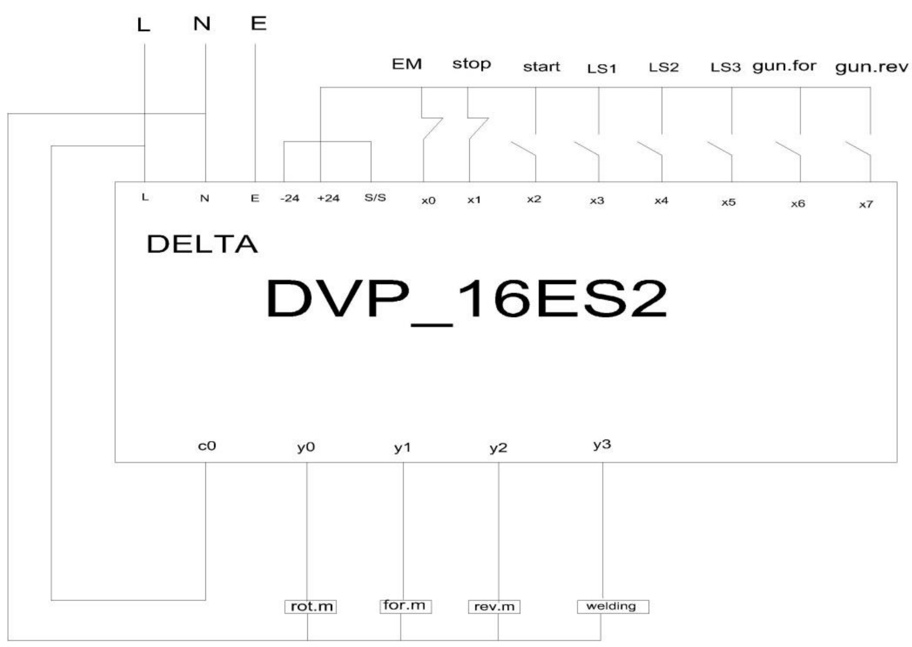

Figure 4.8 : Control and load circuit

Protection:

As shown in figure (4.9), Fuse is connected in series with loads, It is used to protect the rectifier from increasing current, fuse is replaceable and has fast response. Circuit breaker is used to discontinue the current in order to protect the loads.

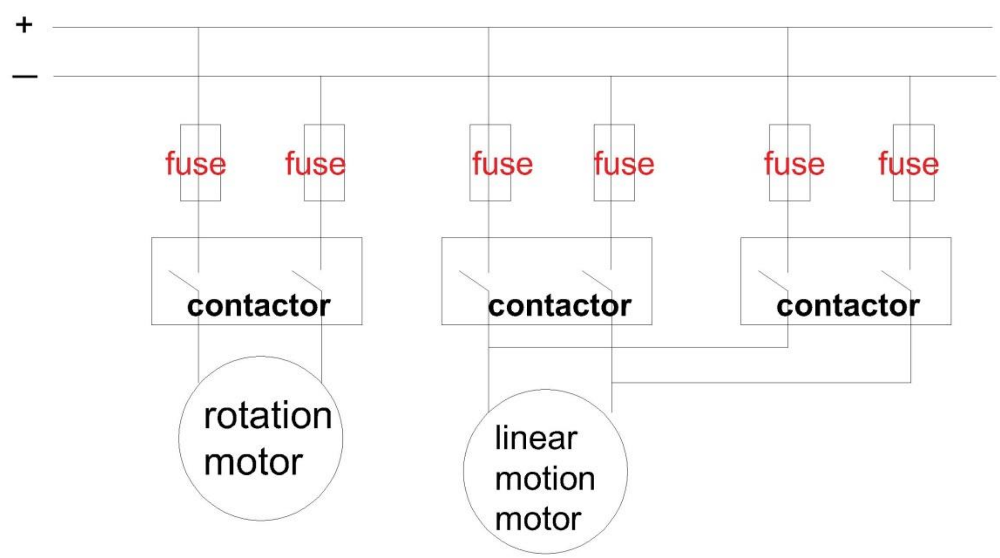

Figure 4.9 : protection circuit

4.6 Comparison between PLC and Microcontroller :

Choosing programmable logic controller instead of microcontroller: There are some reasons for choosing PLC instead of microcontrollers:

1-PLCs are more appropriate for industrial applications due to voltage (24V).

2-Easy Maintenance and Spares Due to modular design.

3-In micro microcontrollers, motors are connected with driving circuits and sensors are connected with condition circuits.

4- programmable logic controller is designed for tough environment (works in higher noise, higher humidity and higher temperature).

5- In microcontrollers, after a long period of work errors will appear.

6- Safety – PLCs manufacturers also provide safety features (Protection/Emergency).

4.7 Modeling the system :

The system can be modeled by a transfer function, G(s), that algebraically relates the Laplace transform of the output to the Laplace transform of the input. This system is divided to two parts:

1) Translational mechanical system in welding torch, as shown in figure (4.10) .

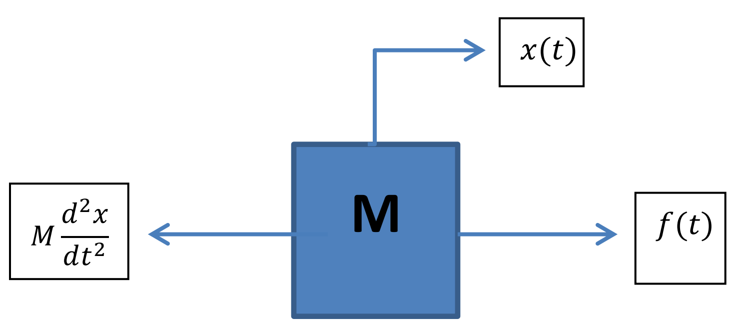

Figure 4.10 : Free-body diagram of welding torch

The differential equation of motion using Newtons law to sum to zero all of the forces is :

$$M\frac{d^2x(t)}{dt^2} = f(t)$$

Taking the Laplace transform, assuming zero initial conditions:

$$Ms^2X(s) = F(s)$$

Solving for the transfer function yields:

$$G(s) = \frac{X(s)}{F(s)} = \frac{1}{Ms^2}$$

2)Rotational mechanical system of rotating parts, as shown in figure (4.11) .

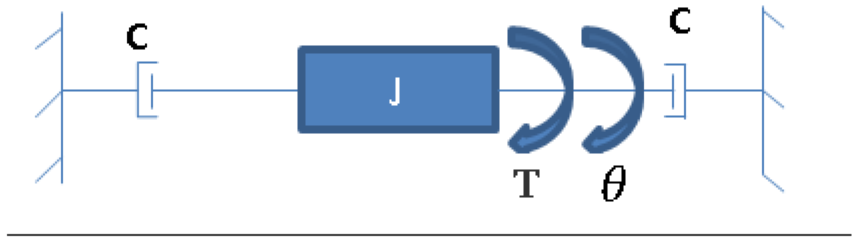

Figure 4.11 : Free-body diagram for rotating parts

The differential equation of motion is :

$$J\frac{d^2\theta}{dt^2} + C\frac{d\theta(t)}{dt} = T(t)$$

Taking the Laplace transform, assuming zero initial conditions:

$$\mathrm{T}(s) = [Js^2 + Cs + Cs]\theta(s)$$

Solving for the transfer function yields:

$$G(s) = \frac{\theta(s)}{T(s)} = \frac{1}{Js^2 + 2Cs}$$

*** Note that damping constant (C) is very small can be neglected**

4.8 Controlling :

1) Rotational motion motor

Through open loop test for rotational motion motor (M1) and linear motion motor (M2) , we got the response from oscilloscope then through laws of control we got transfer functions for Dc motors. First motor (M1) makes barrel rotating, second motor (M2) makes welding torch moving forward and reverse. The mass of welding torch and second moment of inertia of rotating parts is determined From chapter 5 .

- **Mass of welding torch (M) = 5 kg**
- **Second moment of inertia of rotating parts (J) = 9.433 kg.m^2**

As figure (4.10) shows the oscilloscope response for motor responsible for rotational motion (M1).

$$V_f = 1V$$

$$\frac{1}{a} @ 0.63\, V_f$$

$$G(s) = \frac{K}{(s+a)}$$

$$\frac{1}{a} = 500\ mV = 0.5\ V$$

$$a = 2$$

$$\frac{K}{a} = V_f = 1$$

$$K = 2$$

$$G(s) = \frac{2}{(s+2)}$$

Where :

V_f : $final\,Value$

G(s) : Transfer function for Dc motor.

K: Gain.

a: pole of the system.

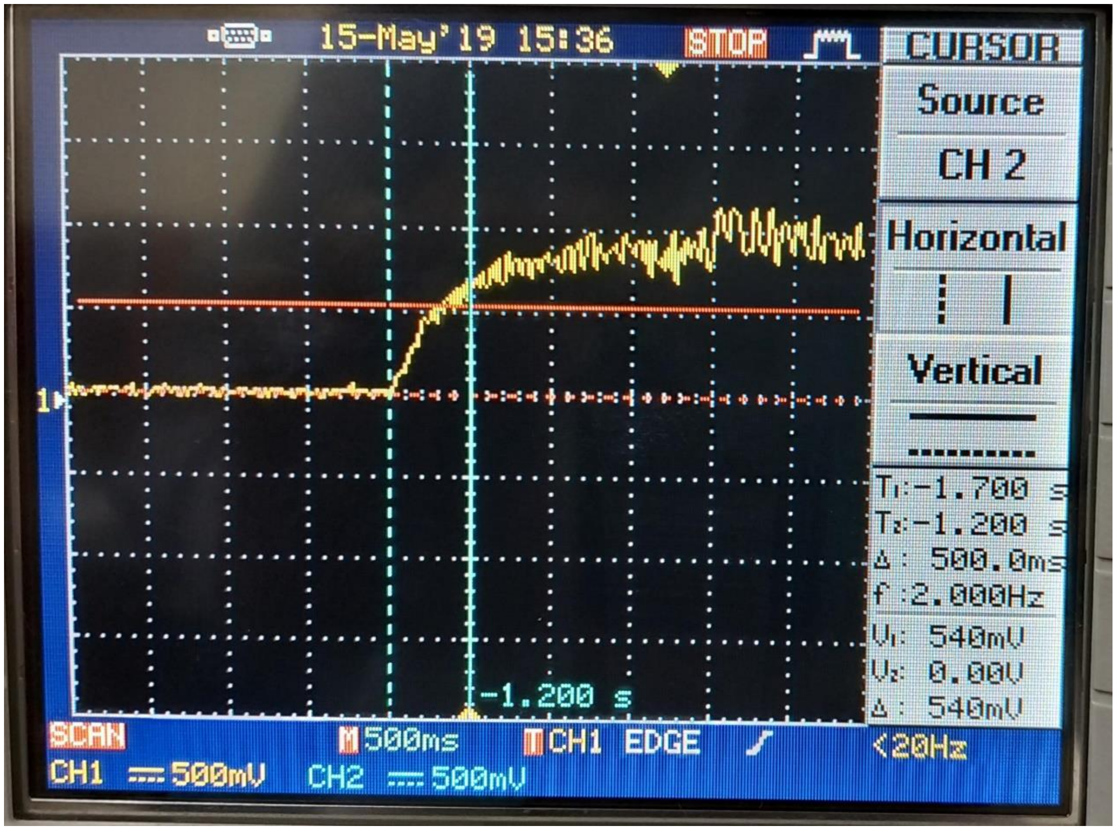

Figure 4.12 : Oscilloscope response for motor responsible for rotational motion

We select the appropriate control method through SISOTOOL in MATLAB. We design PD controller for rotation motor (M1). As figure 4.13 shows, one zero is added to the system in order to improve the transient response.

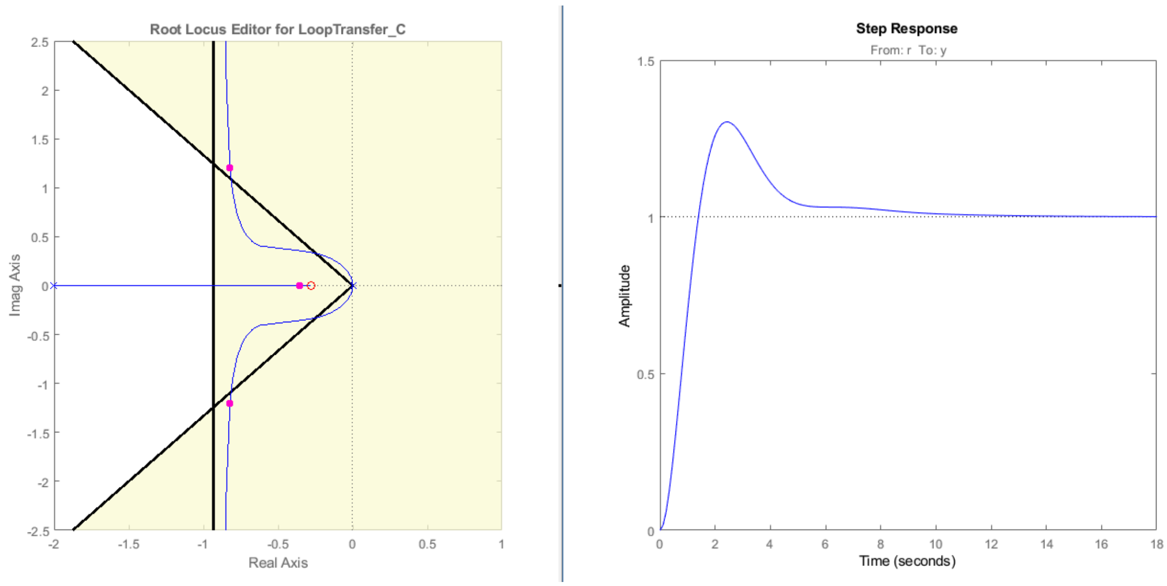

figure 4.13: Systole design for rotational motor

Simulation:

As figure 4.14 shows, the system was built with step input entered to PD controller, control signal entered to the plant motor, the output is position. Scope was used to compare between step input and the response of step input after PD controller .Speed response for rotation motor is shown in figure 4.15

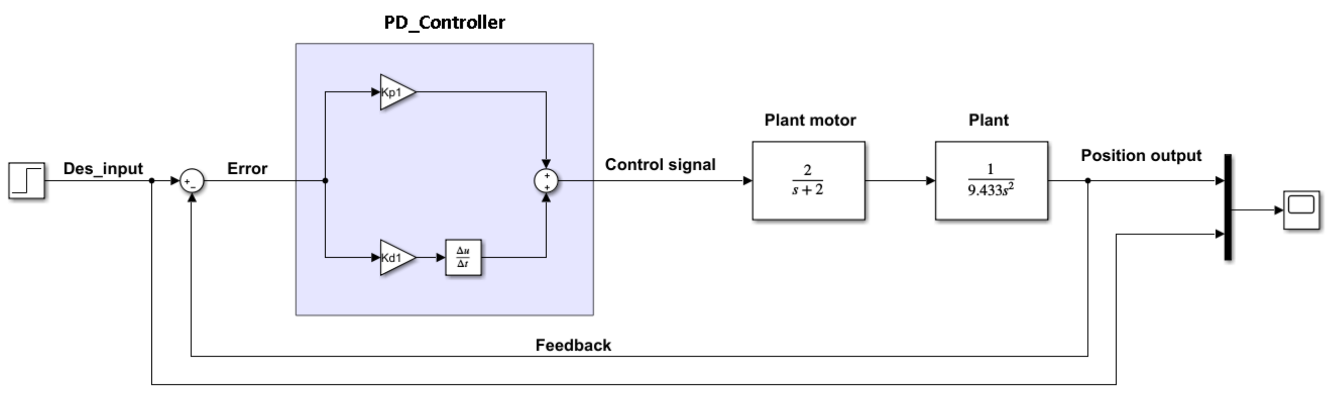

Figure 4.14: Speed control Simulink model for rotation motor

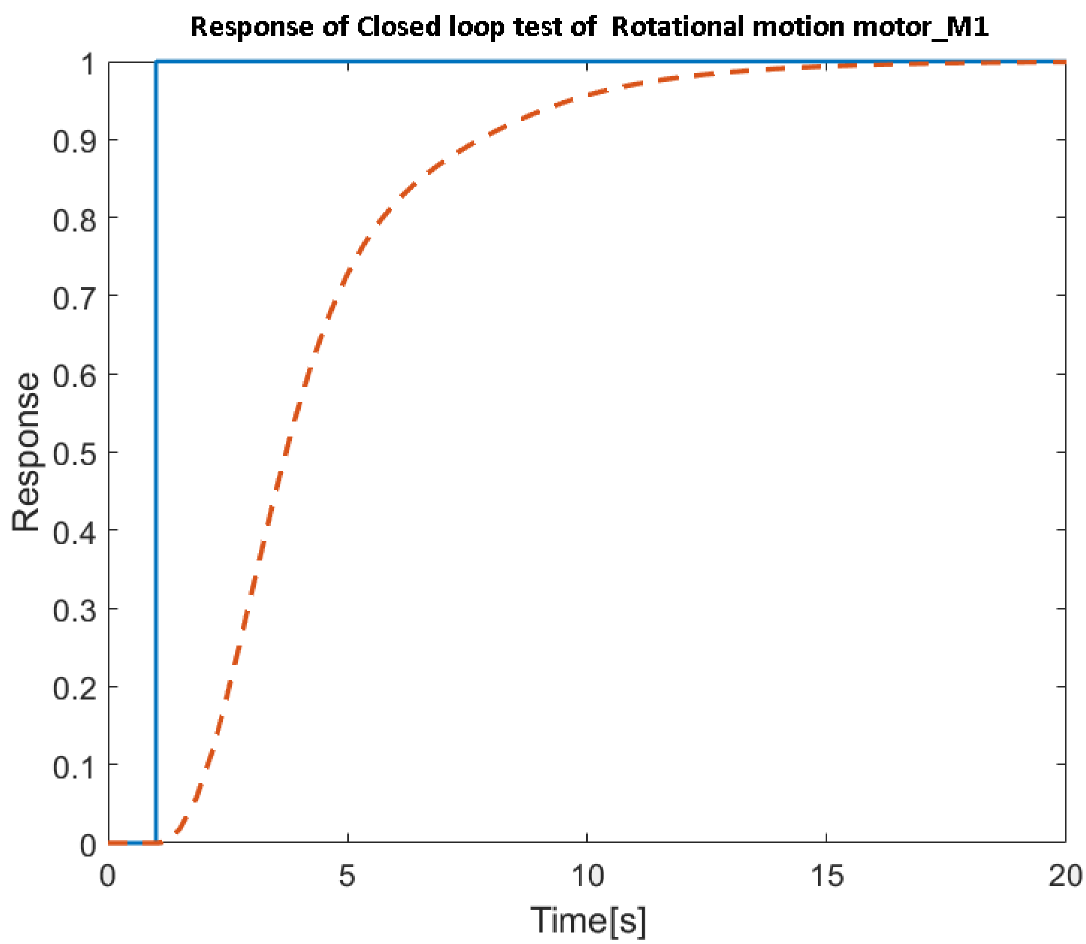

Figure 4.15: Response of Closed loop test of Rotational motion

Results of closed loop for rotational motor :

*** Shorter settling time than open loop (uncompensated system).**

*** Faster response than uncompensated system, due to single zero added.**

*** Smaller peak time than uncompensated system.**

*** Smaller steady-state error than uncompensated system.**

*** Smaller overshoot than uncompensated system.**

As shown in figure 4.16 , the system was built with step input without PD controller and without feedback.

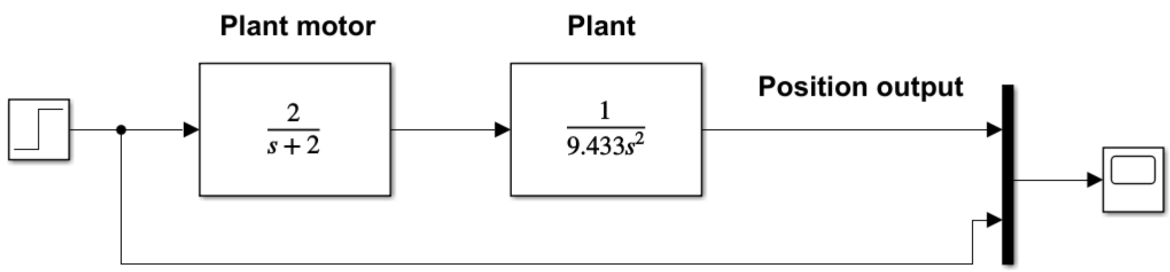

Figure 4.16: Speed response of rotation motor

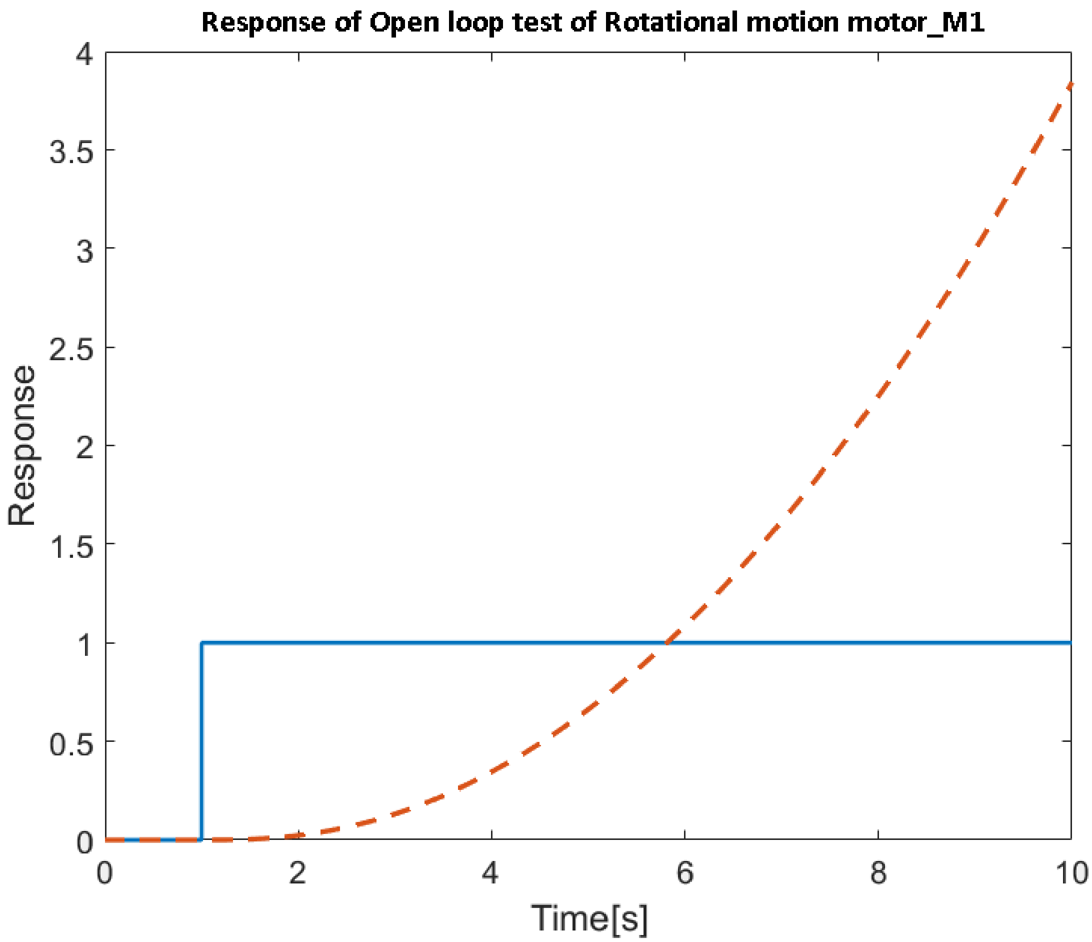

Figure 4.17: Response of Open loop test of Rotational motion motor

Results of open loop for rotational motor :

*** Bigger settling time than compensated system.**

*** Slower response than compensated system.**

*** Bigger peak time than compensated system.**

*** Bigger steady-state error than compensated system.**

*** Bigger overshoot than compensated system.**

2) Linear motion motor

Through open loop test for linear motor, we got the response from oscilloscope then through laws of control we got transfer function for Dc motors . As figure 10.15 shows the oscilloscope response for motor responsible for linear motion (M2).

$$V_f = 1V$$

$$\frac{1}{a} \; @ \; 0.63 \, V_f$$

$$G(s) = \frac{K}{(S+a)}$$

$$\frac{1}{a} = 120 = mV = 0.12 \, V$$

$$a = 8.3$$

$$\frac{K}{a} = V_f = 1$$

$$K = 8.3$$

$$G(s) = \frac{2}{(S+2)}$$

Where :

V_f : $final\ value$

G(s) : Transfer function for Dc motor.

K: Gain.

a: pole of the system.

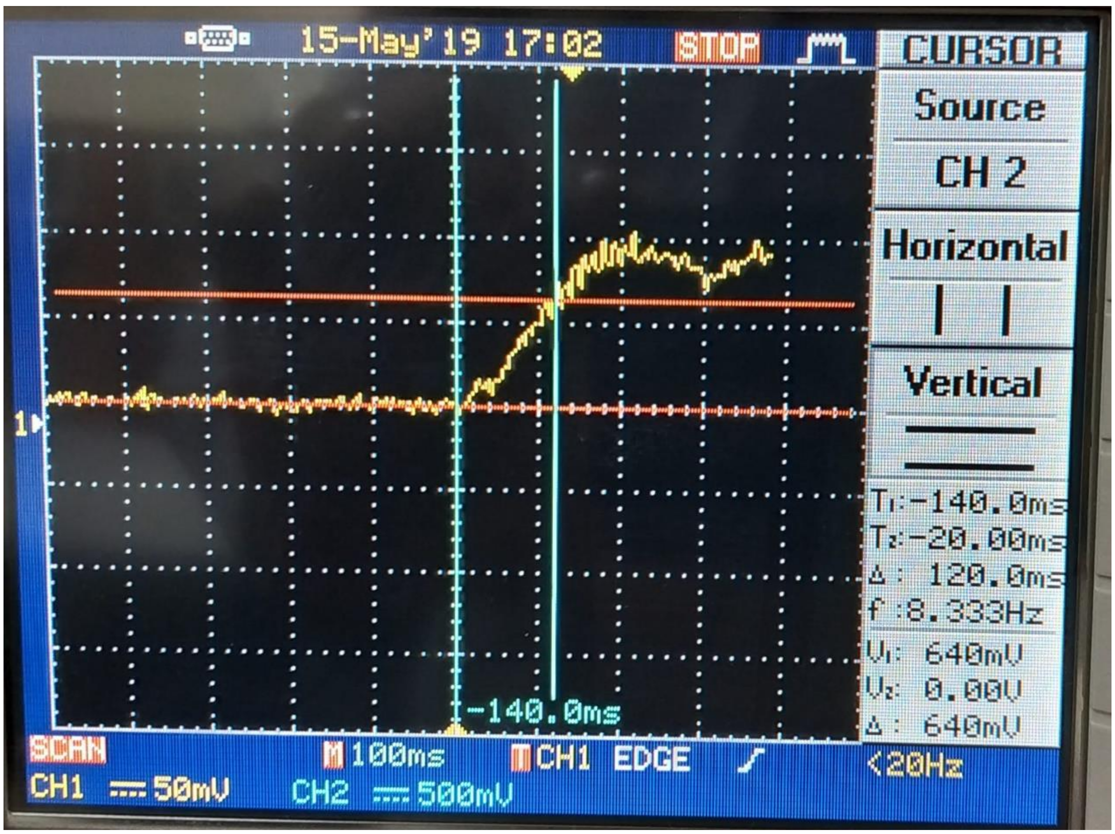

Figure 4.18 : Oscilloscope response for motor responsible for linear motion

We select the appropriate control method through sisotool in MATLAB. We design PID controller for linear motor (M2). As figure 4.19 shows, two zeros and single pole are added to the system, in order to improve transient response with zero steady-state error for step input.

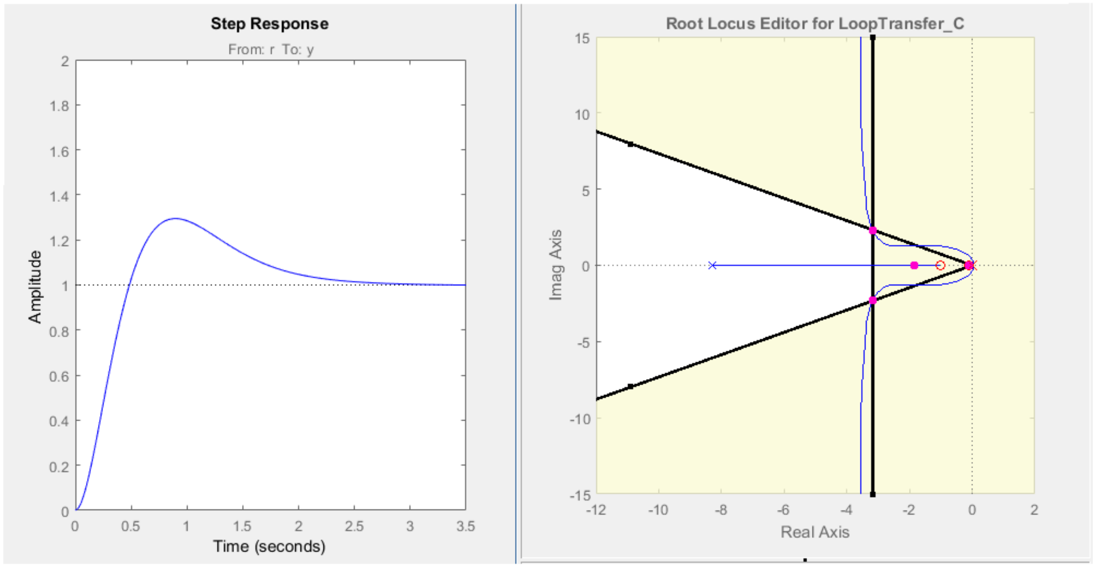

Figure 4.19: systole design for linear motor

Simulation :

As figure 4.20, shows the speed control for linear motor. The system was built with step input entered to PID controller, control signal entered to the plant and the output is position. Scope was used to compare between the step input and the response of step input after PID controller.

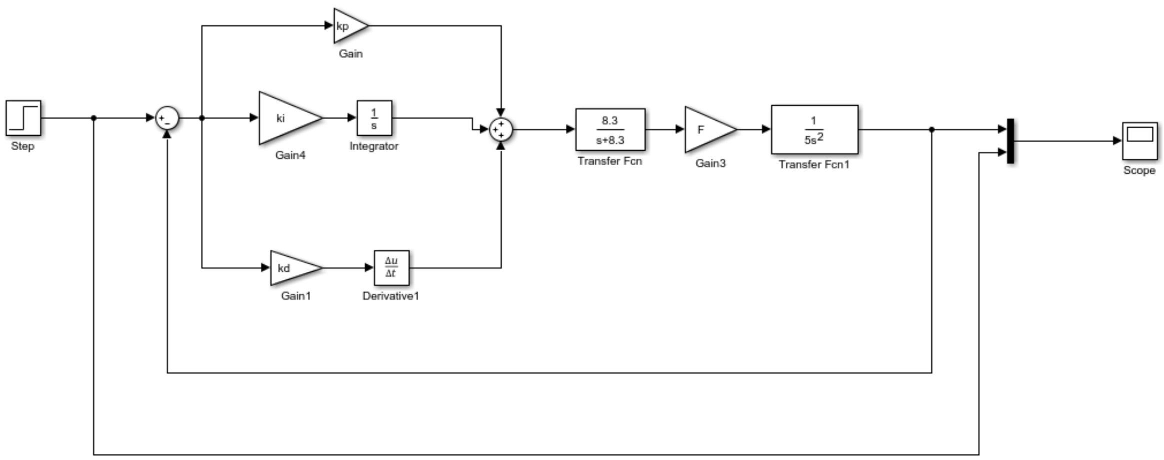

Figure 4.20: Speed control Simulink model for linear motor

Note that :

F: Force

T: Required torque in screw belt mechanism

L: length

$$F = \frac{T}{L} = \frac{0.091}{0.005} = 18.2$$

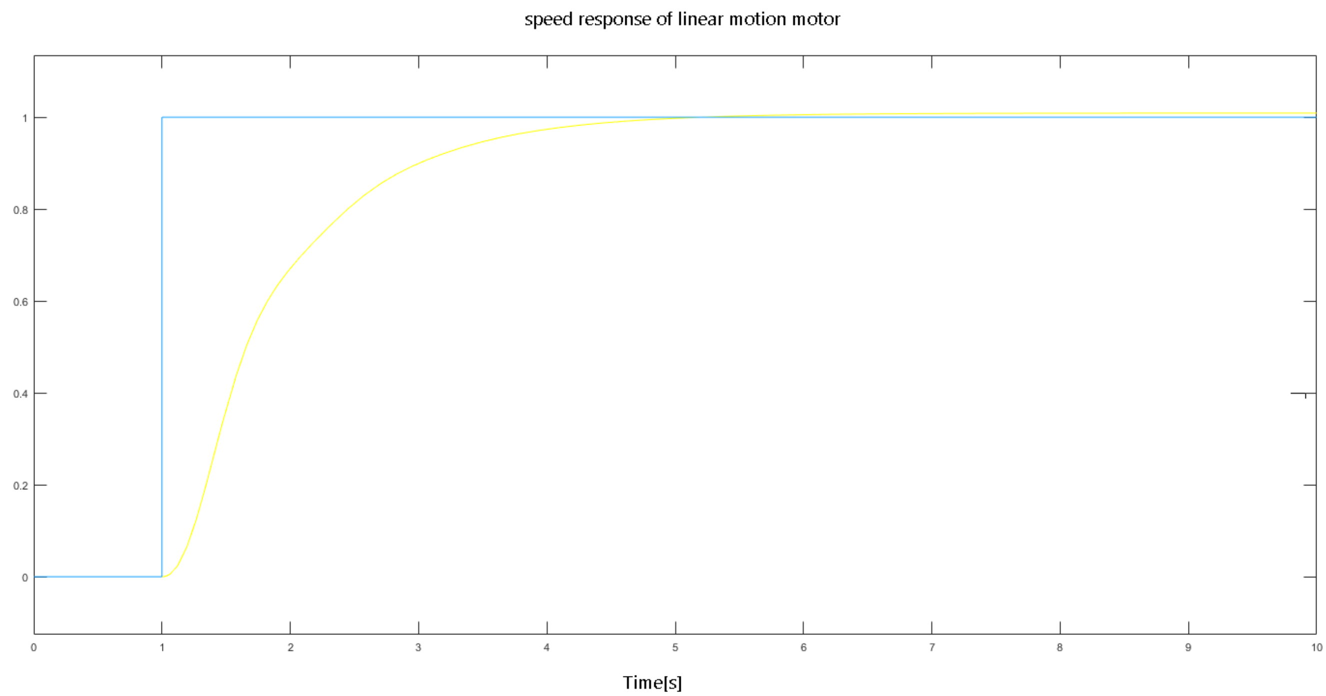

Figure 4.21: Speed response of linear motor

Results of closed loop for linear motor :

*** Shorter settling time than open loop (uncompensated system).**

*** Faster response than uncompensated system, due to single zero added.**

*** Smaller peak time than uncompensated system.**

*** Smaller steady-state error than uncompensated system.**

*** Smaller overshoot than uncompensated system.**

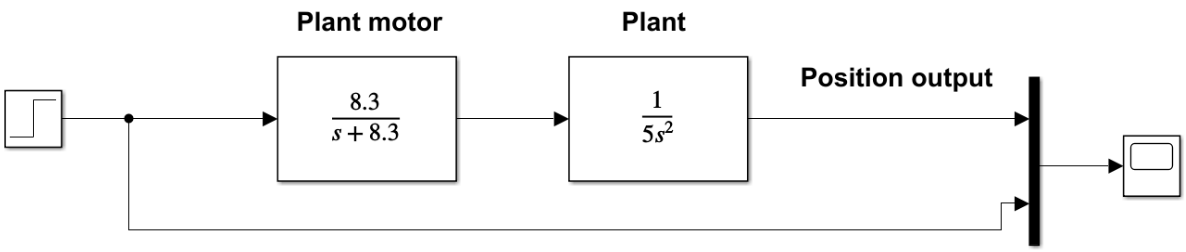

Figure 4.22: Simulink of Open loop of Linear motor

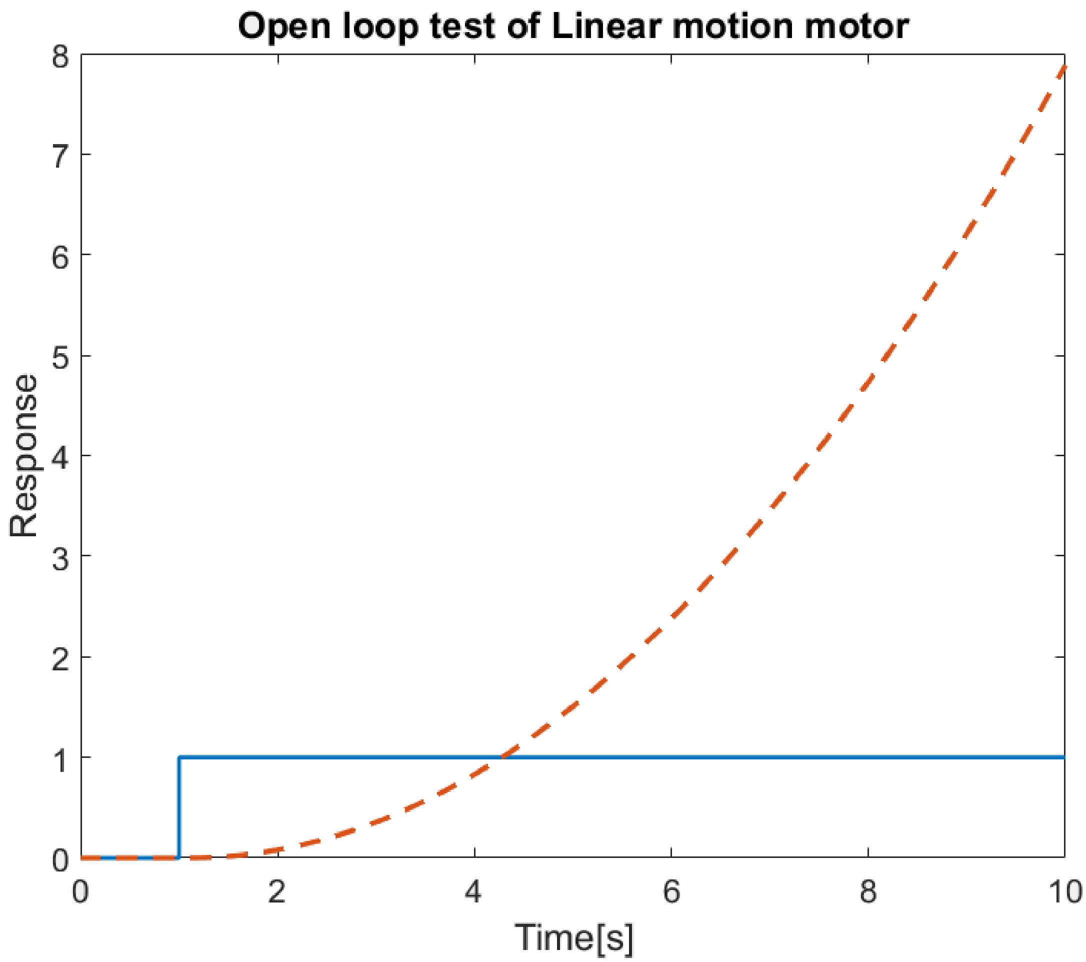

Figure 4.23: Response of Open loop test of Linear motion motor

Results of open loop for linear motor :

*** Bigger settling time than compensated system.**

*** Slower response than compensated system.**

*** Bigger peak time than compensated system.**

*** Bigger steady-state error than compensated system.**

*** Bigger overshoot than compensated system.**

Chapter 5 : Design of Mechanical Parts

1.1. Introduction

1.2. Specification of Machine

1.3. Shape design

1.4. Mechanical Parts

1.5. Factor of Safety

1.6. Calculation of motor

Chapter 5 : Design of Mechanical Parts

5.1. Introduction

In this chapter will make the calculation for a factor of safety in structure of the machine . Factor of safety against fatigue failure in rotating shaft , selection type and dimensions of bearing used to support of rotating shaft , make calculation torque and power for motor used to circular motion and make calculation torque and power for motor used for linear motion.

5.2. Specifications of the machine

These specifications were chosen after comparing the specifications of the other machines. To meet the needs of the local market and to make the machine the best possible accuracy and the lowest price compared to the machines used. As shown in the table 5-1 .

Table 5-1 : Specifications of the machine

Maximum radius of the barrel	500 mm
Maximum length of the barrel	1800 mm
Maximum weight of the barrel	150 kg
Rotating speed	(0.5 – 2.5) rpm
Linear welding speed	(5 – 20) mm/s
Current of welding	300 A

5.3. Shape design

By looking at the designs in the previous chapter, the exterior design of the machine was reached according to the chosen specifications. So that this design consists of the mechanical parts needed to produce the machine in the best form. As shown in figure 5-1 .

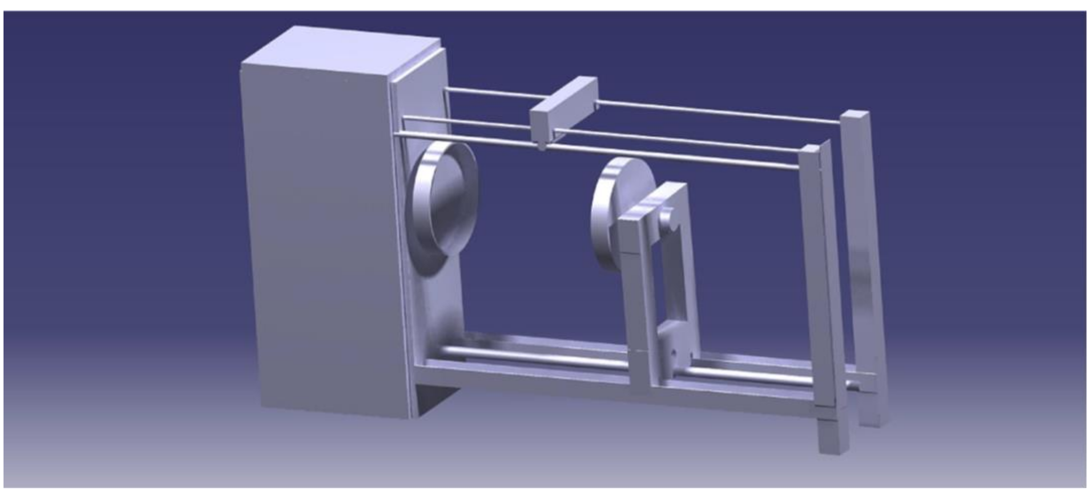

Figure 5 -1 : Mechanical design of the machine

5.4. Parts of machine

After selecting the specifications and shape of the machine, the mechanical and electronic parts were chosen to suit the specifications of the machine and its working mechanism. Also for better performance, lower price and a security system compared to machines used in the local market.

Part 1 : Two I – beam : cause of less cost and it's make the movement easy .Also it's perfect for maintenance. And the operator can expand the length of I-beam when its essential, As shown figure 5-2 .

B = 6.67 cm , D = 10 cm , T = 0.732 cm , t = 0.482cm (from tables)

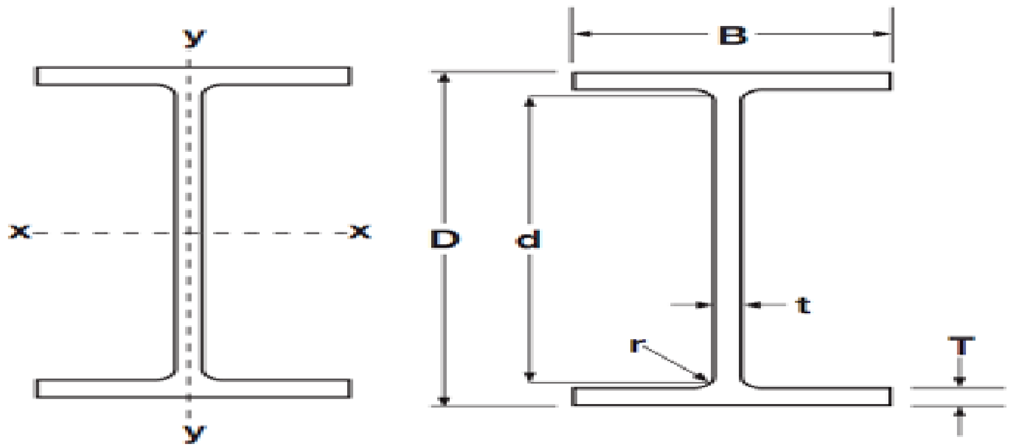

Figure 5-2 : I – beam dimension

Part 2 : Moving part support : The machine has two support made up of an I-beam, supporting the parts of the machine. The height of the support is 70 cm and the width is 60 cm, as shown in figure 5-3 .

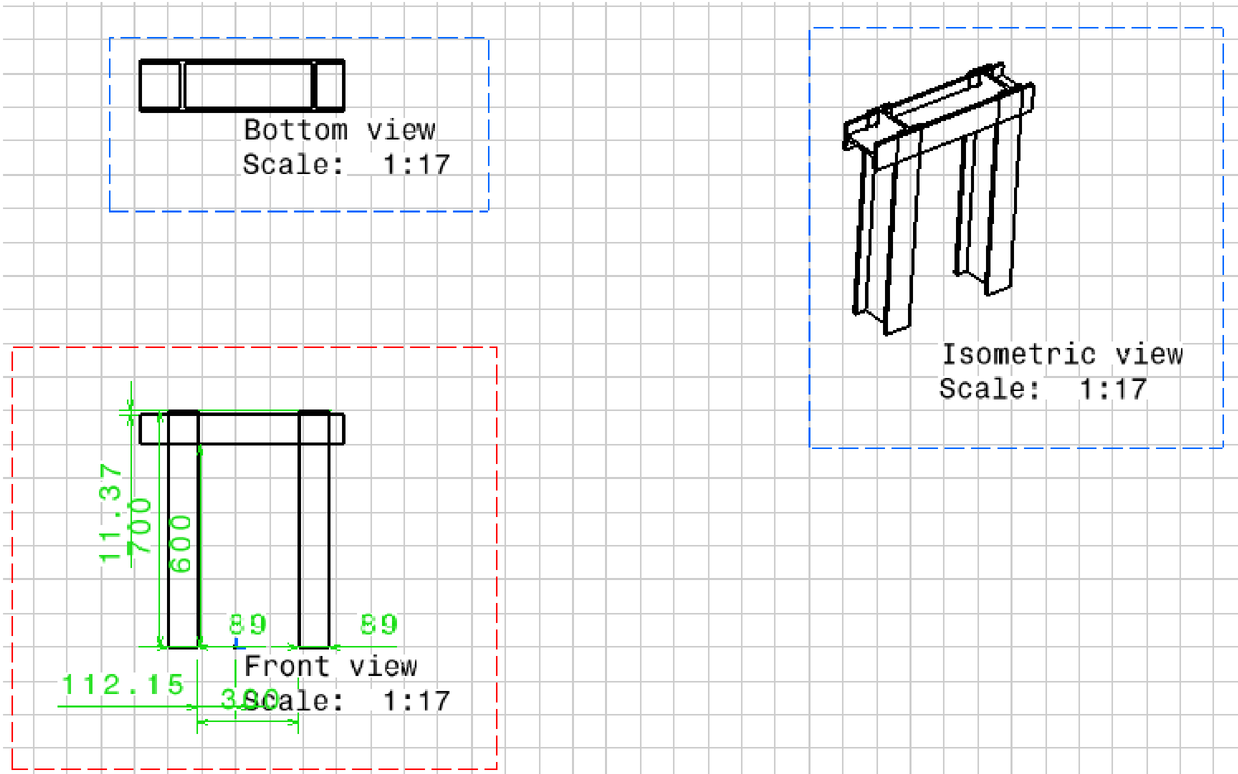

Figure 5-3 : Support of the machine

Part 3 : Rotation cylinder : The circular cylinder is 20 cm long and 8 cm in diameter. As shown in figure 5-4 .

Part 4 : Support of the barrel : It is used to fixed the barrel , to prevent movement or vibration of the barrel during the welding process. The maximum diameter of the support is 50 cm and varies according to the diameter of the barrel to be weld. As shown in figure 5-4 .

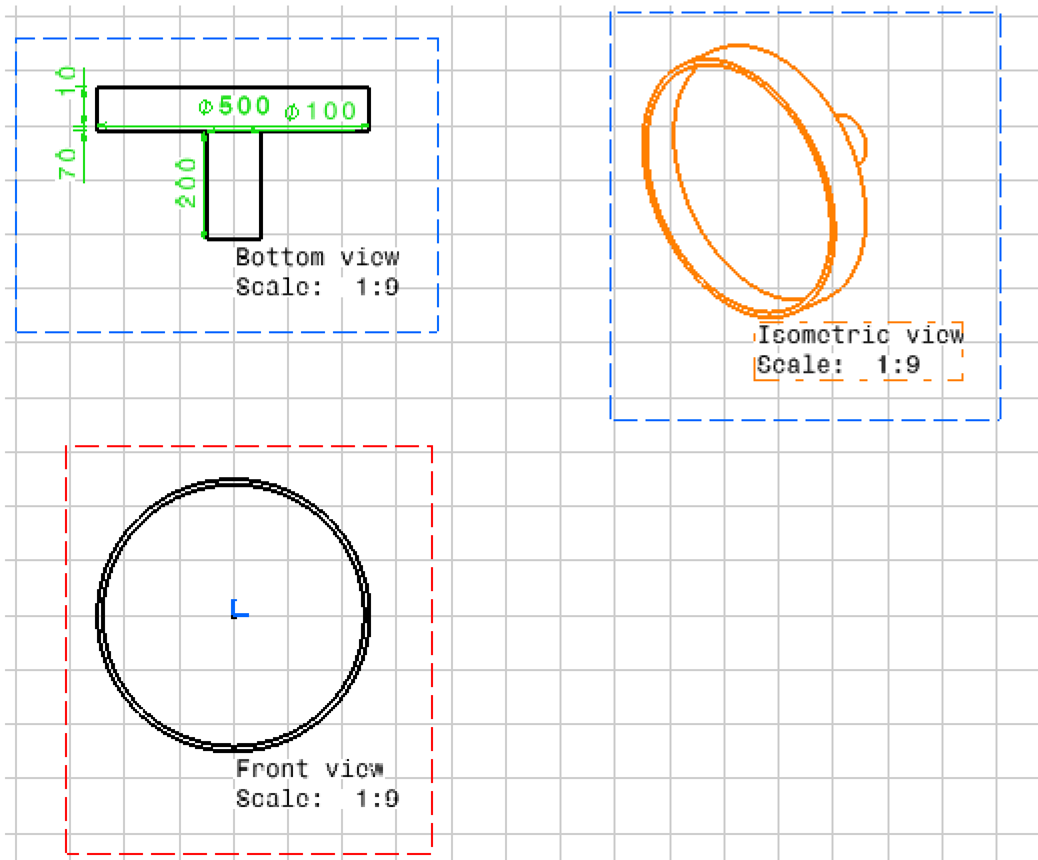

Figure 5-4 : Rotation cylinder and support of barrel

Part 5 : This table is used to assist the worker in fixing the work piece, which varies according to the diameter of the barrel used, and is important in Target cases where the work piece is prevented from falling on the ground .As shown in figure 5-5 .

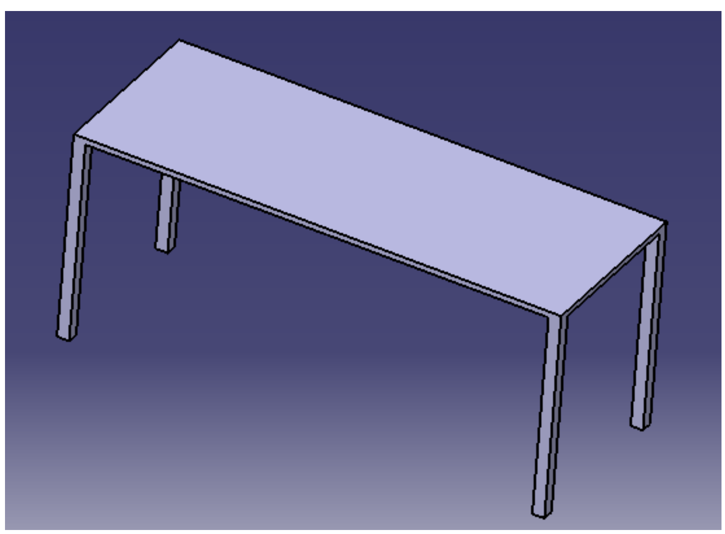

Figure 5-5 : Table

5.5. Calculate factor of safety for structure of machine.

5.5.1. Calculate factor of safety for I - beam

To calculate the factor of safety for the structure of machine , required calculate the force acting in the structure , the force acting in structure came from weight of component of structure and working piece . as shown in figure 5-6

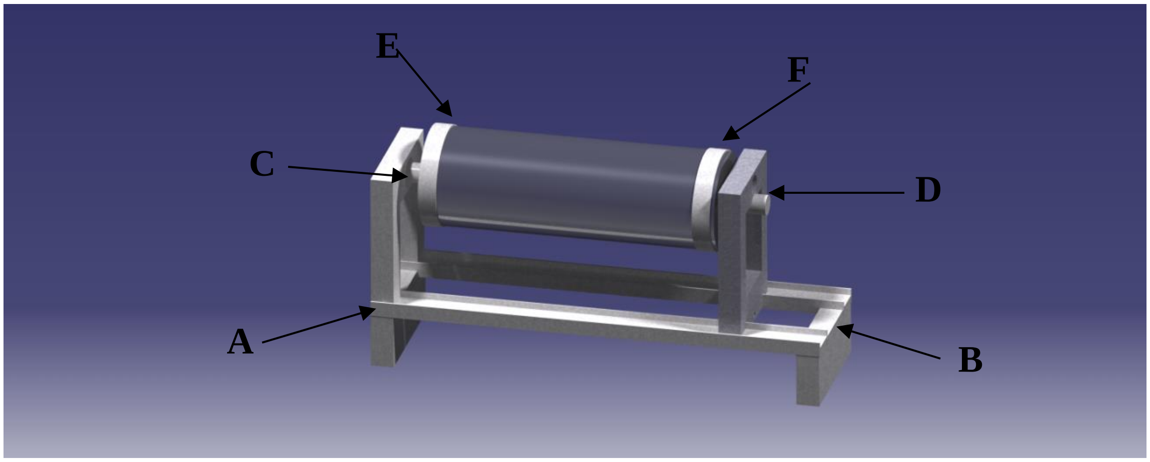

Figure 5-6 : Major structure of the machine

First step to calculate factor of safety required determine masses of each part, that can be made from calculate volume lf part or from stander table if that found.

Calculate mass of I beam that support working piece .
Weight per Length of beam that show in figure (5-2).

$L = 3.41$ kg/ m (from table)

Total length for beam

$L_{Total} = 2\times55+60 = 170$ cm = 1.7 m

Mass of beam

$M = 3.41$ kg/m × 1.7 m = 5.8 kg

Total mass for Barrel holder

$M_{Total} = 2 \times 5.8 = 11.6$ kg

Calculated mass of rotation cylinder show in figure (5-3) .

Outer diameter = 8 cm
Inner diameter = 7 cm
Length = 20 cm

This dimension from Factor of safety against fatigue failure design

Calculated mass from calculate volume and density of iron .

$$V = \frac{\pi \times ({d_0}^2 - {d_i}^2)}{4} l \quad (5.1)$$

$$V = \frac{\pi \times (0.8^2 - 0.7^2)}{4} 0.2 = 2.355 \times 10^{-4} m^3$$

density of iron = ρ = 7850 kg / m^3

Mass = V × ρ (5.2)

= $2.355 \times 10^{-4} \times 7850$ = 1.848 kg

Calculated mass of disk .

Thickness = 1 cm

Diameter = 50 cm

These dimensions are approximate.

Calculated mass from equation (5.1) and (5.2)

$$V = \frac{\pi \times L \times d^2}{4} = \frac{\pi \times 0.01 \times 0.5^2}{4} = 1.96 \times 10^{-3}$$

Mass = V × ρ = $1.96 \times 10^{-3} \times 7850$ = 15.4 kg

Mass for support of the working piece

Out diameter 50 cm

In diameter 48cm

Length = 3.5 cm

These dimensions were chosen based on the dimensions of the work piece

Calculated mass from equation (5.1) and (5.2)

V = 5.385×10^{-4} m^3

Mass = 5.385×10^{-4} × 7850 = 4.227 kg

Mass of barrel

Maximum mass of barrel = 150 kg (From specification of machine) .

Second Step : Drawing free body diagram for I beam to calculate reaction force at point A and B. As shown figure 5-7,5-8,5-9 .

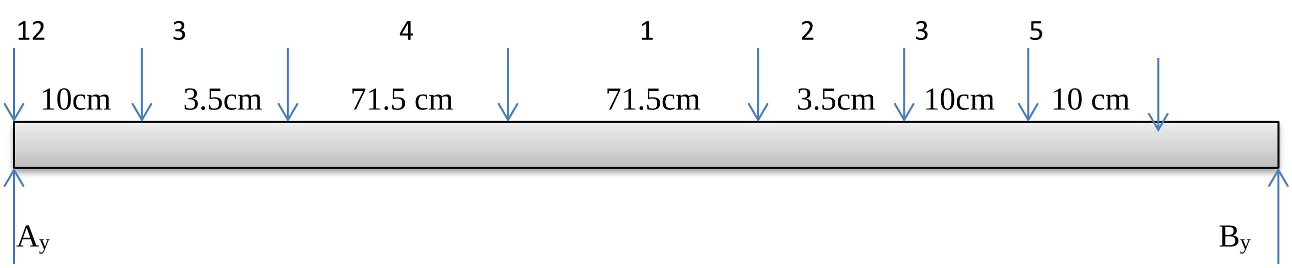

Figure 5-7 : Free body diagram for I – beam in X-Y direction

Where : 1: mass of I beam support the working piece.
2: mass of rotating shaft.
3: mass of disk .
4: mass of working piece .
5: mass of pneumatic piston .

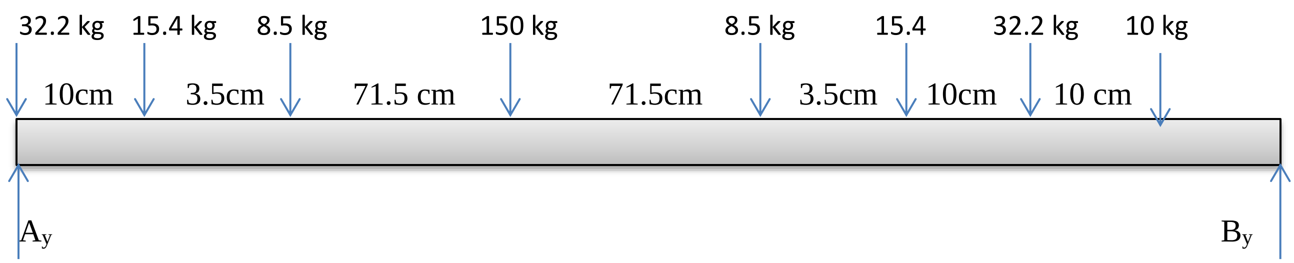

Figure 5-8 : Free body diagram of the major structure in (X-Y) direction

Where :
Ay is the support element in left side from beam .
By is the support element in right side from beam.

Static force analyses .
Force acting in each beam half force in structure.

Summation of moment about point A equal zero in X and Y direction .

$$\sum M_A = 0$$

$$9.81((15.4\times10) + (8.5 \times 13.5) + (150\times95) + (8.5 \times166.5) + (15.4 \times 170) + (32.2 \times180) + (10 \times 185) - (R_{By} \times220)) = 0$$

$$R_{By} = 1074 \text{ N}$$

$$R_{Ay} = 1198.7 \text{ N}$$

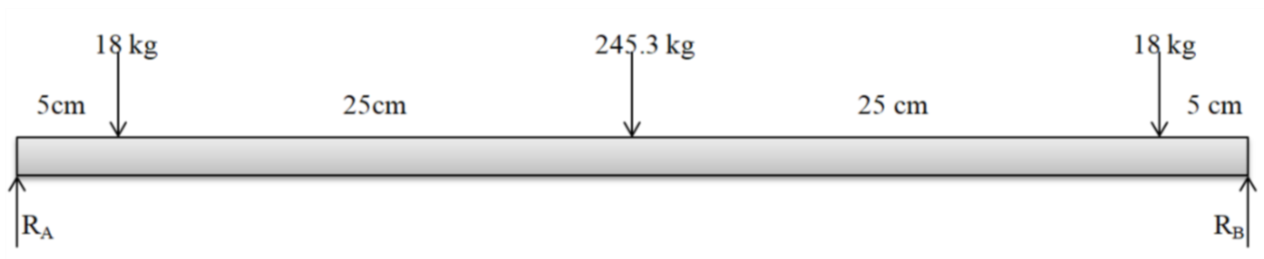

Figure 5-9 : Free body diagram of the major structure in (X-Z) direction

Where : 18kg is mass of I beam in horizontal.
245.3 kg total mass effect in beam .

$$\sum M_A = 0$$

$$0 = 9.81\times (18\times5 + 18\times55 + 245.3 \times30 - R_B . 60)$$

Assume that $R_{A2z} = R_{B2z}$

$R_{A2z} = R_{B2z} = 1379.8$ N

Third step: Draw the shear force diagram and pending moment diagram X-Y direction . As shown in figure (5-10 , 5-11)

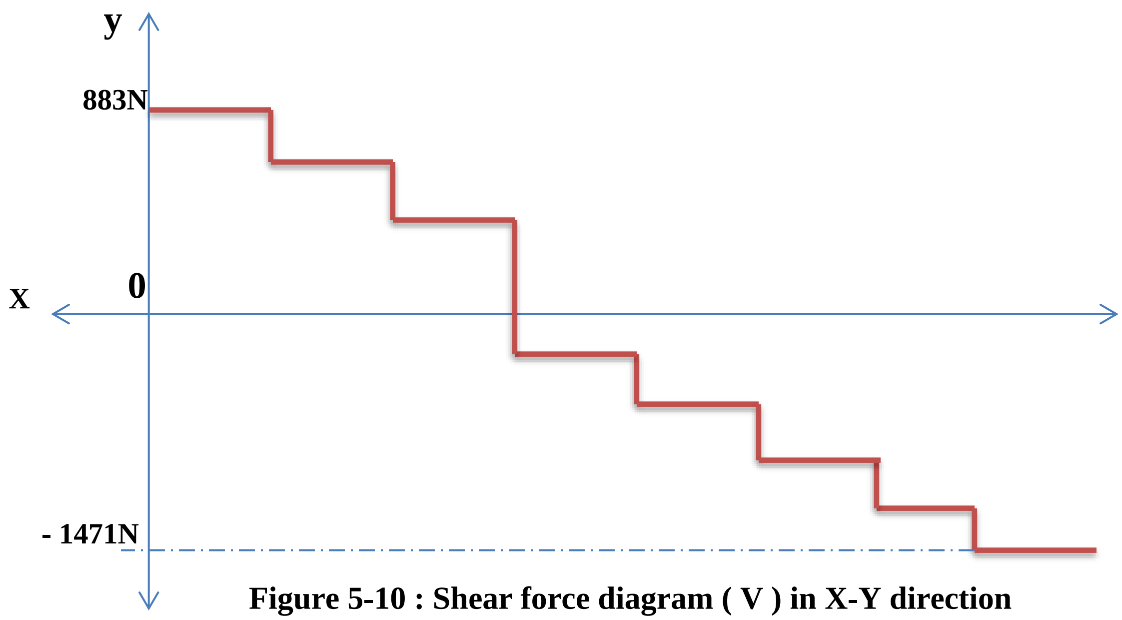

Figure 5-10 : Shear force diagram (V) in X-Y direction

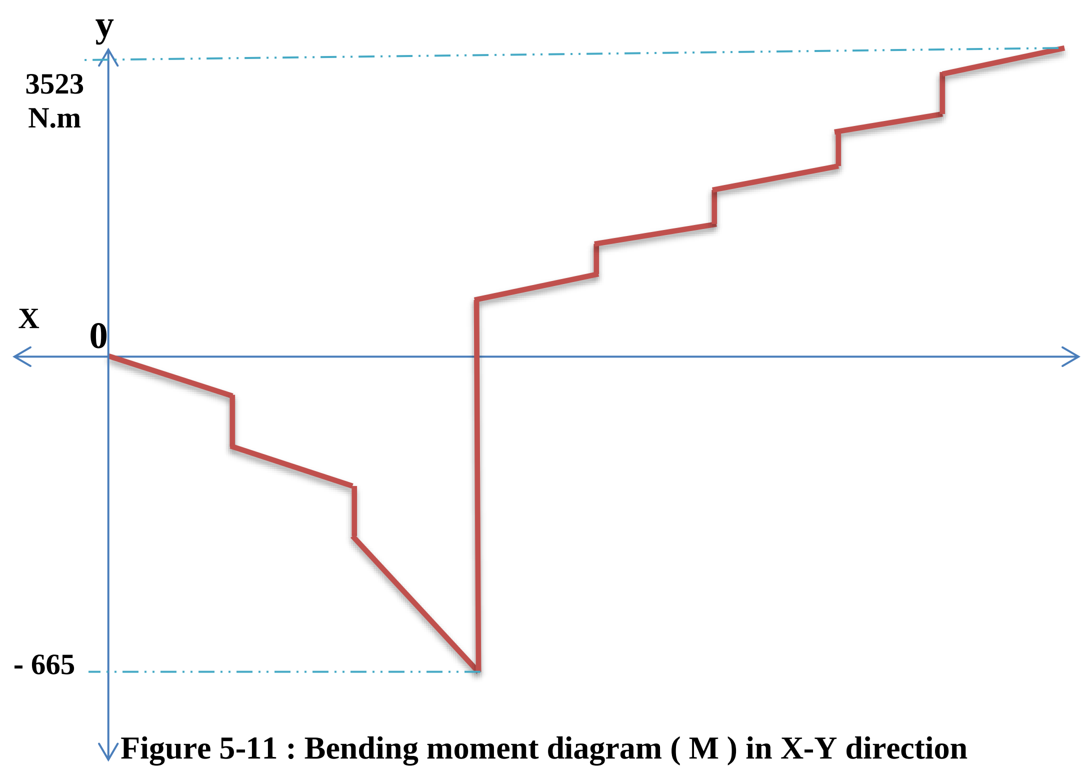

Figure 5-11 : Bending moment diagram (M) in X-Y direction

The magnitude of maximum bending moments for each beam is: $M = 0.5 \times 3523 = 1761.5$N.m

Fourth step: Draw the shear force diagram and Bending moment diagram X-Z direction . As shown in figure (5-12 , 5-13)

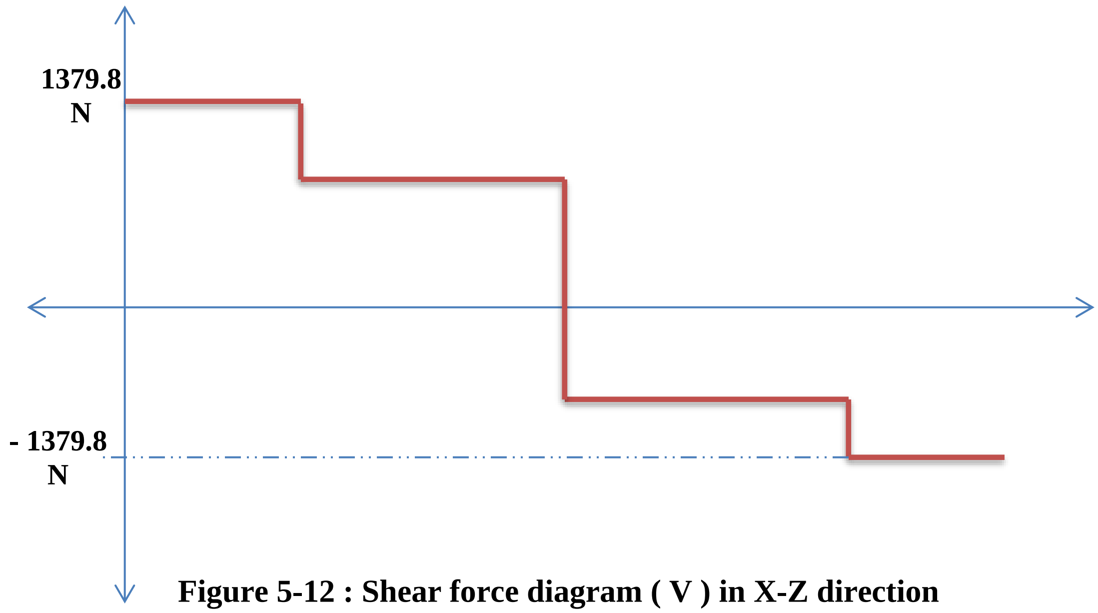

Figure 5-12 : Shear force diagram (V) in X-Z direction

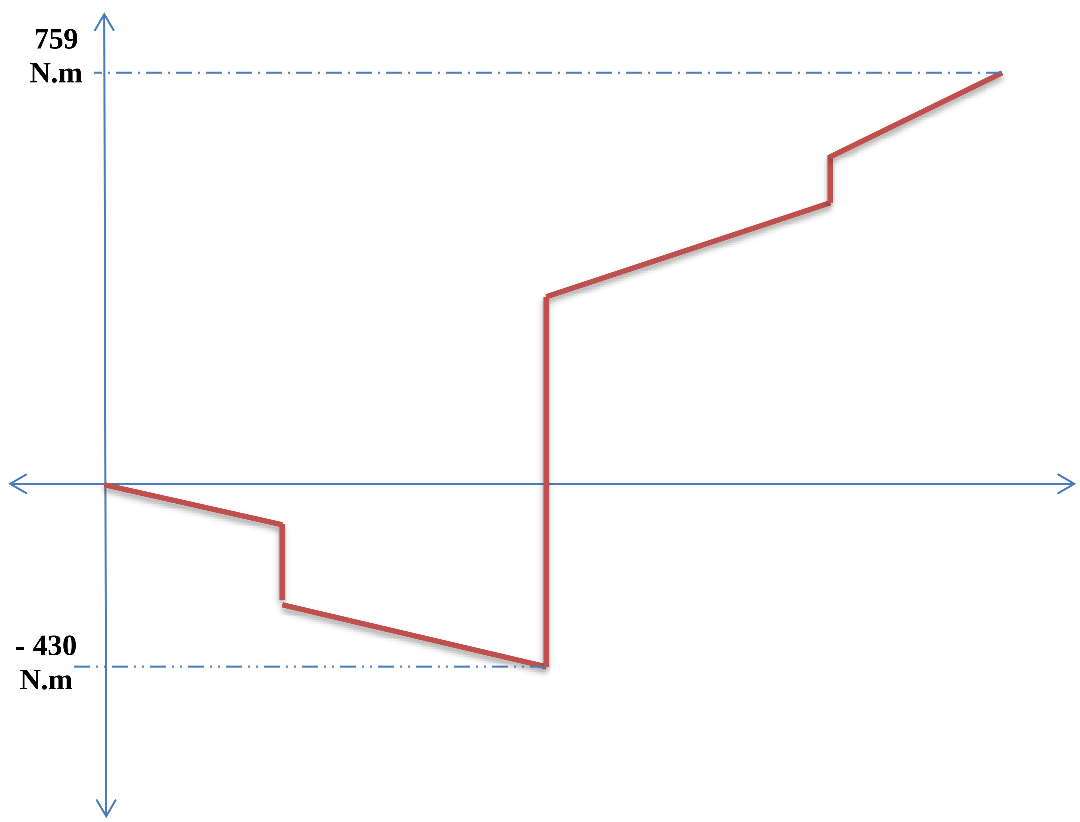

Figure 5-13 : Bending moment diagram (M) in X-Z direction

The magnitude of maximum bending moments for each beam is: M = 0.5 × 759 N = 380 N.

Fifth step: Calculation second moment of inertia for I beam has section .

$$I = \frac{1}{12} \ b\, h^3 \tag{5.3}$$

$$I_1 = \frac{1}{12}(8.532 \times 10^{-2})(\ 0.482 \times 10^{-2})^3 = 7.96 \times 10^{-7} m^4$$

$$I_2 \ = \ \frac{1}{12}(0.732 \times 10^{-2})(\ 6.657 \times 10^{-2})^3 = 4.78 \times 10^{-7} m^4$$

$$I_3 \ = \ I_2 = 4.78 \times 10^{-7} m^4$$

$I_{y,\ total} = I_1 + I_2 + I_3 = 1.752 \times 10^{-6}\ m^4$

$$I_{x1} = \frac{1}{12}(6.657 \times 10^{-2})(\ 0.732 \times 10^{-2})^3 = 2.2 \times 10^{-9} m^4$$

$$I_{x2} = \frac{1}{12}(0.482 \times 10^{-2})(\ 8.536 \times 10^{-2})^3 = 2.498 \times 10^{-7} m^4$$

$I_x = 2\ I_{1x} + \ I_{2x} = 2.542 \times 10^{-7}\ m^4$

$$\sigma \ = \ \frac{M\, c}{I} \tag{5.4}$$

$$\sigma \ = \frac{1761.5 \times 0.03323}{4.78 \times 10^{-7}} = 122.5 \ MPa$$

$$\tau = \frac{Tc}{J} \tag{5.5}$$

$$\tau \ = \frac{380 \times 0.03335}{2.542 \times 10^{-7} + \ 1.752 \times 10^{-6}} \ \ = \ 6 \text{ MPa}$$

$$\sigma = \frac{\sigma_1 + \sigma_2}{2} \mp \sqrt{\left(\frac{\sigma_1 + \sigma_2}{2}\right)^2 + \ \tau^2} \tag{5.6}$$

σ = 123 MPa , -0.3 MPa

σ_{min} (123 , 0 , -0.3) = -0.3 MPa

σ_{max} (123 , 0 , -0.3) = 123 MPa

Maximum shear stress calculation :

$$\tau_{max} = \ \frac{\sigma_{max} - \sigma_{min}}{2} \tag{5.7}$$

$$\tau_{max} = \frac{123 - (-0.3)}{2} = 61.35 \ MPa$$

yield shear strength steel 1080 H :

S_{sy} = 110 MPa (from tables)

Factor of safety using maximum shear stress :

The Maximum Shear Stress theory is states that failure occurs when the maximum shear stress from a combination of principal stresses equals or exceeds the value obtained for the shear stress at yielding in the uniaxial tensile test. At yielding, in an uni -axial test, the principal stresses are 1 = Sy; 2 = 0 and 3 = 0. Therefore the shear strength at yielding Ssy =[1 - (2 or 3 =0)]/2. Therefore

$$Ssy = \frac{Sy}{2} \qquad (5.8)$$

Where :

Ssy : is shear strength at yielding.

Sy : yielding strength.

$$n = \frac{Ssy}{\tau_{max}} \qquad (5.9)$$

$$\boldsymbol{n = \frac{110}{61.35} = 1.8}$$

Factor of safety is 1.8 that to large but we will use it because of we use smaller dimensions , factor of safety happened smaller than (1).

5.5.2. Shear, Moment, and Deflection of Beams

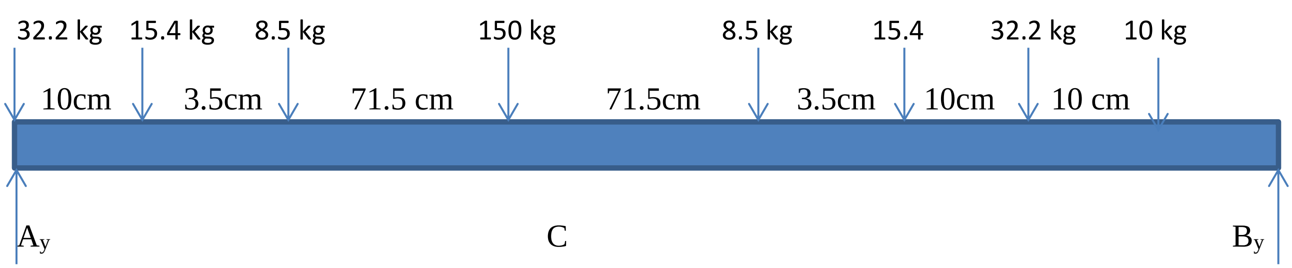

Figure 5-14 : Free body diagram for I - beam

Shift all force to point C

150 + 15.4 – 11.55 kg.m + 8.51 - 6.0846 kg.m + 8.61 + 6.0846 kg.m + 15.4 + 11.55 kg.m + 16.3 + 15.8 + 27.285 kg.m + 10 + 9.51 kg.m

Force = 240.02 × 9.81 = 2354.6 N

Moment = 361 N.m

Force for each beam = 1177.3 N

Moment for each beam = 180.5 N.m

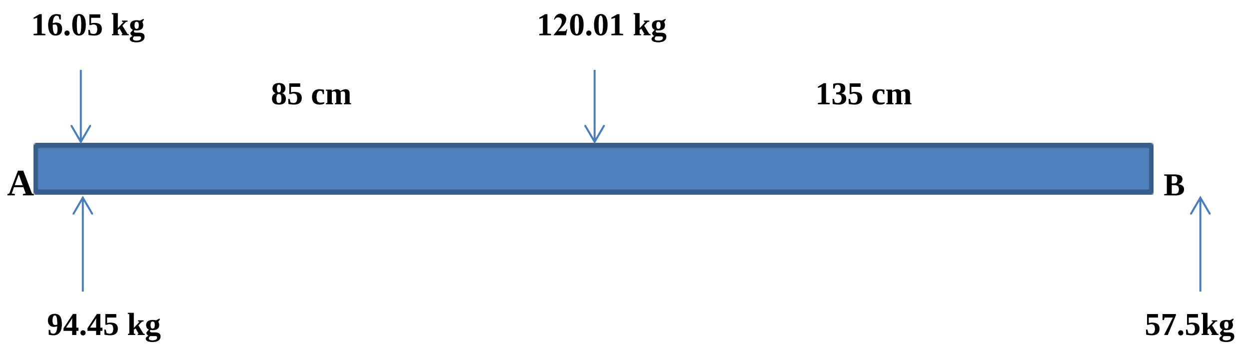

Figure 5-15 : Free body diagram

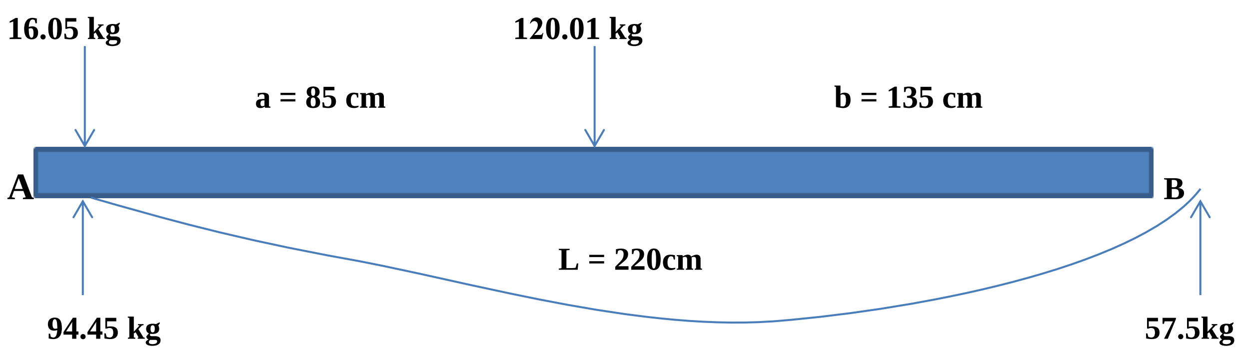

Figure 5-16 : Free body diagram

V_{AC} = 78.36 kg

V_{CB} = - 57.5 kg

M_{AC} = - 78.36 kg.m

M_{CB} = 57.5 × (220 – X)

$$y_{AC} = \frac{-78.36\, X}{6EI}(X^2 + b^2 - l^2)$$

$$y_{CB} = \frac{57.5(2.2 - X)}{6EI}(X^2 + a^2 - 2xl)$$

$$\frac{dy_{AC}}{dx} = \frac{-78.36}{6EI}(\, 3x^2 + b^2 - l^2) = 0$$

$$3x^2 + 1.35^2 - 2.2^2 = 0$$

$$X = 1.003$$

$$y_{AC} = \frac{-78.36 \times 1.003}{6 \times 200 \times 10^9 \times 4.78 \times 10^{-7}}(1.003^2 + 1.35^2 - 2.2^2) = 1.0003$$

Maximum yield = 1.003

5.5.3. Rotating shaft design

Fatigue failure: in materials science, fatigue is the weakening of a material caused by repeatedly applied loads. It is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. The nominal maximum stress values that cause such damage may be much less than the strength of the material typically quoted as the ultimate tensile stress limit, or the yield stress limit.

Factor of safety against fatigue failure: the limit between infant life and finite life for rotating member.

Calculate factor of safety against fatigue failure use mod-Goodman theory.

$$\frac{\sigma a}{Se} + \frac{\sigma m}{Sut} = \frac{1}{nf} \qquad (5.10)$$

n_f : factor of safety against fatigue failure.

σ_m: mid rang steady component of stress.

σ_a: amplitude of alternating component of stress .

S_e : Endurance limit .

S_{ut} :ultimate strength of material .

Shaft material ASTM 30 (Sut=213.42 MPa)

$$Se=K_a \times K_b \times K_c \times K_d \times K_e \times K_f \times 0.5 \times S_{ut} \qquad (5.11)$$

S_e : Endurance limit .

K_a : surface condition modification factor .

K_b :size modification factor .

K_c : load modification factor .

K_t : temperature modification factor .

K_e : reliability factor .

K_f : miscellaneous –effects modification factor .

$K_a = a \times Sut^{\wedge b}$

(a , b) surface finish factor

(a , b) for machine finish (4.51 , -0.265)

$K_a = 4.51 \times (213.42)^{\wedge -0.265}$

$K_a = 1.089$

$K_b = 1$ for axial load

$K_c = 1$ for bending load

$K_t = 1$ no temperature change

$K_e = 0.753$ with reliability =99.9%

$K_f = 1.1$ from table

$Se = K_a \times K_b \times K_c \times K_d \times K_e \times K_f \times 0.5 \times S_{ut}$

$Se = 1.089 \times 1 \times 1 \times 1 \times 0.753 \times 1.1 \times 0.5 \times 213.42 = 96.25$ MPa

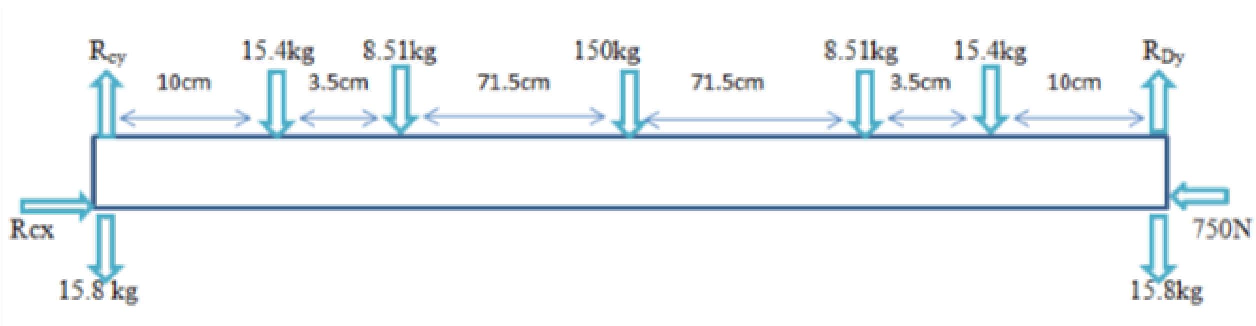

Figure 5-18 : Free body diagram for rotation shaft

$\sum M_C = 0$

$9.81(15.4 \times 10 + 8.5 \times 13.5 + 150 \times 85 + 8.5 \times 156.5 + 15.4 \times 160 + 15.8 \times 170$
$- R_{Dy} \times 173) = 0$

$R_{Dy} = 114.7$ kg

$\sum F_y = 0$

R_{Cy} = 114.7 kg

$\sum F_x$ = 0

R_{CX} = 350N

maximum moment at C =R_d ×1.5

M max = 1687.8 N.m

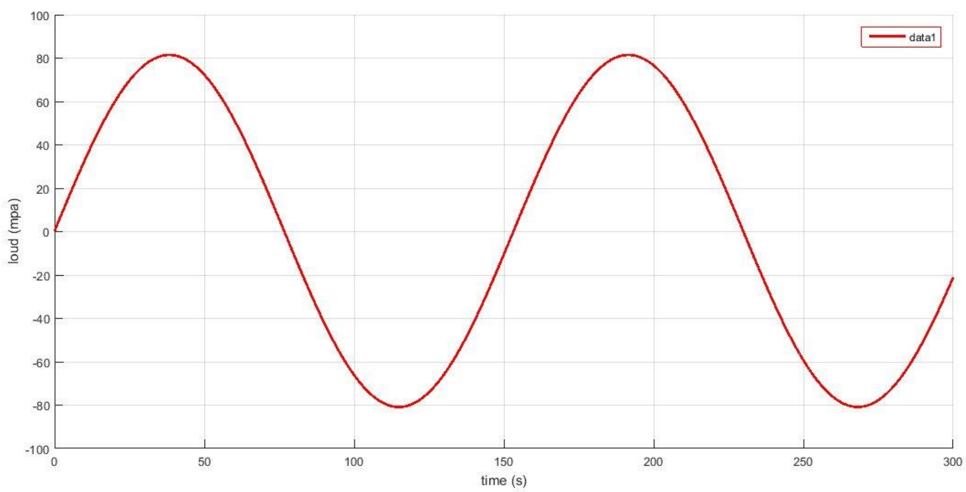

Figure 5-19 : fluctuating force acting in shaft

shaft dimension d=8cm , thick=0.5 cm

$$I_x = \frac{\pi}{64} \times (do^4 - din^4) \quad (5.12)$$

$$I_x = \frac{\pi}{64} \times (0.08^4 - 0.07^4) = 8.32 \times 10^{-7} m^4$$

$$\sigma = \quad = \frac{1687.8 \times 0.04}{8.32 \times 10^{-7}} = 81.144\ MPa$$

$$\sigma = \frac{F}{a} = \frac{350}{\frac{\pi}{4} \times (do^2 - din^2)} = \frac{350}{\frac{\pi}{4} \times (0.08^2 - 0.07^2)} = 0.298 MPa$$

($\sigma_{max}, \sigma, \sigma_{min}$) = **(81. 44 , 0 ,0.298)**

$$\sigma_m = \frac{(\sigma_{max}+\sigma_{min})}{2} \quad (5.13)$$

$$\sigma_m = \frac{81.44 + 0.298}{2} = 40.87MPa$$

$$\sigma_a = \frac{(\sigma_{max}-\sigma_{min})}{2} \quad (5.14)$$

$$\sigma_a = \frac{81.44 - 0.298}{2} = 40{,}57\ MPa$$

$$\sigma = \sigma \boldsymbol{o} \times \boldsymbol{Kf} \quad (5.15)$$

$$\boldsymbol{\sigma m} = \boldsymbol{\sigma mo} \times \boldsymbol{Kf} = 40.87 \times 1.1 = 44.95MPa$$

$$\boldsymbol{\sigma a = \sigma ao \times Kf = 40.44 \times 1.1 = 44.48\ MP}$$

Calculate factor of safety against fatigue failure use mod-Goodman theory from equation (5.10)

$$\frac{\sigma a}{Se} + \frac{\sigma m}{Sut} = \frac{1}{nf}$$

$$\frac{44.48}{\mathbf{96.25}} + \frac{44.95}{\mathbf{213.42}} = \frac{1}{nf}$$

$$nf = \mathbf{1.486}$$

5.5.4. For support working piece

The support of working piece loads the moving parts of the machine. Therefore, this part must be properly selected to suit the parts of the machine and for the welding process to be done safely. Therefore, the design of this part was done so that a safety factor was chosen to suit the working conditions and calculate the forces influencing it, through which appropriate dimensions are chosen for this part.

Assume the factor of safety = 2.5 (under dynamic load)

$\sum F_y = 0$
$R_E + R_F = 150$ N
$R_F = 75$ N
$R_E = 75$ N

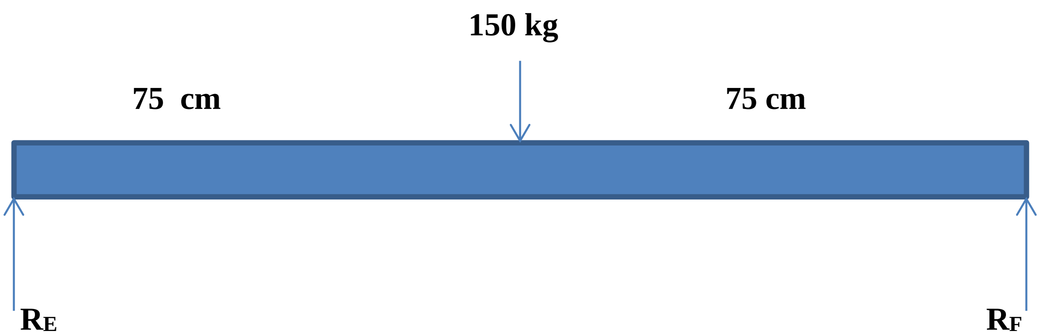

Figure 5-20 : Free body diagram for support working piece

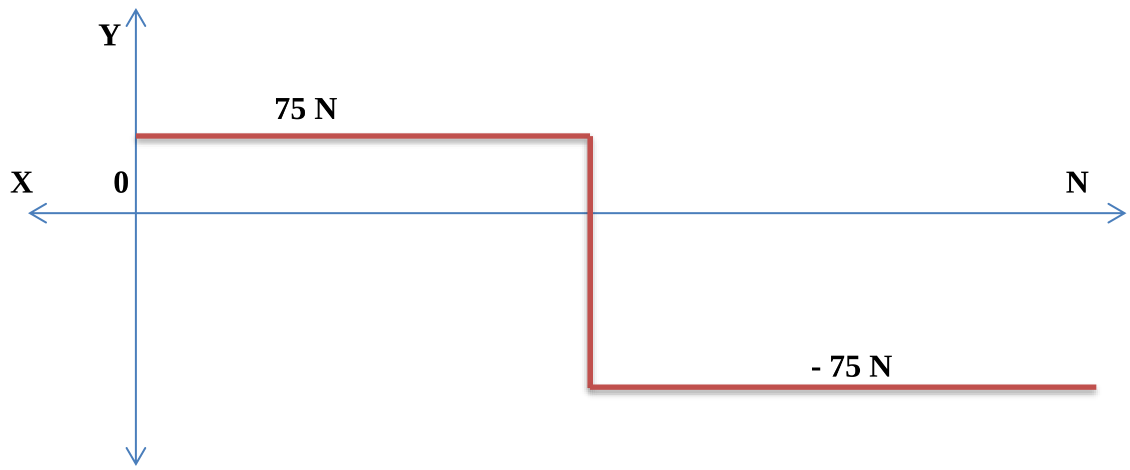

Figure 5-21 : Shear force diagram V

Figure 5-22 : Bending moment diagram (M)

Maximum moment = 551.8 N.m

Factor of safety = n = 2.5

Yield shear strength = S_{sy} = 110 MPa

Maximum shear stress = τ_{max}

$\tau_{max} = \frac{S_{sy}}{n} = \frac{110}{2.5} = 44\ MPa$

$\sigma = 2\ \tau_{max} = 88$ MPa

$\sigma = \frac{Mc}{I}$

$I = \frac{Mc}{\sigma} = \frac{551.8 \times 0.24}{88 \times 10^6} = 1.57 \times 10^{-6} m^4$

$I = \frac{\pi}{64}(D^4 - d^4) = \frac{\pi}{64}(D^4 - 0.48^4) = 1.57 \times 10^{-6} m^4$

D = 0.482 m = 48.2 cm

Out Diameter for Support of barrel = 48.2 cm

5.5.4. Selection for bearing

Rolling contact bearings are used to minimize the friction associated with relative motion performed under load to facilitate circulation of the barrel and moving parts.

Ball bearing : Radial and Thrust Load

1- **Calculate the resultant radial and thrust load . As shown in figure 5-23.**

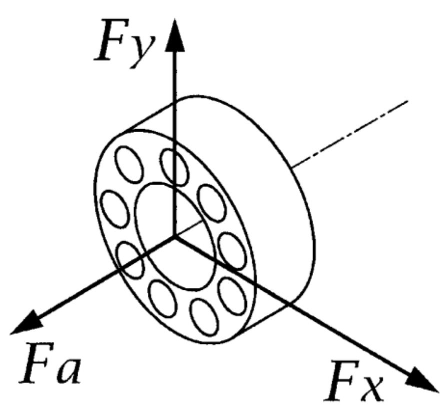

Figure 5-23 : Radial & Thrust load

F_y = 114.7 × 9.81 = 1125.2 N (from figure 5-18)

F_a = 375 N (from figure 5-18)
F_r = 1125.2 N

2- Assume the desired life (L_D) with 5 years

L_{Dh} = 5 × 365 × 24 = 43200 hours

$L_D = L_{Dh} \times n \times 60$ (5.16)

$= 43200 \times 1.5 \times 60 = 3.888 \times 10^6$ rev

$X_D = \frac{L_D}{L_{10}}$ (5.17)

$= 3.888 \times 10^6 / 10^6 = 3.888$ rev

3- Assume equivalent radial load (F_e)

$F_e = a_f \times V \times F_r$ (5.17)

a_f = Application Factor = 1.2 (from tables)

V = Rotation Factor = 1 (rotation inner ring)

$F_e = 1.2 \times 1 \times 1125.2 = 1350.24$ N

4- Calculate the required catalog rating (C_{10}) :

$C_{10} = (\frac{L_D}{L_{10}})^{\frac{1}{a}} \times F_e$ (5.18)

a = 3 for boll bearing

$C_{10} = (3.888)^{\frac{1}{3}} \times 1350.24 = 2123.18$ N = 2.12318 kN

5- Load rating (C_{10}^*) for angular contact bearing is :

C_{10}^* = 4.94 kN (from tables)

$$\frac{F_a}{C_{10}} = \frac{1125.25}{2123.18} = 0.53$$

$e = 0.44$ (from tables)

$$\frac{F_a}{V \times F_r} = 2.99 > e$$

X_2 = 0.56 , Y_2 = 1 (from tables)

6- Equivalent radial load (F_e)

$F_e = X_2 \times V \times F_r + Y_2 \times F_a$ (5.19)

$= 0.56 \times 1 \times 375 + 1 \times 1125.25$

$= 1335.25$ N = 1.33525 kN

Angular contact O_2 – 30 mm ball bearing for the locations of C & D .

5.6. Calculation for motor .

Selection a motor that satisfies the specifications required by the equipment is an important key to ensuring the desired reliability and economy of the equipment. As shown in figure 5-24 .

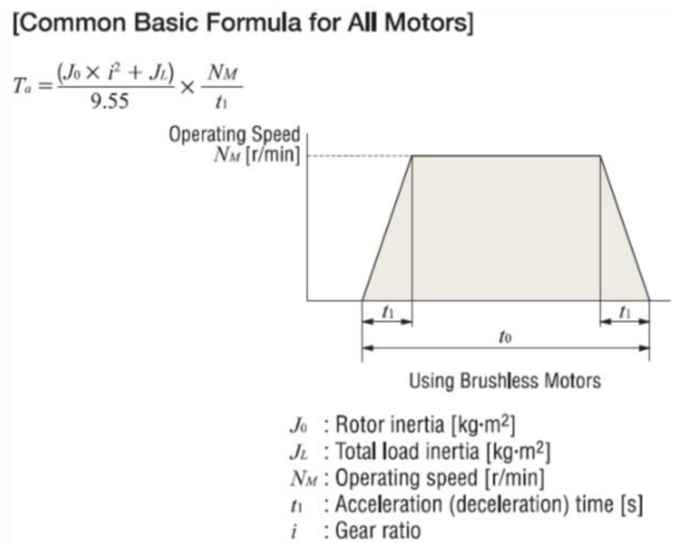

Figure 5-24 : Common basic formula

$$T_a = \frac{(J_O \times i^2) + J_1}{9.55} \frac{N}{t_1} \quad (5.20)$$

Where :

J_o : Rotor inertia
J_L : Total load inertia
N : Operation speed
t_1 : Acceleration (deceleration) time
i = Gear ratio

5.6.1. Calculation for circular motion

$\mathbf{T_m = (T_L + T_a) \times f_s}$ (5.21)

Where :

T_m: motor torque
T_L: load torque
T_a :acceleration torque
f_s : safety factor

T_L = is very small can me neglected .
t_1 = 0.1 s to get desired thickness in shortest possible time .

Calculation the second moment of inertia for rotating component (J)

$$J = \frac{m}{8}\left({d_0}^2 - {d_i}^2\right) \qquad (5.22)$$

1- For rotating shaft from figure (2.3) :
Mass = 1.18 kg

$$J = \frac{m}{8}\left({d_0}^2 - {d_i}^2\right) = \frac{1.18}{8}(0.1^2 + 0.08^2) = 2.42 * 10^{-3}\ kg.m^2$$

2- For disk from figure (2.4) :

$$J = \frac{m}{8}(d^2) = \frac{15.4}{8}(0.5^2) = 0.48\ kg.m^2$$

3- For supported cylinder from figure (2.5)

$$J = \frac{m}{8}\left({d_0}^2 - {d_i}^2\right) = \frac{8.45}{8}(0.48^2 + 0.46^2) = 0.466\ kg.m^2$$

4- For welding part :

$m = \frac{\pi}{8} d^2\, t \times \rho = I_x = \frac{\pi}{4} \times 0.48^2 \times 0.01 \times 4650 = 13.84$ kg

$J = \frac{m}{8} d^2 = \frac{2 \times 13.84 \times 0.48^2}{8} = 0.797$ kg.m^2

From cylinder part

$J = \frac{m}{8}({d_o}^2 + {d_i}^2)$

$J = \frac{122}{8}(0.48^2 + 0.46^2) = 6.74$ kg.m^2

$J_{total} = \sum J$ from rotating part

$= (2 \times 2.42 \times 10^{-3}) + (2 \times 0.48) + (2 \times 0.466) + 6.74 = 9.433$ kg.m^2

$$T_a = \frac{(J_o \times i^2) + 10}{9.55}\,\frac{2.5}{0.1}$$

$$T_a = (J_o \times i^2 \times 3.5) + 26.18$$

$$T_m = \left((J_o \times i^2 \times 3.5) + 26.18\right) \times 2 = 52.36\ N.m$$

$$M_P = \frac{2\pi}{60}\ 2.5 \times (52.38) = 14.2\ W$$

Rated torque =0.01 NM
Start torque =52.36 NM

Speed range (0.5 to 2.5)rpm

5.6.2. Design the Belt and screw mechanism

Belt and screw mechanism : system used to convert circular motion to linear motion .

Force the start of motion for welding motion :

$$F_{st} = \mu_s \; w \tag{5.24}$$

Where : μ_s is coefficient of static friction

W is weight required transfer

$$F_{st} = 0.7 \times 5 \times 9.81 = 34.7 \; N$$

Force to continuously motion :

$$F = \mu_k \; w \tag{5.25}$$

Where : μ_k is coefficient of dynamic friction

W is weight required transfer

$$F = 0.6 \times 5 \times 9.81 = 29.43 \; N$$

Required torque to start of motion :

$$T_R = \frac{F \, d_m}{2} \frac{l + \pi f d_m \, sec\alpha}{\pi d_m - f l \, sec\alpha} \tag{5.26}$$

$$l : lead \; pitch = 1 * 0.2'' = 0.2''$$

$$\alpha = thread \; angle = \frac{29}{2} = 14.5°$$

$$d_m : \; pitch \; diameter = 0.9'' = 22.5 * 10^{-3} \; m$$

From standard acme thread dimension :

Major diameter = 1.0" , thread pitch = 0.2"

Pitch diameter = 0.9" , miner diameter = 0.8"

$$T_R = \frac{3.47 \times 22.5 \times 10^{-3}}{2} \frac{5 \times 10^{-3} + \pi \times 0.16 \times 22.5 \times 10^{-3}\ sec14.5}{\pi \times 22.5 \times 10^{-3} - 0.16 \times 5 \times 10^{-3}\ sec14.5}$$

$$T_R = 0.091\ N.m$$

Required torque for motion = 0.063 N.m

Number of revaluation for motor

$$\frac{L_T}{lead} = \frac{1.5}{5 \times 10^{-3}} = 300\ revalution$$

Maximum speed of linear motion : 2.5 cm/s

$$Time = \frac{length}{speed} \tag{5.27}$$

$$T = \frac{L}{s} = \frac{1.5}{0.025} = 60sec$$

Motor speed maximum = 300 rpm

Minimum speed of linear motion : 0.5 cm/s

$$Time = \frac{length}{speed} = \frac{1.5}{0.005} = 300sec$$

Motor speed maximum = 60rpm

Motor torque due to acceleration

$$Ta = J\ \alpha \tag{5.28}$$

$$\alpha = \frac{W}{T} \tag{5.29}$$

$$\alpha = \frac{2\pi}{60} \frac{300}{0.1} = 314 \text{ rad/s}$$

Calculated mass from equation (4.1) and (4.2)

$$V = \frac{\pi}{4} \times 0.025^2 \times 2.2 = 1.08 \times 10^{-3}$$

$$m = 7600 \times 1.08 \times 10^{-3} = 8.2\ kg$$

Calculation the second moment of inertia for rotating component from equation (5.22)

$$J_x = \frac{1}{8}\ m\ d^2 = 6.4 \times 10^{-4} m^2.kg$$

$$T_a = 6.4 \times 10^{-4} \times 314 = 0.2\ N.m$$

Calculation the torque of motor from equation (5.20)

$$T_{m,start} = F_s(T_l + T_a) = 0.58\ N.m$$

Motor power = 18.28 watt
Start torque =0.58NM
Rated torque =0.3 NM
Speed range (60 _ 300) rpm

Force the start of motion for welding mot Install work piece:

$$F_{st} = \mu_s \ w \tag{5.24}$$

where : μ_s is coefficient of static friction

W is weight required transfer = weight of trolley(490.5N)

$$F_{st} = 0.7 \times 490.5 = 347 \ N$$

Force to continuously motion :

$$F = \mu_k \ w \tag{5.25}$$

Where : μ_k is coefficient of dynamic friction

W is weight required transfer

$$F = 0.6 \times 490.5 = 294.3 \ N$$

Required torque to start of motion :

$$T_R = \frac{F \ d_m}{2} \frac{l + \pi f d_m \ sec\alpha}{\pi d_m - fl \ sec\alpha} \tag{5.26}$$

$$l : lead \ pitch = 1 * 0.2'' = 0.2''$$

$$\alpha = thread \ angle = \frac{29}{2} = 14.5°$$

$$d_m : \ pitch \ diameter = 0.9'' = 22.5 * 10^{-3} \ m$$

From standard acme thread dimension :

Major diameter = 1.0" , thread pitch = 0.2"

Pitch diameter = 0.9" , miner diameter = 0.8"

$$T_R = \frac{347 \times 22.5 \times 10^{-3}}{2} \frac{5 \times 10^{-3} + \pi \times 0.16 \times 22.5 \times 10^{-3}\, sec 14.5}{\pi \times 22.5 \times 10^{-3} - 0.16 \times 5 \times 10^{-3}\, sec 14.5}$$

$$T_R = 0.851\ N.m$$

Required torque for motion = 0.734 N.m

Number of revaluation for motor

$$\frac{L_T}{lead} = \frac{1.5}{5 \times 10^{-3}} = 300\ revalution$$

Speed of linear motion : 2.5 cm/s

$$Time = \frac{length}{speed} \tag{5.27}$$

$$T = \frac{L}{s} = \frac{1.5}{0.025} = 60 sec$$

Motor speed = 300 rpm

Motor torque due to acceleration

$$Ta = J\ \alpha \tag{5.28}$$

$$\alpha = \frac{W}{T} \tag{5.29}$$

$$\alpha = \frac{2\pi}{60} \frac{300}{0.1} = 314 \text{ rad/s}$$

Calculated mass from equation (4.1) and (4.2)

$$V = \frac{\pi}{4} \times 0.025^2 \times 2.2 = 1.08 \times 10^{-3}$$

$$m = 7600 \times 1.08 \times 10^{-3} = 8.2\ kg$$

Calculation the second moment of inertia for rotating component from equation (5.22)

$$J_x = \frac{1}{8}\ m\, d^2 = 6.4 \times 10^{-4} m^2.kg$$

$$T_a = 6.4 \times 10^{-4} \times 314 = 0.2\ N.m$$

Calculation the torque of motor from equation (5.20)

$$T_{m,start} = F_s(T_l + T_a) = 0.58\ N.m$$

Motor power = 66.25 watt
Start torque =0.851**NM**
Rated torque =0.734 **NM**
Speed 300 rpm

Chapter 6 : Prototype Design and Implement

6.1. Overview

6.2. Specification

6.3. Factor of Safety

6.3.1. For rectangular beam

6.3.2. For support working piece

6.4. Project execution

Chapter 6 : Prototype Design

6.1. Introduction

In this chapter, a prototype design for the welding machine will be designed. This prototype will be designed with machine specifications and will be implemented by the project to test the work of the machine and make sure the validity of the specifications chosen. And mention the mechanical parts used in the design of the machine in this chapter.

6.2. Prototype Specification

A prototype that is different in some mechanical parts will be designed for the main machine , and is similar in the same welding process specification (circular and linear) . The following table (6-1) shows the specifications selected.

Table 6-1 : Specification of Prototype

Linear rotating speed	(5 - 20) rpm
Circular rotating speed	(0.5 – 1.5) rpm
Length of barrel	30 cm
Maximum mass of barrel	30 kg
Radius of barrel	50 cm
Welding type	CO_2 Welding
Current of welding	300 A

6.3. Mechanical Design :

6.3.1. Factor of safety for rectangular beam :

First Step : To calculate the force affecting on rectangular beam .

Calculate mass of beam that support working piece .

Weight per Length of beam

$L = 3.41$ kg/ m (from table)

Total length for beam

$L_{Total} = 2\times55+60 = 170$ cm = 1.7 m

Mass of beam

$M = 3.41$ kg/m $\times$ 1.7 m = 5.8 kg

Total mass for Barrel holder

$M_{Total} = 2 \times 5.8 = 11.6$ kg

Calculated mass of rotation cylinder .

Diameter = 8 cm

Thickness = 0.5 cm

Length = 20 cm

This dimension from Factor of safety against fatigue failure calculation

Calculated mass from calculate volume and density of iron .

$V = \frac{\pi \times (d_0{}^2 - d_i{}^2)}{4} l$ (6.1)

$$V = \frac{\pi \times (0.8^2 - 0.7^2)}{4} 0.2 = 2.355 \times 10^{-4} m^3$$

density of iron = ρ = 7850 kg / m^3

Mass = V × ρ (6.2)

= $2.355 \times 10^{-4} \times 7850$ = 1.848 kg

Calculated mass of disk

Thickness = 1 cm

Diameter = 50 cm

These dimensions are approximate.

Calculated mass from equation (6.1) and (6.2)

$$V = 6.25 \times 10^{-4}$$

Mass = V × ρ = $6.25 \times 10^{-4} \times 7850$ = 4.9 kg

Mass for support of the working piece

Out diameter 50 cm

In diameter 48cm

Length = 3.5 cm

These dimensions were chosen based on the dimensions of the work piece

Calculated mass from equation (6.1) and (6.2)

V = 5.385×10^{-4} m^3

Mass = 5.385×10^{-4} × 7850 = 4.227 kg

Mass of barrel

Maximum mass of barrel = 30 kg .

Second Step : Drawing free body diagram for I beam to calculate reaction force at point A and B.

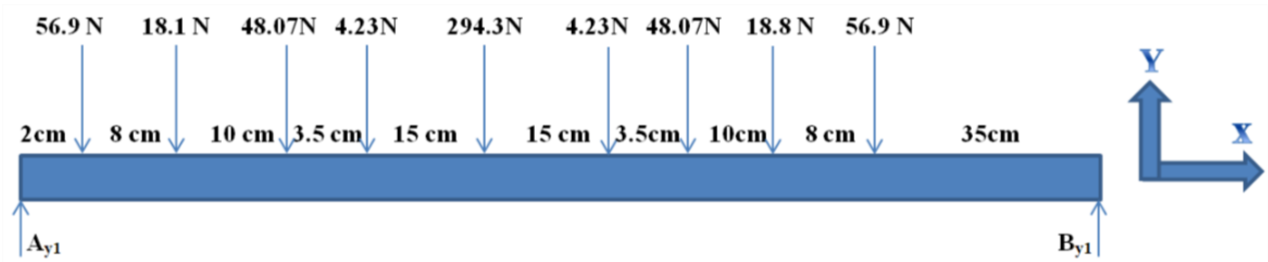

Figure 6-1 : Free body diagram of the major structure in X-Y direction

Static force analyses .

Force acting in each beam half force in structure.

Summation of moment about point A equal zero in X ,Y and Z direction .

$$\sum M_A = 0$$

$$((56.9\times2) + (18.1\times8) + (48.07\times20) + (4.23\times23.5) + (294.3\times38.5) + (41.23\times53.5) + (48.07\times57) + (18.8\times67) + (56.9\times75) - (R_{Bx}\times110)) = 0$$

$$R_{By} = 255 \text{ N}$$

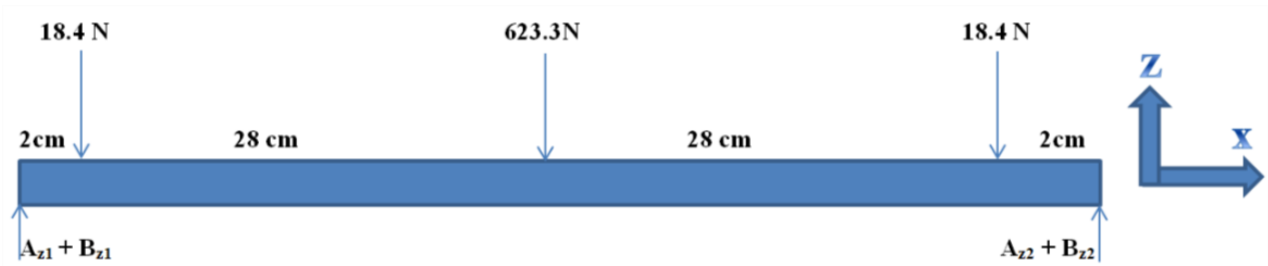

Figure 6-2 : Free body diagram of the major structure in X-Z direction

$$\sum M_{zA1} = 0$$

$$0 = 9.81\times(1.876\times20 + 84.6\times30 + (1.876\times58) - (R_{A2z} + R_{B2z})\times60)$$

Assume that $R_{A2z} = R_{B2z}$

$$R_{A2z} = R_{B2z} = 216.7 \text{ N}$$

Third step: Draw the shear force diagram and bending moment diagram X-Y direction . As shown in figure (6-3 , 6-4)

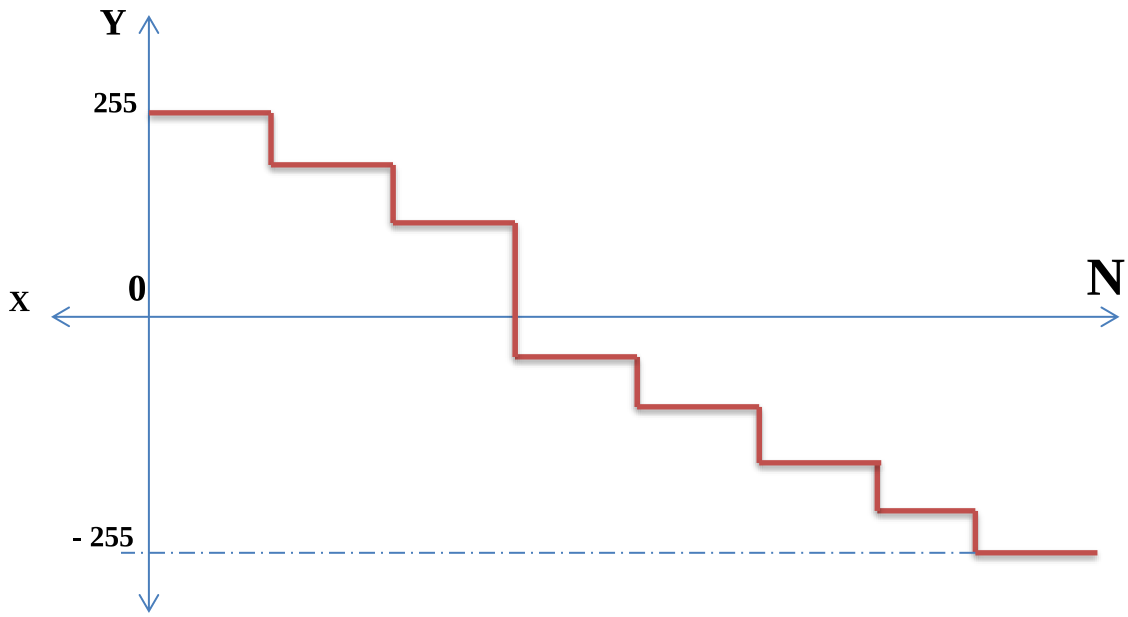

Figure 6-3 : Shear force diagram (V) in X-Y direction

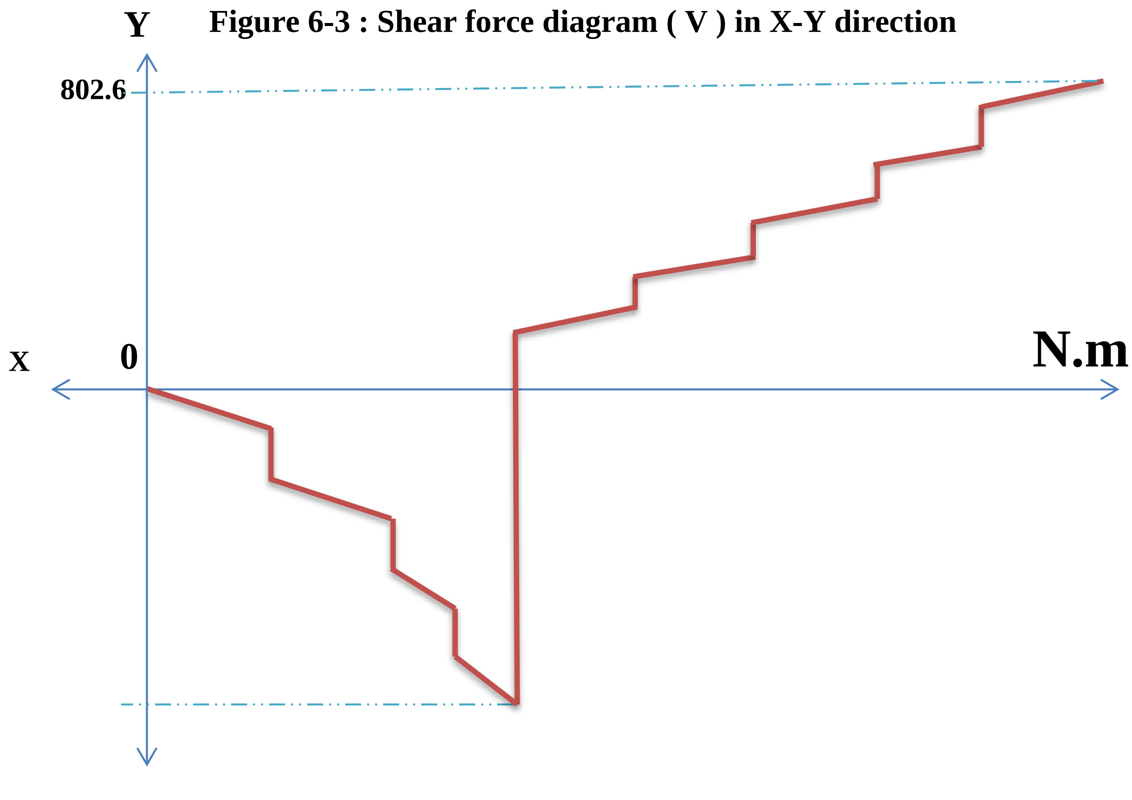

Figure 6-4 : Bending moment diagram (M) in X-Y direction

The magnitude of maximum bending moments for each beam is: $M = 0.5 \times 802.6 = 401.3$N.m

Fourth step: Draw the shear force diagram and bending moment diagram X-Z direction . As shown in figure (6-5 , 6-6)

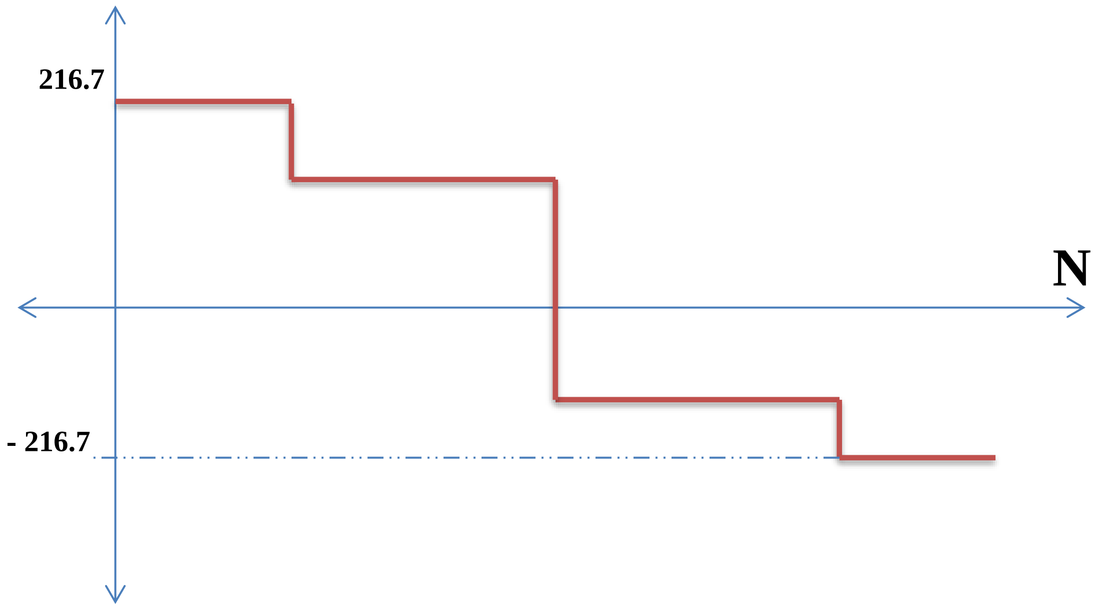

Figure 6-5 : Shear force diagram (V) in X-Z direction

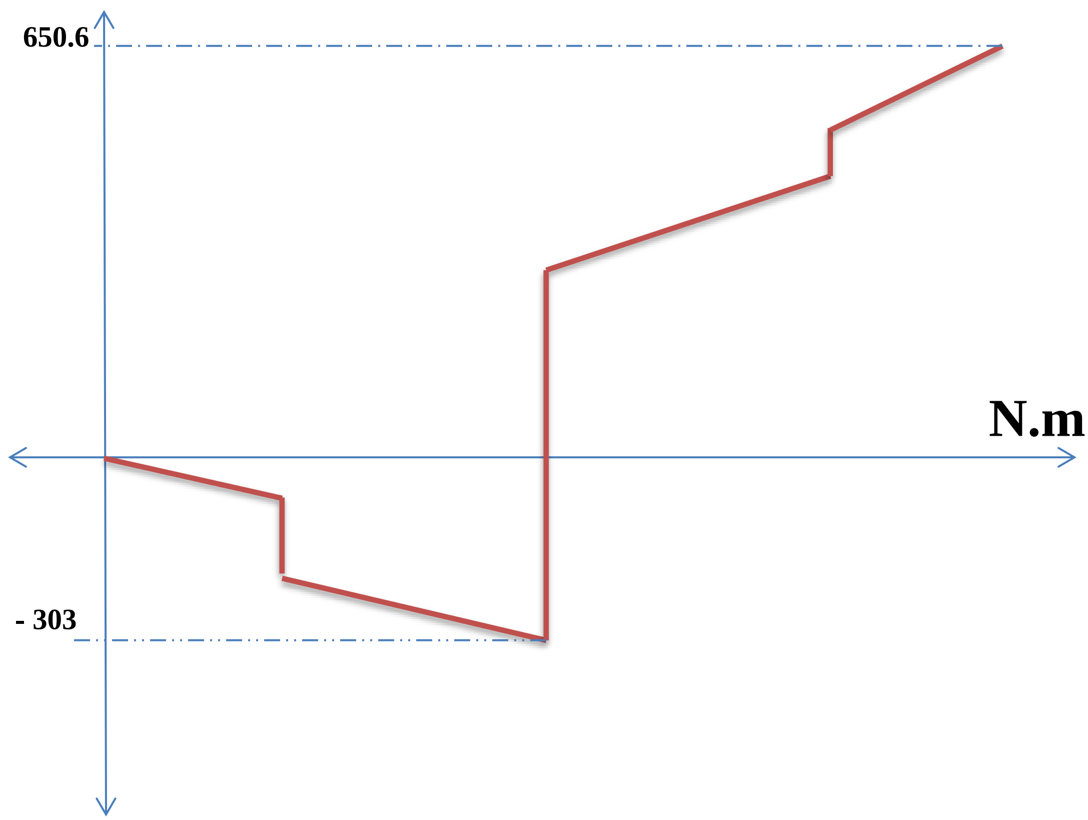

Figure 6-6 : Bending moment diagram (M) in X-Z direction

The magnitude of maximum bending moments for each beam is: M = 0.5×650.6 N = 325.3 N .

Fifth Step : Calculation second moment of inertia for rectangular beam

$I = \frac{1}{12}\ b\, h^3$ (6.3)

$$I_1 = \frac{1}{12}(0.04)(\ 0.04)^3 = 2.13 \times 10^{-7} m^4$$

$$I_2 = \frac{1}{12}(0.034)(\ 0.034)^3 = 1.11 \times 10^{-7} m^4$$

I_{total} = I_1- I_2= $1.02\times10^{-7}\ m^4$

$$\sigma = \frac{M\,c}{I} \qquad (6.4)$$

$$\sigma = \frac{401.23 \times 0.02}{1.02 \times 10^{-7}} = 78.67\ MPa$$

$$\tau = \frac{Tc}{J} \qquad (6.5)$$

$$\tau = \frac{325.27\times0.02}{2.04\times10^{-7}} = 30.19 \text{ MPa}$$

$$\sigma = \frac{\sigma_1 + \sigma_2}{2} \mp \sqrt{\left(\frac{\sigma_1 + \sigma_2}{2}\right)^2 + \tau^2} \qquad (6.6)$$

σ = 88.92 MPa , -10.245 MPa

σ_{min} (88.92 , 0 , -10.245) = -10.245 MPa

σ_{max} (88.92 , 0 , -10.245) = 88.92 MPa

Maximum shear stress calculation :

$$\tau_{max} = \frac{\sigma_{max} - \sigma_{min}}{2} \quad (6.7)$$

$$\tau_{max} = \frac{88.92 - (-10.245)}{2} = 49.58\ MPa$$

yield shear strength steel 1080 H :

S_{sy} = 110 MPa (from tables)

Factor of safety using maximum shear stress :

$$Ssy = \frac{Sy}{2} \qquad (6.8)$$

$$n = \frac{Ssy}{\tau_{max}} \quad (6.9)$$

$$n = \frac{110}{49.58} = 2.22$$

6.3.2. For support working piece

The support of working piece loads the moving parts of the machine. Therefore, this part must be properly selected to suit the parts of the machine and for the welding process to be done safely. Therefore, the design of this part was done so that a safety factor was chosen to suit the working conditions and calculate the forces influencing it, through which appropriate dimensions are chosen for this part.

Assume the factor of safety = 2

$\sum F_y = 0$
$R_A + R_B = 217.9$ N
But $R_A = R_B$
$R_A = 109$ N

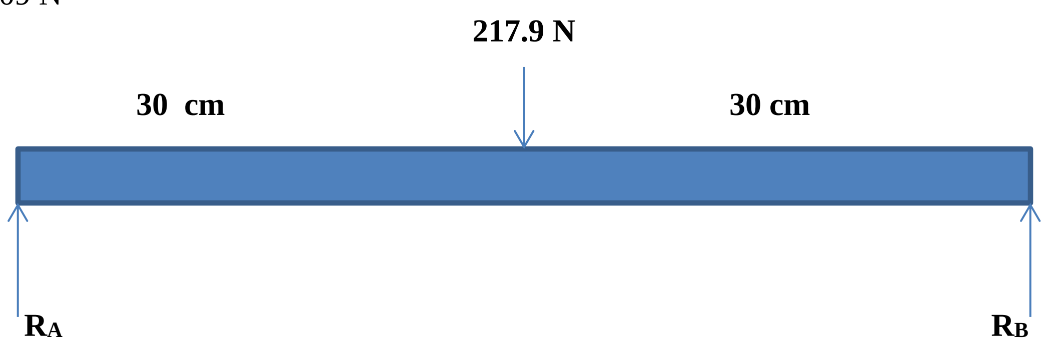

Figure 6-7 : Free body diagram for support working piece

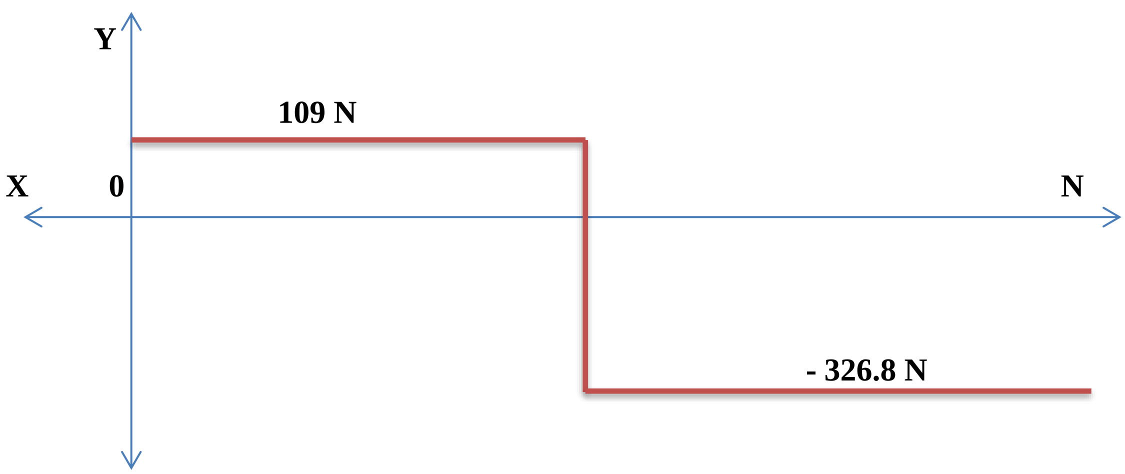

Figure 6-8 : Shear force diagram

Figure 6-9 : Bending moment diagram (M)

Maximum moment = 163.38 N.m

Factor of safety = n = 2

Yield shear strength = S_{sy} = 110 MPa

Maximum shear stress = τ_{max}

$\tau_{max} = \frac{S_{sy}}{n} = \frac{110}{2} = 55\ MPa$

$\sigma = 2\ \tau_{max} =\ 110$ MPa

$\sigma = \frac{Mc}{I}$

$I = \frac{Mc}{\sigma} = \frac{163.38 \times 0.02}{110 \times 10^6} = 2.97 \times 10^{-8} m^4$

$I = \frac{1}{12}(D^4 - d^4) = \frac{1}{12}(0.04^4 - d^4) = 2.97 \times 10^{-8} m^4$

d = 0.0385 m

Thickness = $\frac{0.04 - 0.0385}{2}$ = 0.00075 m = 0.75 mm

Thickness = 0.75 mm

6.4. Project execution

1. The iron is cut according to the length of the project design. As shown in figure 6-10 .

Figure 6-10 : Major Structure

2. Work on assembling the fixed and moving base, which works to carry the rotary parts and electronic parts to the appropriate length and shape . As shown in figure 6-11 .

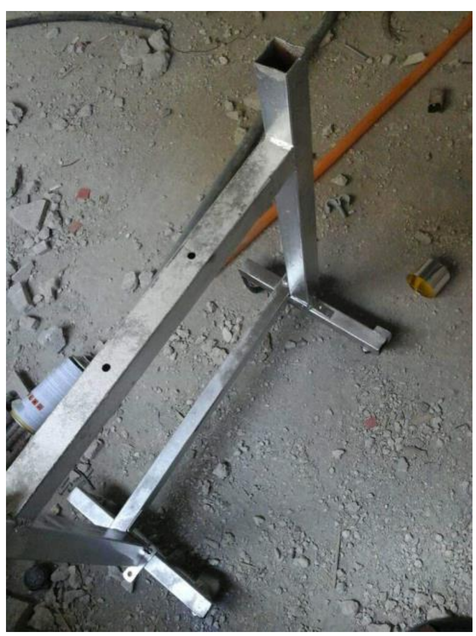

Figure 6-11 : Fixed and moving base

3. Working on assembly of linear motion systems. As shown in figure 6-12 .

Figure 6-12 : Linear System

4. Assembly of control system and electrical parts . As shown in figure 6-13 .

Figure 6-13 : Control System

Final Shape

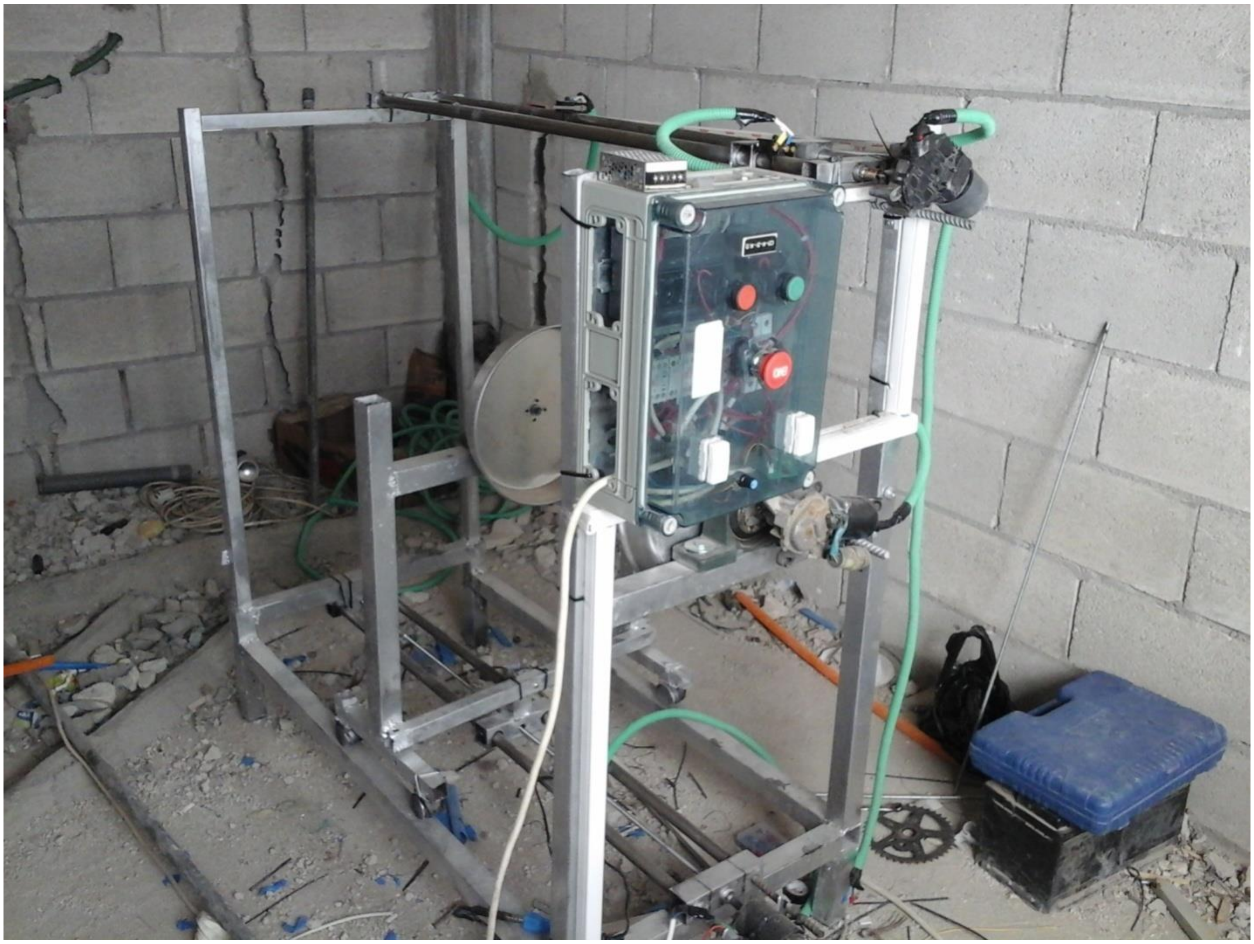

Figure 6.14 : Final Shape

Conclusion

The design of this machine was carefully thought and documented throughout the entire process it went through. From the basic idea all the way, special consideration and care had given. This machine is of a very simple design while also being comparably cheaper to other very similar machines. The machine is designed to produce the best and most beautiful form, so that the machine is obtained at a lower cost than other machines and the production of welding process accurately and high quality. Also, a control system will work so that it will work more easily.

Difficulties encountered by the non-acceptance of companies and factories in financing the project before implementation. So that the companies and factories asked to buy the project after its implementation in case the project is compatible with the specifications requested by the factory.

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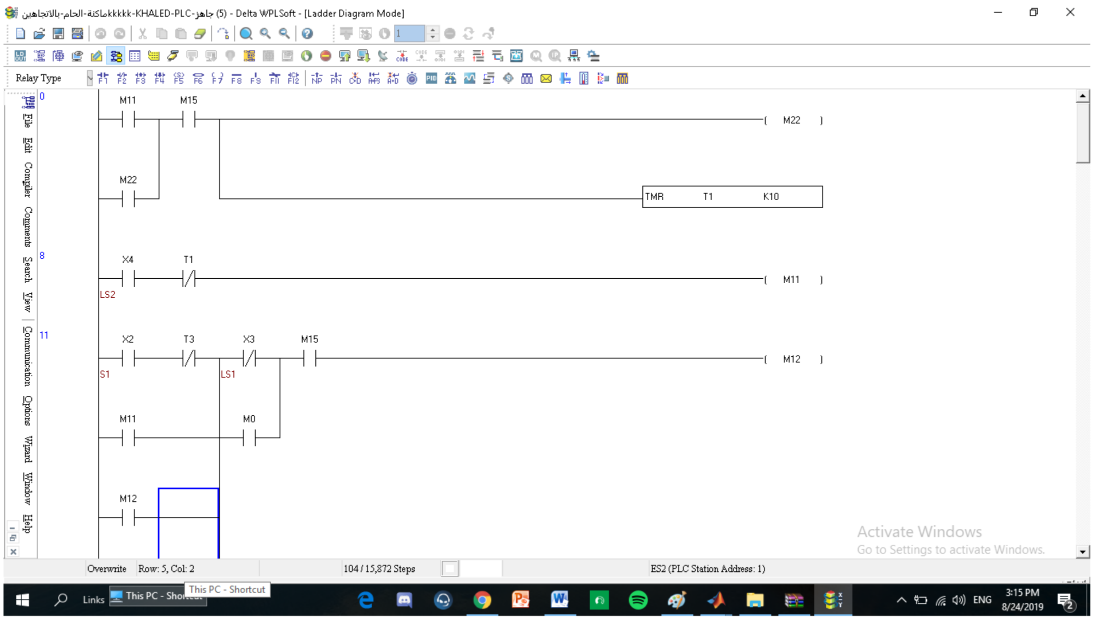
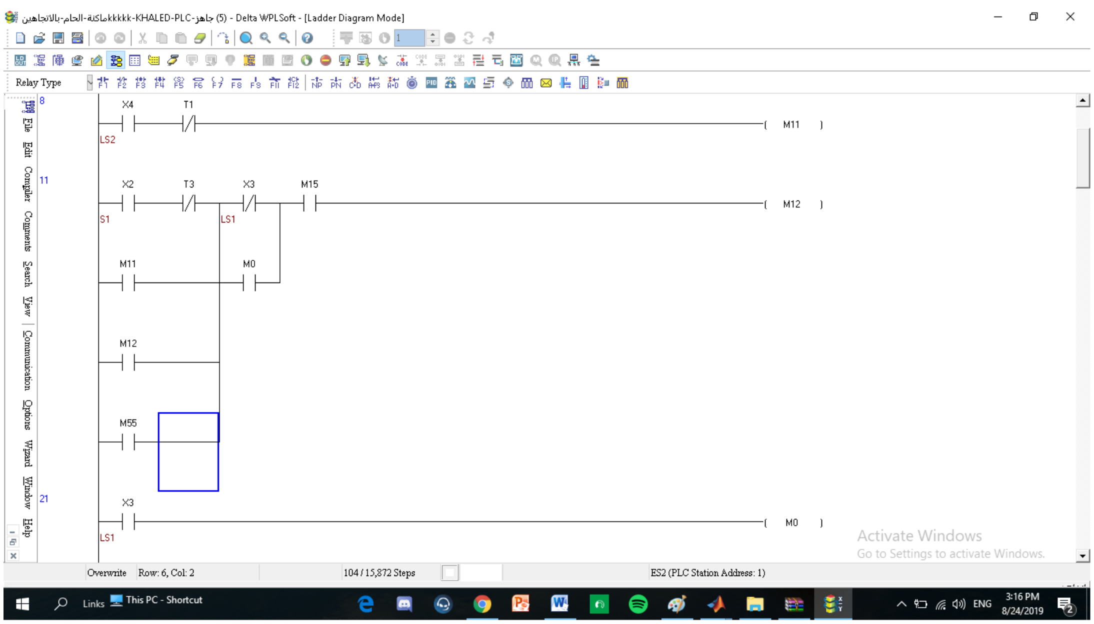
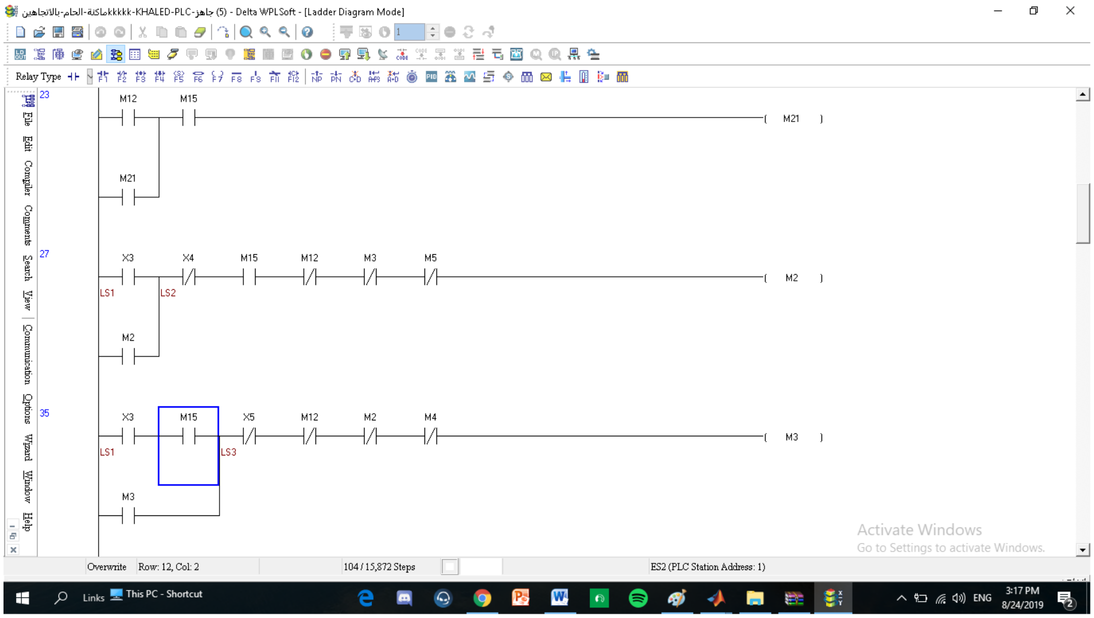
Appendix



M11
M15
M22
TMR T1 K10
X4
T1
LS2
M11
X2
T3
X3
M15
S1
LS1
M12
M0



X4
T1
LS2
M11
X2
T3
X3
M15
S1
LS1
M12
M0
M55
M0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M15
M21
M21
27
X3
X4
M15
M12
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M5
M2
LS1
LS2
M2
35
X3
M15
X5
M12
M2
M4
M3
LS1
LS3
M3
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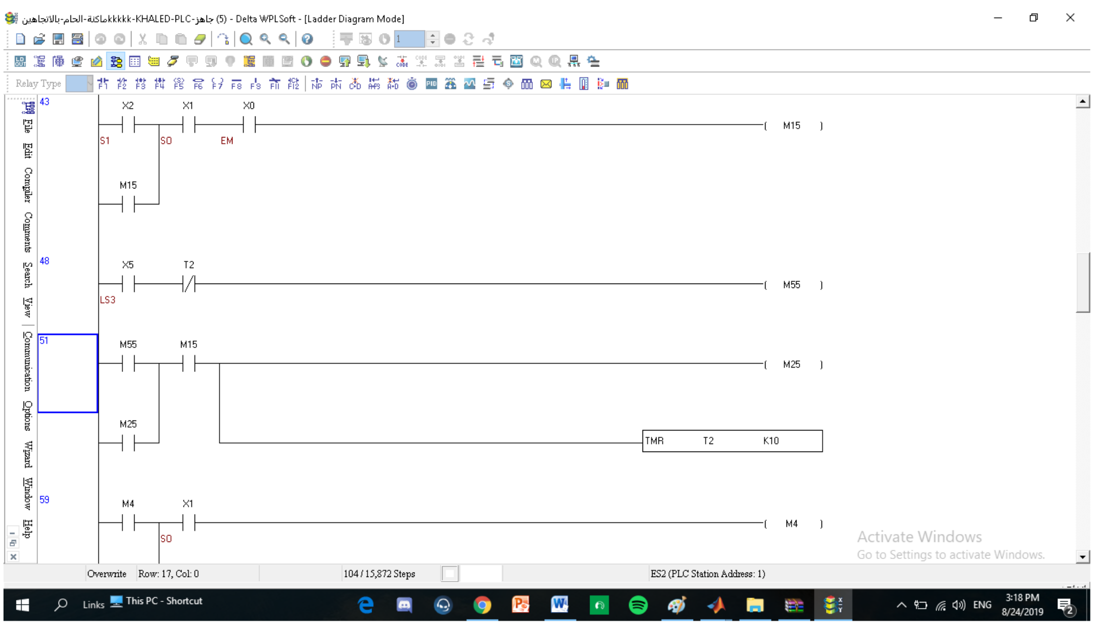
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X1
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S1
SO
EM
M15
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X5
T2
M55
LS3
51
M55
M15
M25
M25
TMR
T2
K10
59
M4
X1
M4
SO
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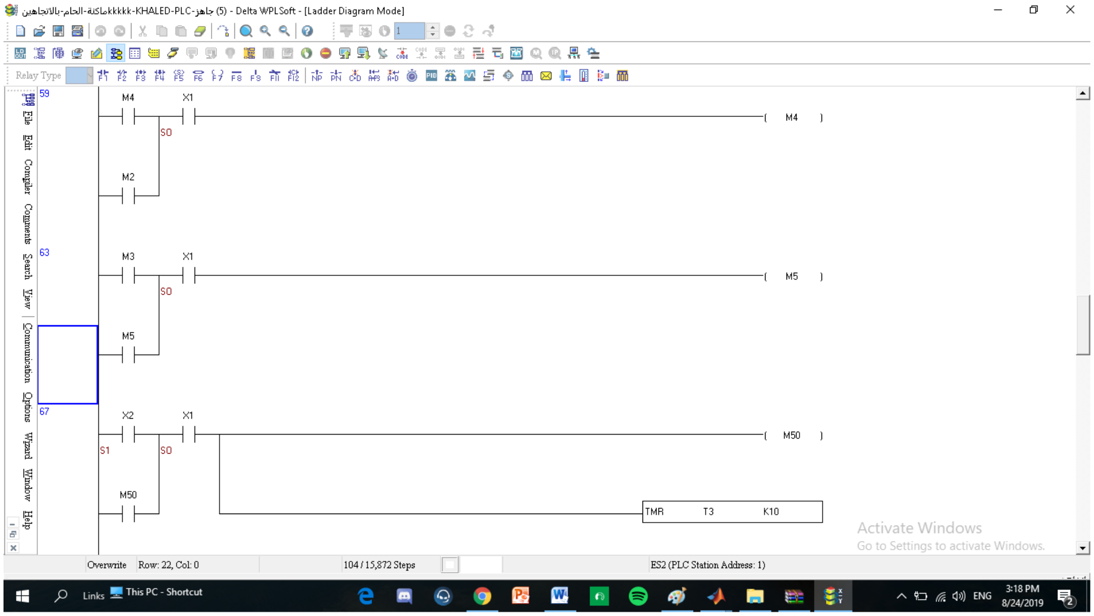
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M4
M2
63
M3
X1
S0
M5
M5
67
X2
X1
S1
S0
M50
M50
TMR
T3
K10
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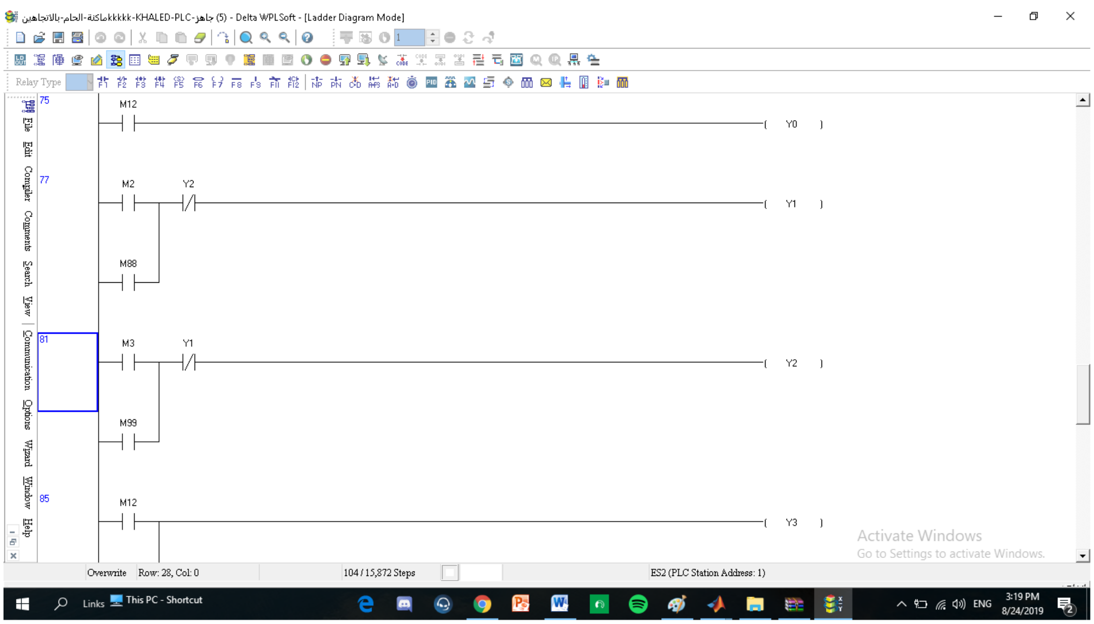
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M2
Y2
Y1
M88
81
M3
Y1
Y2
M99
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Y3
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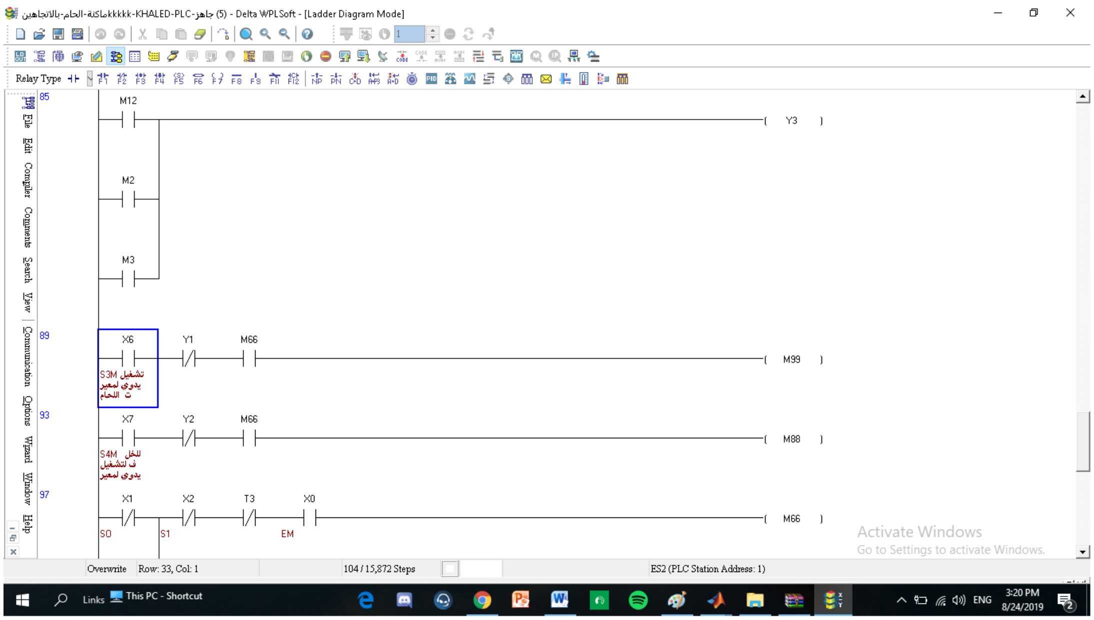
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S3M تشغيل يدوي لمعير الخام ت
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X7
Y2
M66
M88
S4M للخل ف لتشغيل يدوي
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X0
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S0
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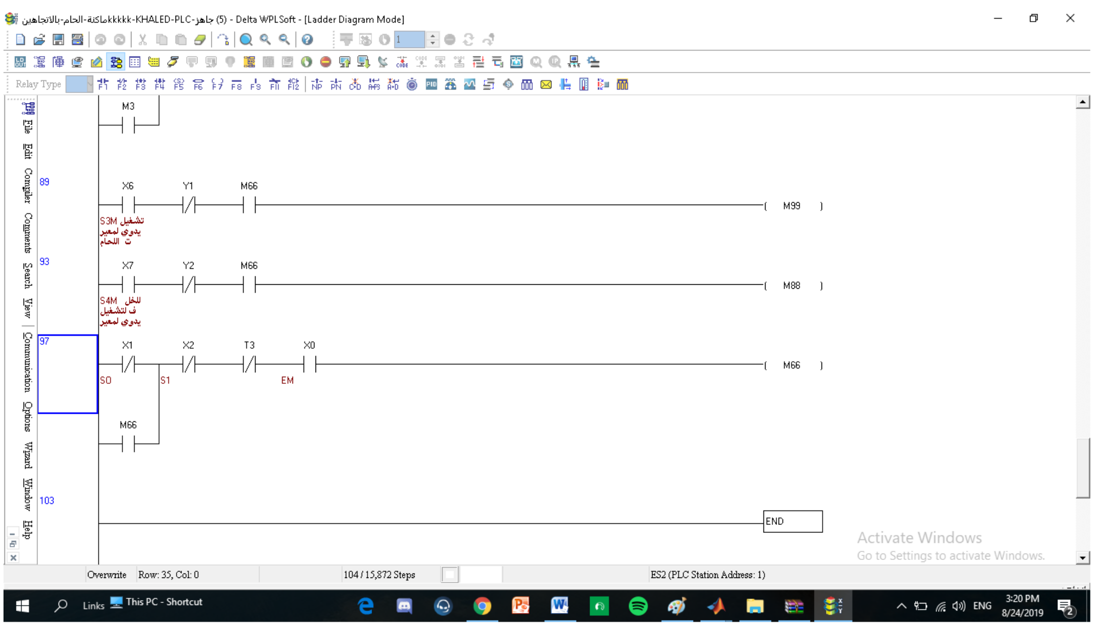
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93
X7
Y2
M66
M88
S4M للخل ف لتشغيل يدوي
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X1
X2
T3
X0
M66
S0
S1
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M66
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