بسم الله الرحمن الرحيم

**Palestine Polytechnic University**
**Electrical and Computer Engineering Department**

**Industrial Automation Engineering Program**

**Bachelor Thesis**

**Graduation Project**

# Design and Implementation Of CNC Stone Engraving Machine


**Project Team**

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### *Abstract*

This Project discusses the CNC machines structure and its purpose of existence, and then it shows the designing and implementing procedure of this machine starting from making a theoretical designation and selecting parts of the project and ending with arranging its working status.

This Report Contains an Introduction that describes the machine in general, the next chapter describes the hardware components used in the machine, the third chapter describes the software used to operate the machine and the fourth chapter includes the selection of the servo motor and equipment of the machine, and the working procedure to implement the machine.

We work through some programs electrician and mechanical simulation system to represent the work of the machine using the computer, because of the lack of support for the implementation of this project, and we were able to represent the work of the machine and use microcontrollers to control the engraving motor which is drilling and drawing on the work piece.

The first of these programs is Mastercam, we enter the image to be converted to special orders to control servo motors through the controller, or through pic simulator which we programmed these commands and convert them into electrical signals we tested through the proteus.

We represent the work of the machine mechanically by using CATIA program which we can show machine work.

# الملخص

هذا المشروع سيناقش تصميم ألة للنقش على الحجر وكيفية التحكم بها من خلال الحاسوب، وكما سيناقش تصميمها وخطوات بنائها على أرض الواقع ابتداء من نظريات التصميم واختيار القطع اللازمة لعمل الالة.

ومن خلال الدراسة،لتصميم الة للنقش على الحجر نحن بحاجة للتحكم بموقع رأس الحفر في ثلاث اتجاهات محورية ،ويتم ذلك باستخدام محركات خاصة تعالج الخطأ عن طريق التغذية الراجعة،ذلك للوصول لقطعة عمل معالجة بشكل أفضل وأكثر دقة،وبوقت أقل .

*قمنا من خلال مجموعة من البرامج بعمل نظام محاكاة كهربائي وميكانيكي لتمثيل عمل الأله باستخدام الحاسوب, وذلك لعدم توفر الدعم لتنفيذ هذا المشروع ,ولقد استطعنا ان نمثل عمل الماكينه واستخدام المتحكمات الدقيقة والمبرمجه للتحكم براس العمل والذي هو عباره عن محرك يقوم بعملية الحفر والرسم على قطعة العمل ,وأول هذه البرامج هو برنامج Mastercam والذي ندخل الصورة المراد نقها من خلاله وتحويلها الى أوامر خاصة للتحكم بها من خلال المتحكم أو من خلال برنامج pic simulator والذي من خلاله نستطيع برمجة هذه الأوامر وتحويلها الى اشارات كهربائية نستطيع اختبارها عن طريق برنامج proteus.*

*وقمنا بتمثيل عمل الماكينة ميكانيكيا عن طريق استخدام برنامج catiaوالذي نستطيع من خلاله اظهار عمل الماكينة بشكل نظري .*

# *Table of Contents*

## *Table of Figure*

### Chapter One: Introduction



### Chapter Two: Hardware



### Chapter Three: Software



### Chapter Four: motors selection

**CHAPTER FIVE: SIMULATION AND PIC**



**CHAPTER SIX: SIMULATION DESIGN**

## *Table of Tables*

# CHAPTER ONE

# INTRODUCTION

**1.1 Project Overview.**

**1.2 Project Objective.**

**1.3 Time Schedule.**

**1.4 Project Scope.**

## 1.1 Project Overview

After the difficulties that facing the stone and marble industry in Palestine, such as high production costs due to the large number of manpower and slow work, it became necessary to have advanced manufacturing systems to work to reduce losses and increase production.

Through research in the local market notes absence of an effective systems for engraving on stone, the process is done in traditional ways using incendiary devices to engrave states and certain slogans for one stone in the house for decorations, as well as by engraving manually on building stones using simple iron tools that take a long time to be completed, as consumed a large workforce.

Therefore we aim from this project to find a way to produce these products with less time and more accuracy.

Figure 1-1 shows the main components of the desired working machine, where there are three servo motors to control the head motor through axes x, y and z, within a controlling system that provide the production aim, as will be discussed in later chapters.

As shown in the following Figure1-2, operating principle of the machine depends on the movement in three directions to transfer the location of the engraving from point to point as painting required with the installation of a piece to be engraved.

**Figure 1-1 Machine construction**

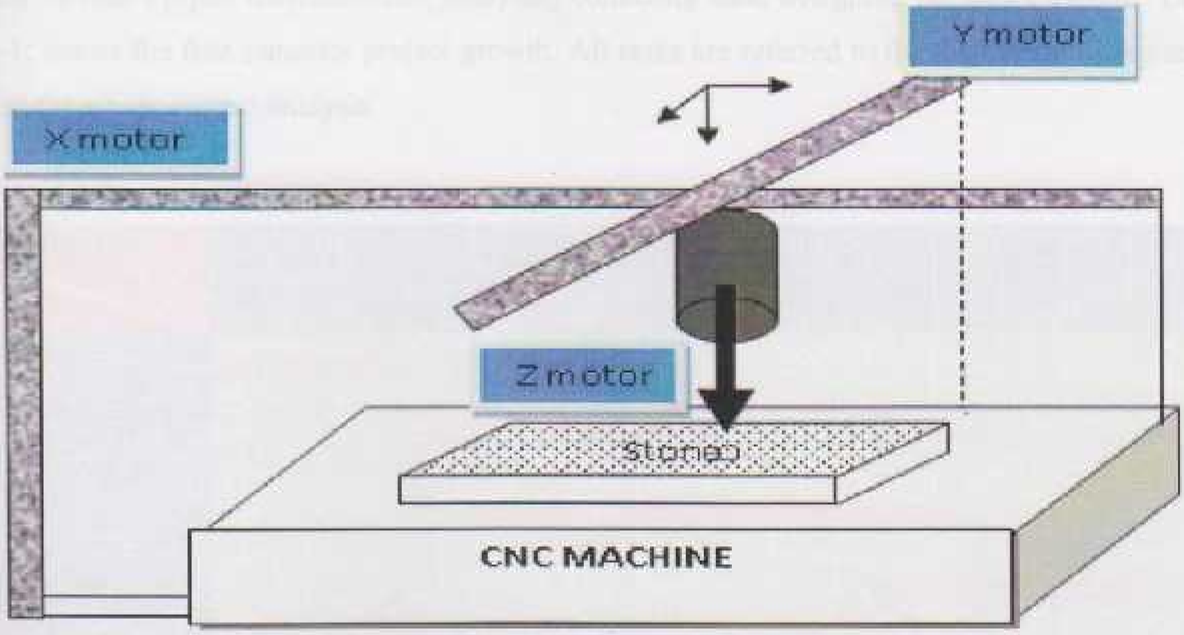



**Figure 1-2 Simplified idea for the design of the machine**

## 1.2 Project aims

This Project aims at:

- Reducing time working in peace of stone and accuracy work.
- Increase number of product in time unit.
- Assistance in solving the problem of the stone industry and get distinctive forms of stone for use in construction.
- Learn how to make complete project contains electrical and mechanical system.

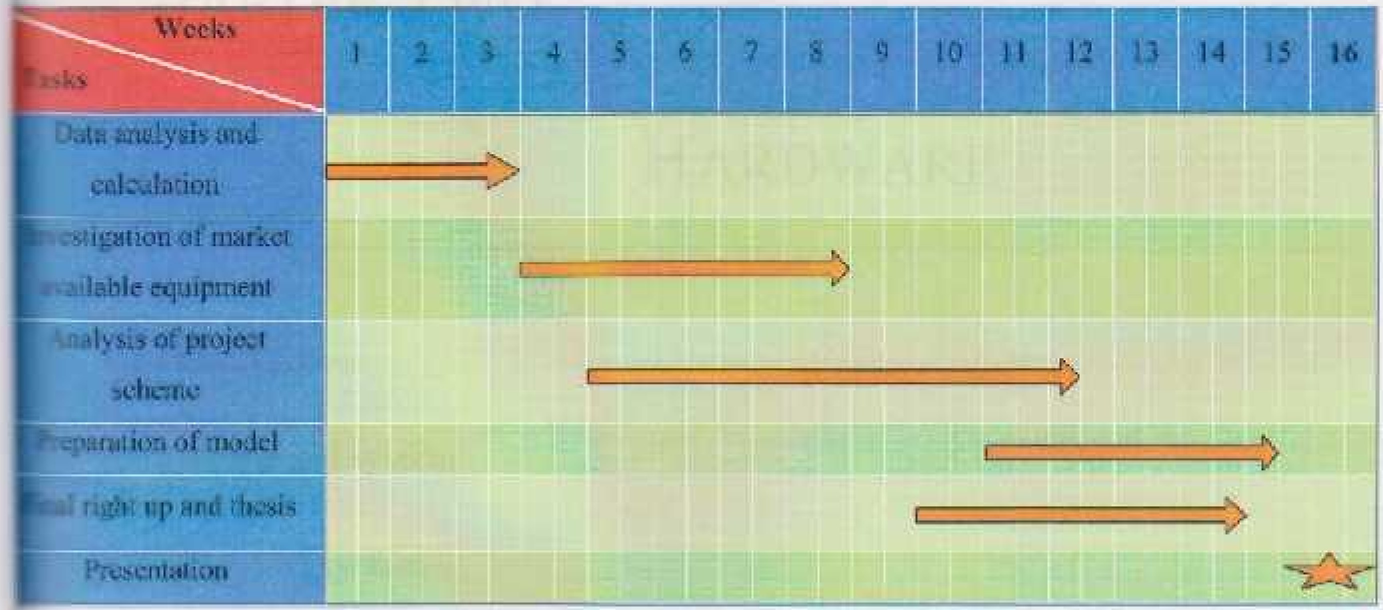
## 1.3 Time Table

The time schedule shows the stages of developing in our work and the process of project growth that include Project determination, studying, collecting data, designing the entire system. Table 1-1; shows the first semester project growth. All tasks are referred to the theoretical background and the whole system analysis.

**Table 1-1 Time Schedule**

| Weeks / Tasks | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Project idea | | | | | | | | | | | | | | | | |
| …ect analysis and plane | | | | | | | | | | | | | | | | |
| Data analysis and calculation | | | | | | | | | | | | | | | | |
| Simulations | | | | | | | | | | | | | | | | |
| …ction the components of the projects | | | | | | | | | | | | | | | | |
| Presentation | | | | | | | | | | | | | | | | |

Table 1-2 Time Schedule for second semester




## 1.4 Project Scope

This project consists of four chapters as follows:

Chapter One "**Introduction**"

Chapter Two "**Hardware**"

Chapter Three "**Software**"

Chapter Four "**Design & Calculation**".

Chapter Five "**Simulation and PIC**".

Chapter Six "**Simulation design**".

Chapter Seven "**Conclusion and Recommendation**".

# CHAPTER TWO

# HARDWARE

**2.1 Introduction**

**2.2 Mechanical system**

**2.3 Electrical system**

## 2.1 Introduction

In this chapter we will describe the system of the machine component, there are three major subsystems to this CNC design as shown in Figure 2-1, they are:

- Mechanical.
- Electrical.
- Software.

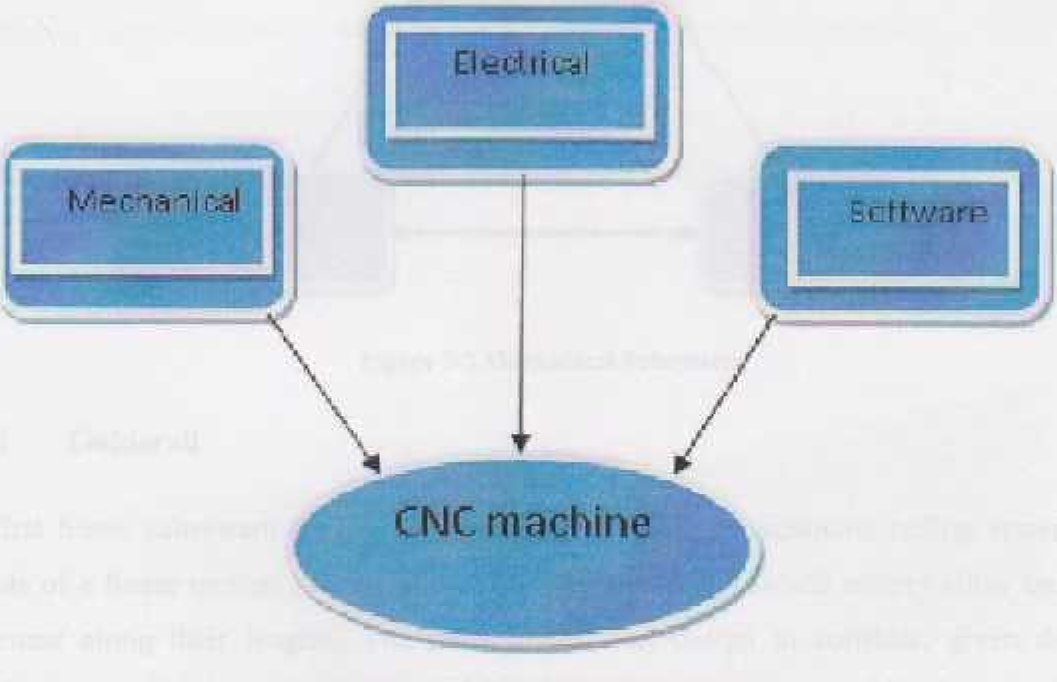



**Figure 2-1 CNC major Subsystems**

## 2.2 Mechanical system

The mechanical subsystem of a CNC provides the means needed to cut and machine various materials for a given job. The choice of materials has a direct impact on performance, precision, repeatability, longevity, and mechanical noise transfer into the parts. The mechanical subsystem is comprised of the guide system, the drive system, and the frame housing structure. Each of these systems has a direct impact on the aforementioned qualities of a CNC.

The mechanical subsystem, shown in Figure 2.2, is further broken down into the following subsections:

1. Frame.
2. Drive.
3. Guide.

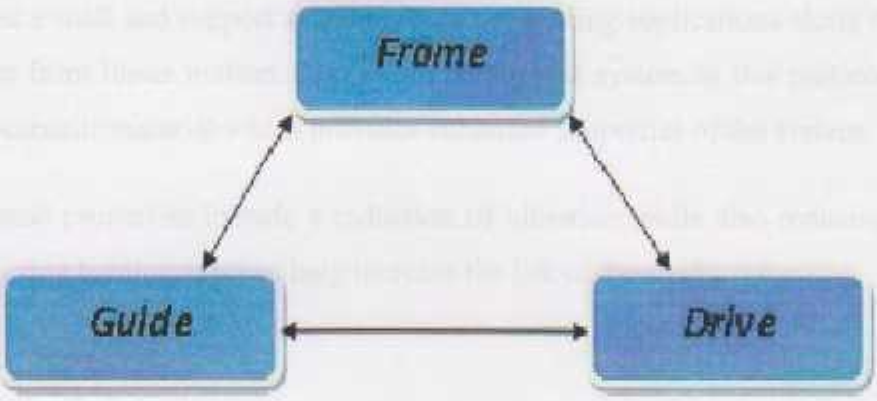



**Figure 2-2 Mechanical Subsystem**

### 2.2.1 Guiderail

The first frame subsystem design to consider would be a conventional railing system, which consists of a linear motion bearing and shaft assembly which would simply allow unrestricted movement along their lengths. The most logical rail design to consider, given the design specifications and size requirements, would be the sort of railing that could be supported in some way to handle the loads applied to it without much deflection. [4]

#### 2.2.1.1 Type of guide

1. **Steel shaft railing**

As seen in Figure 2-3 is both a simple and efficient design for linear motion applications. The shaft provides support to loading applications along the shaft, along with forces generated from linear motion, which makes this a perfect concept for this particular system.

**Figure 2-3 shaft**

2. Shaft and support system

Which uses a shaft and support system to support loading applications along the shaft, along with forces from linear motion. The shaft and support system in this particular system can come in a ceramic material which provides enhanced properties of the system.

The enhanced properties include a reduction of vibration while also reducing deflection of the shaft during loading cases to help increase the life of the shaft.

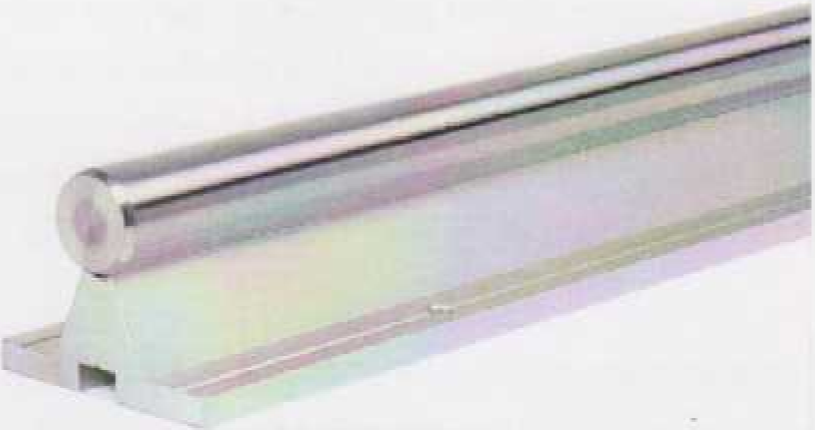


**Figure 2-4 Shaft and support rail**

For our project and because of the sensitivity of the stone engraving we will use the shaft and support rail system due to reduction of vibration while also reducing deflection of the shaft during loading cases to help increase the life of the shaft.

### 2.2.2 Drive design

The purpose of the drive mechanics is to transfer the torque provided by the electric drive motors into linear motion to move the tool head. Since CNC machines require linear movement in multiple axes, multiple screw systems are most often used to accomplish this goal. These systems offer a simple and compact means of transmitting power and motion with excellent reliability. For these machines, the screws are turned by motors, generating linear motion and thrust in the nut. There are two main types of screws, power screws and ball screws, both can be operated in this way. However, the differences arise in the efficiency with which this motion is transmitted, the friction loss, the allowable rotational speed, and the required linear speeds. [4]

#### 2.2.2.1 There are two types

1. Power screw

**Figure 2-5 power screw**

2. Ball screw

CNC machines currently on the market use both power screws and ball screws. Most of the lower end machines use power screws such for cost savings and design simplicity. However, as speeds increase and higher reliability requirements are desired, ball screws become more common so we will use it in our project, Shown Figure 2-6.

Figure 2-6 Ball screw

### 2.2.3 Frame

A variety of materials have been used in the building of CNC machines. In comparing the materials there are five selection factors that need to be reviewed. CNC frame materials need to have some strength in order to support the weight of the gantry and the cutting head as well as withstand forces resulting from the engraving process. Stiffness is also required to prevent any deflections due to both static forces and dynamic forces resulting from the acceleration of the tool head. [4]

Weight is also important because the mass of the frame contributes to both the static and acceleration forces. The best frame material would accomplish all three and offer excellent machinability and be available at a low cost.

Comparing metals is not easy as strength and modulus of elasticity, but it have a great weight and are more difficult to machine. It's interesting to note that both steel and aluminum have similar stiffness to weight properties, while the aluminum has a significant advantage in strength to weight. But in this project we adopted to use steel to the frame of the machine for its presence in abundance in the local market, and the lack of a large difference by weight compared to aluminum.

## 2.3 Electrical system

Provides the electrical system of the machine in terms of control work and the flow of energy to the devices used, and here we use the CNC program to control the motion of servo motor, and control the protection system and all of valve and drilling motor, and the communication system

### 2.3.1 Communication

In order for the CNC to process any design implanted into it, the machine must have a connection system between itself and the software being used by the computer.

Many connections used today are very common to people from using cable linking to add pictures to their computer hard drive. We will discuss the three major types of communication systems between computers and other hardware including:

- **USB Ports.**
- **Serial Ports.**
- **Parallel ports.**

#### 2.3.1.1 USB port

The USB ports, or universal serial bus ports, are most likely the simplest and one of the most widely available connection systems between computers and devices. The cable connector between the device and the computer uses either an "A" connector seen in Figure which travels upstream to the computer or a "B" connector seen in Figure which travels downstream to the device. [4]

**A connector**

**B connector**

**Figure 2-7 USB connectors**

The computer will act as the host once the connection is made. The computer will then use enumeration to provide an address to the device depending upon what other types of USB connections are attached at the same time. The device will respond to the host and describe what kind of data transfer it wants to perform. There are three types of data transfers: interrupt, bulk, and isochronous. Interrupt transfer is for devices that will provide very little information. Bulk transfers will send information in very large packets that must be confirmed as correct by the device. Isochronous transfers will send information in a streaming pattern to prevent error connections.

2.3.1.2 Serial Ports

The serial port was the most widely used connection system until the use of USB connectors and parallel ports were integrated into most computers. Although not as widely used, serial ports are still used by some devices and most computers still allow for the connection of about two serial ports at a time. It is given the name serial because of its ability to serialize or take a byte of data and transmit the bits one at a time over just one wire. It can use either parity or start/stop bits to communicate with the device when the incoming byte is completed. Serial ports are considered bi-directional communication systems because they use one pin on the device for incoming information from the computer and a different pin for outgoing information from the device to be handled simultaneously which is called full-duplex communication. There are two major types of serial port connections:


9pin connection 25pin connection

Figure 2-8 Serial port

Each pin of the 9-pin connector device provides a specific task while the 25-pin connector does all the same tasks, but many of the pins are not used. [4]

2.3.1.3 Parallel ports

Parallel ports are the most common way of connecting bulk transfer devices to a computer although they are slowly being replaced by USB ports. Unlike the serial port, the parallel port is able to send a byte of information at one time which allows the standard parallel port to send 50 to 100 kilobytes of data per second. The most common use for parallel ports is for printing purposes. [4]

Figure 2-9 Parallel port

The use of the port is dependent of the type of servo motor type.

#### 2.3.2 **Drive system**

##### 2.3.2.1 Introduction to servo motor

Is an automatic device that uses error sensing feedback to correct the performance of a mechanism, the term correctly applies only to systems where the feedback or error correction signals help control mechanical position or other parameters.

The purpose of a servomechanism is to provide one or more of the following objectives:

- Accurate control of motion without the need for human attendants (automatic control)
- Maintenance of accuracy with mechanical load variations, changes in the environment, power supply fluctuations, and aging and deterioration of components (regulation and self-calibration)
- Control of a high-power load from a low-power command signal (power amplification)
- Control of an output from a remotely located input, without the use of mechanical linkages remote control, shaft repeater.

##### 2.3.2.2 Servo motor

A Servo Motor is a motor which is part of a servomechanism. It is typically paired with some type of encoder to provide positioning and speed feedback and also defined as an automatic device that uses an error-correction routine to correct its motion. The term servo can be applied to systems other than a Servo Motor; systems that use a feedback mechanism such as an encoder or other feedback device to control the motion parameters. Typically when the term servo is used it applies to a 'Servo Motor' but is also used as a general control term, meaning that a feedback loop is used to position an item shown Figure 2-10. [1]

Figure 2-10 Servo motor connections

#### 2.3.2.3 Construction

A servo motor is typically part of a feedback loop containing electronic, mechanical, and electrical components.

The servo loop is a means of controlling the motion of an object via the motor. A requirement of many such systems is fast response. To reduce acceleration robbing inertial, the iron core is removed from the rotor leaving only a shaft mounted aluminum cup to rotate. Figure 2.12 the iron core is reinserted within the cup as a static (non-rotating) component to complete the magnetic circuit. Otherwise, the construction is typical of a two phase motor. The low mass rotor can accelerate more rapidly than a squirrel cage rotor.

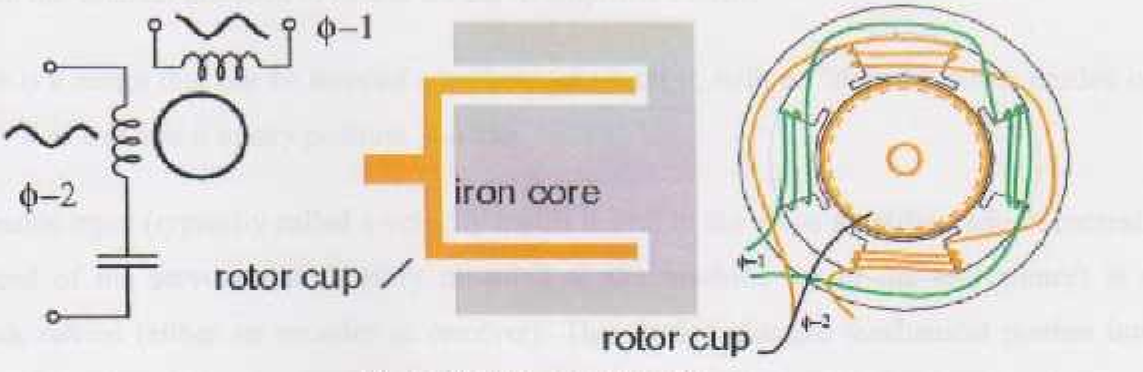


Figure 2-11 Servo construction

2.3.2.4 Mechanism

Servo motor mechanism is not complex. The servo motor has control circuits and a potentiometer that is connected to the output shaft. The shaft, links to a potentiometer and control circuits that are located inside the servo. The potentiometer, coupled with signals from the control circuits, control the angle of the shaft – anywhere from 0 to 180 degrees, sometimes further. The potentiometer allows the control circuitry to monitor the current angle of the servo motor. If the shaft is at the correct angle, the servo motor idles until next positioning signal is received. The servo motor will rotate the correct direction until the angle is correct. [1]

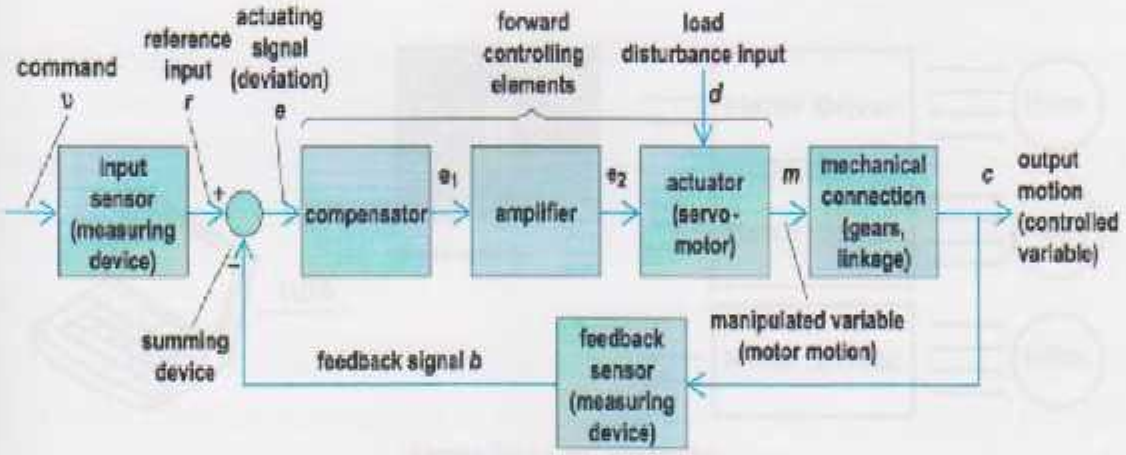



Figure 2-12 Servo mechanism

In a servo system the encoder gives the motors position to the servo amplifier and it compares this with the desired position to get the error. The amplifier then sends current to the servo motor to make the motor move into the proper position, reducing the error. The servo's resolution is based on the encoder attached to it, and the servo amplifier's error.

A servo is a motor that can be stopped anywhere you want it, with no "detents" either needed or present. You can turn it to any position you like.

A reference input (typically called a velocity input) is sent to the servo amplifier, which controls the speed of the servomotor. Directly mounted to the machine (or to the servomotor) is a feedback device (either an encoder or resolver). This device changes mechanical motion into electrical signals and is used as a feedback loop. This feedback loop is then sent to the error detector, which compares the actual operation with that of the reference input. If there is an error, that error is fed directly to the amplifier, which makes the necessary corrections.

### 2.3.3 Controller

To control orders resulting from the computer, which is in the form of G code we have to use special controller, and through research on these controllers , we found that there are a large number and different types of it, we studied them and found controller named MK and after studying in depth we see that it works flexibly and easy-to-use and we expect it to be appropriate to work in the machine.[8]

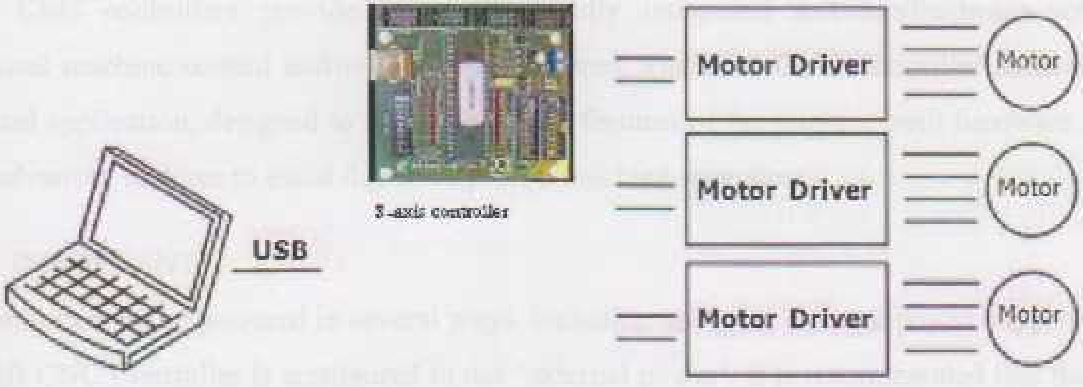



Figure 2-13 CNC controller

The series of USB CNC motion controllers link between a personal computer and motor drivers supporting step/dir control. They are compatible with most drivers. The controllers use the USB port, available on all modern computers and laptops. They can serve as direct replacement or upgrade for many parallel port break-out boards. There are currently three models available.

The Mk1 controller is for up to 4 axes. The Mk2 controller, using up to 9 axes, and the Mk2/4 controller supporting up to 4 axes. The Mk2/4 controller is essentially a 4 axis version of the Mk2 controller, supporting the same high pulse rate and advanced software functions. It also provides DB25 and built-in screw terminal connections.

Installation of Planet CNC USB Controller requires an USB equipped PC or laptop along with motor drivers appropriate to the motors in use. The USB CNC controller is compatible with the vast majority of motor drivers that use step/direction signals.

Optional support hardware can be employed to customize installation to suit user requirement. Use of a screw terminal adapter makes connection to the type of drive in the image much easier.

For maximum flexibility in controller layout, a ribbon cable and plug kit is available. This aids the construction of longer cables and ensures plug-in connections correspond to the USB CNC Controller pin outs.

Planet CNC controllers provide a complete, fully integrated software/hardware solution. Additional machine control software is NOT required. The USB CNC Controller software is a dedicated application, designed to fully exploit the features of the purpose-built hardware. It has many advanced features to assist day-to-day CNC machine operation.

- IMPORTANT:

The controller can be powered in several ways, including use of an external power supply. When the USB CNC Controller is configured to use 'external power', it is recommended that the USB port is NOT connected if no external power supply is present. [8]

When external power supply is used:

- Mk1 - 4 axis controller hardware requires 5V DC supply.
- Mk2 - 9 axis controller hardware requires 7 - 12V DC supply (9V recommended)
- Mk2/4 - 4 axis controller hardware requires 7 - 12V DC supply (9V recommended).
    - Power supply should be at least 200mA.
    - For 3 axis controller we can use MK1up to 4 axis motor

#### 2.3.3.1 Mk1 - 4 axes CNC USB controller description

**Figure 2-14 MK1 controller**

✓ Features:

- ❖ 25 kHz maximum step frequency.
- ❖ 3 digital outputs (flood, mist, spindle).
- ❖ 12 us minimum pulse width.
- ❖ Manual jog input keys for all axes.
- ❖ limit keys for all axes.
- ❖ Control external devices.

2.3.3.2 Mk1 Motor connector

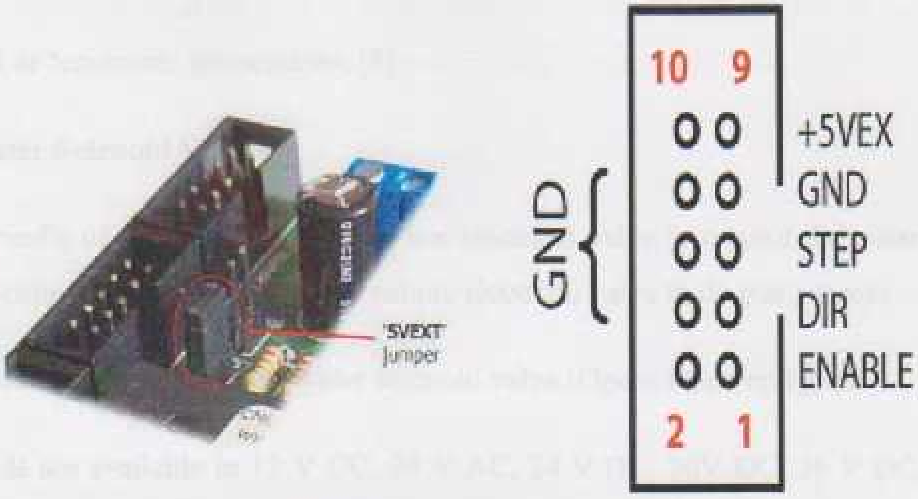



**Figure 2-15 MK1 motor connector**

Each connector controls one motor driver.

Pins 2, 4, 6, 7, 8 and 10 provide the 'Ground' or common side of connections.

**+5VEX:** Motor drivers can be powered from the USB controller. The '5VEXT' jumper, highlighted above, must be closed to enable this feature.

**STEP:** Provides a STEP signal of minimum 12 us pulse width to the motor driver.

**DIR:** Provides DIR or DIRECTION signal to the motor driver.

**ENABLE:** Provides ENABLE signal to the motor driver. The STOP pins on the 'Connector' connector must be connected to OUT 3 pins on the 'Connector' connector to use this feature.

The signal from 'Connector' connector OUT 3 is usually sent to a relay, to allow switching of an external device. If 'Connector' connector STOPS pins are in circuit with the signal from OUT 3, the ENABLE signal on the Motor connector is also controlled by OUT 3 switching. This can provide a useful safety feature if an

E-Stop switch is included in the circuit.

Operation of the E-Stop breaks all connections. Devices controlled by OUT 3 and the ENABLE signal to motor drivers would stop simultaneously on operation of the E-Stop.

**GND:** Ground or 'common' connections. [8]

### 2.3.4 Water Solenoid Valves

To cool the spindle of the drilling motor we use electrical valve to control the water flow from the tank to machine .and here we need any simple electrical valve to do this process.

The valve needed is normally closed water solenoid valve (Opens when energized).

Water solenoids are available in 12 V DC, 24 V AC, 24 V DC, 30V DC, 36 V DC, 48 V DC, 110 V AC, 230 V AC (50/60 Hz) as standard option.

Here we choose a simple 220 volt AC shown below to not use converter or special electrical source.

**Figure 2-16 Electrical water valves**

### 2.3.5 Engraving motor (drilling motor)

The engraving motor or "spindle motor" is the large motor on the top of the carriage assembly. The engraving motor drives the engraving spindle during the engraving process.

The (AC) induction motor is one of the most rugged and most widely used machines in industry. So we use it in the engraving process because of its existence in the market and cheapest Comparison with the universal drilling motor.

#### 2.3.5.1 Induction motor

The induction motor induces magnetism that is leveraged to output rotary motion. The stationary outer stator is connected to an external electrical power source; this is fed to the rotor's poles in a rotating progression that causes revolutions of the magnetic field within the motor. Conducting bars in the rotor interact with the stator's magnetic fields; current is induced in those bars, which in turn generate magnetic fields that are attracted to those of the stator. As the rotor's induced current and magnetism causes it to follow the field generated by the stator, rotary motion is output. [9]

The stator is made up of several thin laminations of aluminum or cast iron. They are punched and clamped together to form a hollow cylinder (stator core) with slots as shown in figure 1. Coils of insulated wires are inserted into these slots. Each grouping of coils, together with the core it surrounds, forms an electromagnet (a pair of poles) on the application of AC supply.

The number of poles of an AC induction motor depends on the internal connection of the stator windings. The stator windings are connected directly to the power source. Internally they are connected in such away, that on applying AC supply, a rotating

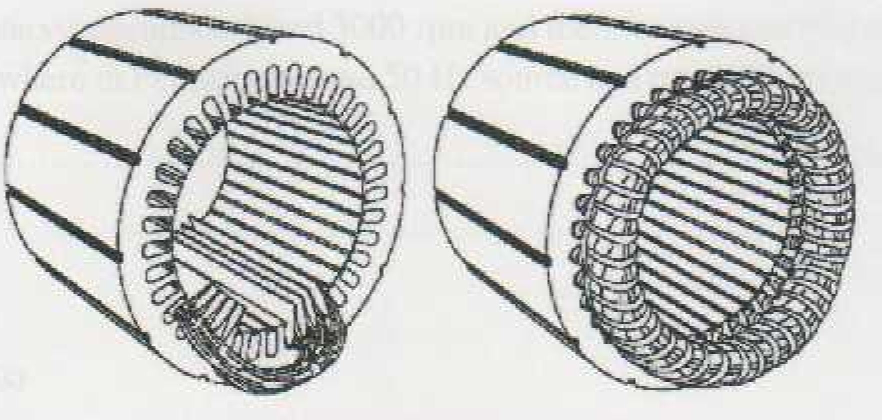


Figure 2-17 Induction motor pole connection

#### 2.3.5.2 Parameters of the motor used in the project

Through the following table 2.1 we know that the speed required for the engraving on the stone or marble should not exceed 3000 rpm.

Table 2-1 Speed motor for deferent material [12]

| Material | 3000 RPM | 6000 RPM | 7500 RPM | |
|---|---|---|---|---|
| Aluminum/Aluminum Alloys | 15-25 | 30-50 | 37.5-62.5 | Feed rates (IPM) |
| Steel, Low Carbon | 13 | 26 | 32.5 | |
| Steel, Medium Carbon | 13 | 26 | 32.5 | |
| Steel, Hardened | 10 | 20 | 25 | |
| Stainless Steel, Hard | 13 | 26 | 32.5 | |
| Titanium, Soft | 13 | 26 | 32.5 | |
| Titanium, Hard | 10 | 20 | 25 | |
| Glass & Stone (with diamond engraving tool - use coolant with spindle rotating or non-rotating) | 17 | Not Recommended | | |
| IPM: Inches per minute. RPM: Spindle Speed | | | | |

We will select the synchronous speed 3000 rpm and therefore we can find a number of poles motor, where in Palestine we use 50 Hz source and return to the equation 2.1:

$n = 120 f / p$ ........................................................................................ (2.1)[3]

$n = 3000$ rpm

$F = 50$ Hz

$P = 120 \times 50 / 3000$

Then we need motor has 2 poles.

# CHAPTER THREE

# SOFTWARE

**3.1 Introduction**

**3.2 Mastercam**

**3.3 Fundamental of G code**

**3.4 Practically work on mastercam**

## 3.1 Introduction

The abbreviation **CNC** stands for **computer numerical control**, and refers specifically to a computer "controller" that reads G-code instructions and drives a machine tool, a powered mechanical device typically used to fabricate components by the selective removal of material. CNC does numerically directed interpolation of a drilling tool in the work envelope of a machine. The operating parameters of the CNC can be altered via **software** load program.[13]

Software stationed here in the program used in inter image to be converted into orders for controller of the machine, a program is mastercam.

## 3.2 Mastercam

The latest release for the Mastercam CNC machine tool programs can bring huge benefits to operatives and give them greater control over the machining process, according to developer CNC Software.

Mastercam introduces a unified interface and streamlined workflow for generating multiaxis tool paths in used CNC machine tools, giving manufacturers the ability to fully utilize the full capabilities of their machines.

It gives programmers complete control over three crucial elements of multiaxis machining drill pattern, tool axis control and collision control.

CNC machines use a special programming language called GN-code (technical name: RS274). MasterCAM is software that allows users to create GN-code programs that can be used to drill different geometric shapes and hole on CNC machines. Here we study MasterCAM for CNC engraving machines.

Practically Machine work begins through this program, where we are introducing the image to be drilled on the stone and then analyzed by the program and converted to G code and then this code will be sent to the controller of the machine to control the servo motor, Thus moving three engines depending on the nature of order presented.

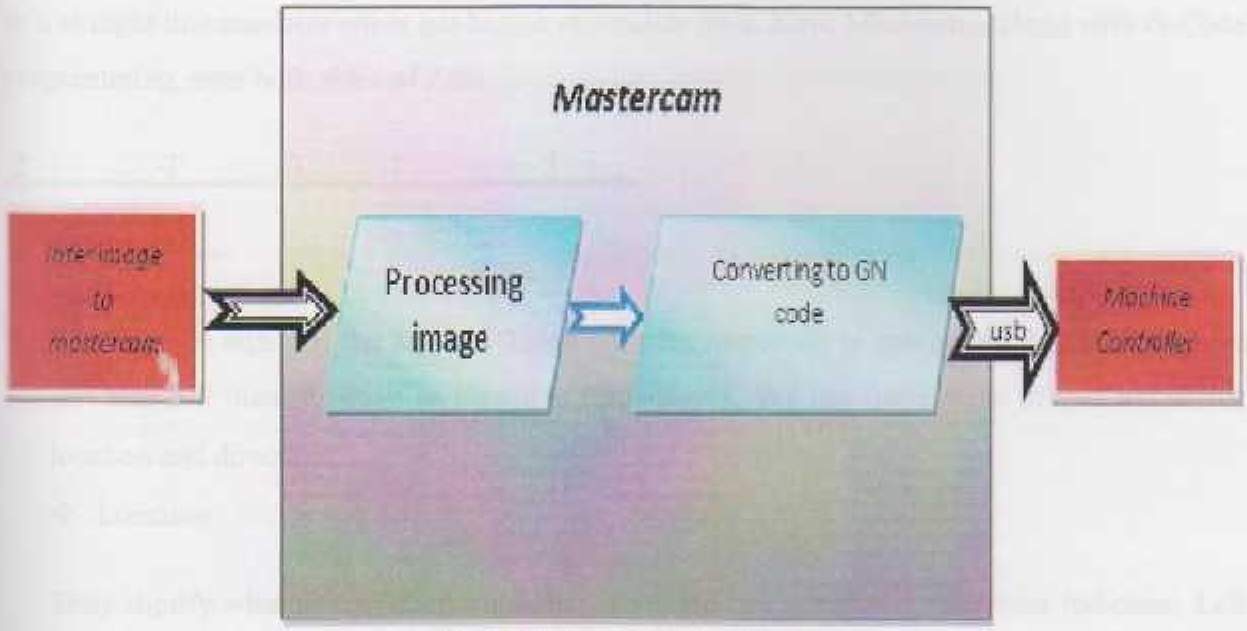



**Figure 3-1 Mastercam work level**

➢ **The main functions are**

- ❖ Describe the geometry of the part to be machined.
- ❖ Create a tool database – this DB carries information about the available drilling tools.
- ❖ Create the GN-code program to cut the part.
- ❖ Upload the program to the CNC machine controller.

## 3.3 Fundamentals of G-Code

G-Code programming is a very simple programming language. When we were kids, we used to and may still do connect the dot puzzle games. G-code works ***exactly*** on the same principle. It takes two simple concepts to understand G-code programming, ***connect-the-dots*** and the ***number line***.

❖ The Number Line

The number line is simply the measurement of units.

In a straight line numbers either get bigger or smaller from Zero. Machining, along with G-Code programming, uses both sides of Zero.

-2 -1 0 1 2

- Signs +/ -

The Plus (+) sign and the Minus (-) sign are very important in machining. In machining we can also call them Positive or Negative respectively. We use these signs in two situations; location and direction.

- Location

They signify what side of Zero a number is on, we can say this is a location indicator; Left for Minus and Right for Positive respectively from Zero.

- Direction

These signs also are used as a tool to tell us which direction to move; Left for minus and Right for Positive.

## Some standard G- code –drill[13]

The G-Codes are what tell the machine to do with positional reference. This is just a simple reference to what standard G-Codes do.

**G0 or G00** – Rapid Movement

The fastest the Machine can go to the next defined position. If moving in multiple axes, each axis will move as fast as they can independently of one another until it reaches its defined end points.

**G1 or G01** – Linear Movement

A straight line move with a speed defined by an F. If moving in multiple axes, the machine will move proportionally in each axis until it reaches its defined end position.

**G2 or G02** – Interpolation Clockwise

A circular movement in 2 axes. Will create an arc to a specified radius defined by R.

**G3 or G03** - Interpolation Counter Clockwise

A circular movement in 2 axes. Will create an arc to a specified radius defined by R.

G4 or G04 – Dwell

Machine will dwell once reached position to a user defined time.

G9 or G09 – Exact Stop/ Exact Position

Machine will not traverse to next line of code until it positions exactly to position.

**G10** - Data Setting

G17 - XY plane selection

G18 - ZX plane selection

G19 - YZ plane selection

G20 - Machine in inch

G21 - Machine in MM

G28 - Return to Reference Position, Normally machine home.

## 3.4 Practically work on Mastercam

- The main functions are

1. Describe the geometry of the part to be machined.
2. Create a tool database – this DB carries information about the available drilling tools.
3. Create the GN-code program to cut the part.
4. Simulate the machining of the part.
5. Upload the program to CNC machine controller.

### 3.4.1 Describe the geometry of the part to be machined

You can create the geometry in one of two ways:

A. By using the graphical design interface provided by Master CAM.

**B.** By making the design in CAD software, e.g. CATIA, Solid Works, and saving it in a format that Master CAM can import (safest format to use).

Method (A): is useful if you want to cut a simple shape; although Master CAM provides some functions to generate 3D curved surfaces, defining the geometry in this environment is not convenient.

Method (B): Here, we have to design the part using a CAD system, and saved it in a form that Master cam can import.

One of the forms that Master cam can import is image that we want to engrave. Here the procedure that we follow shown in Figures in chapter six.

# CHAPTER FOUR

# DESIGN & CALCULATION

**4.1 General block diagram**

**4.2 Flow chart**

**4.3 Mathematical calculations of the motors**

**4.4 Wiring and protection system**

## 4.1 General block diagram

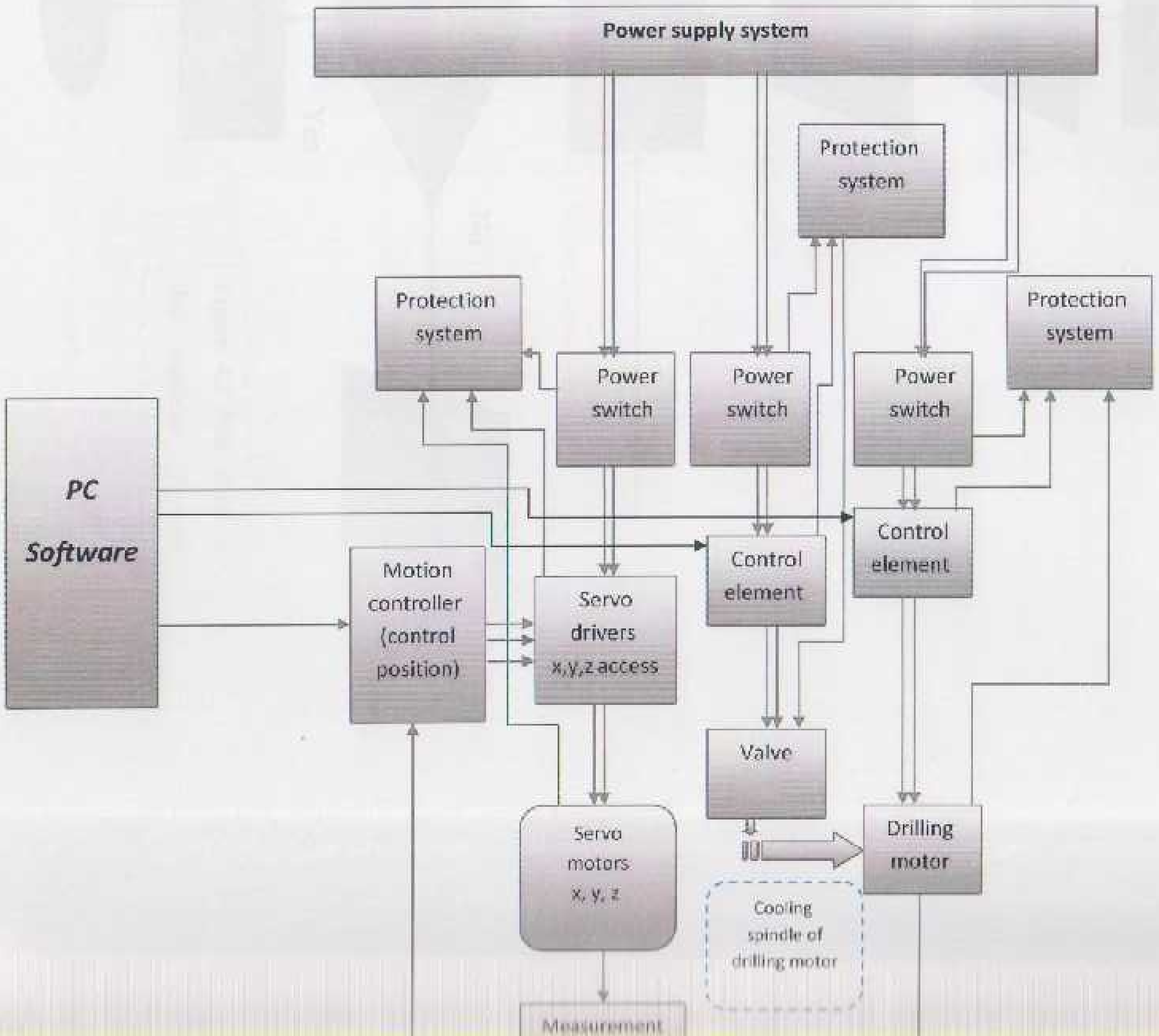
The full system components are shown in Figure 4.1 which was presented in previous chapters. A Technological and modern plants uses software as designing tools, driving block to control the motion of the system and making its operation feasible. Protection elements is not only in the electronic boards, it will be also in the power circuit such as fuses, overloads before the motors, and emergency buttons that could be connected to the controller as it is within its features.

## 4.2 Flow chart

This is an overall flowchart for the working process starting from using the PC to design the graph until working of machine to engrave on stone, following steps illustrated in Figure 4-2 and there will be an extending to the engraving box process according to the desired carving figure.

As what occurred in the practical application of the motor and depending on the Common types of moving machines, the machine is classified to have a moving table and a fixed z-axis mounted on the body of the machine. The following part is considering calculations to determine the load of each axis here.

General block diagram



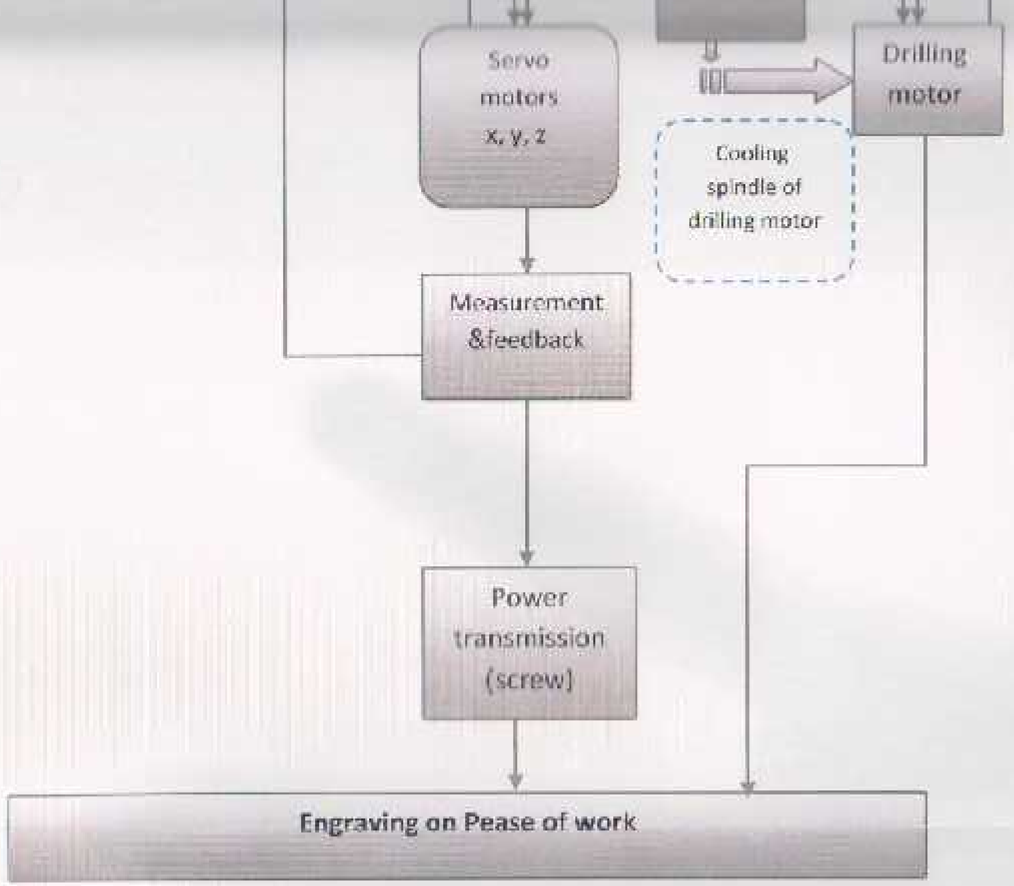



Figure A.( Block diagram)

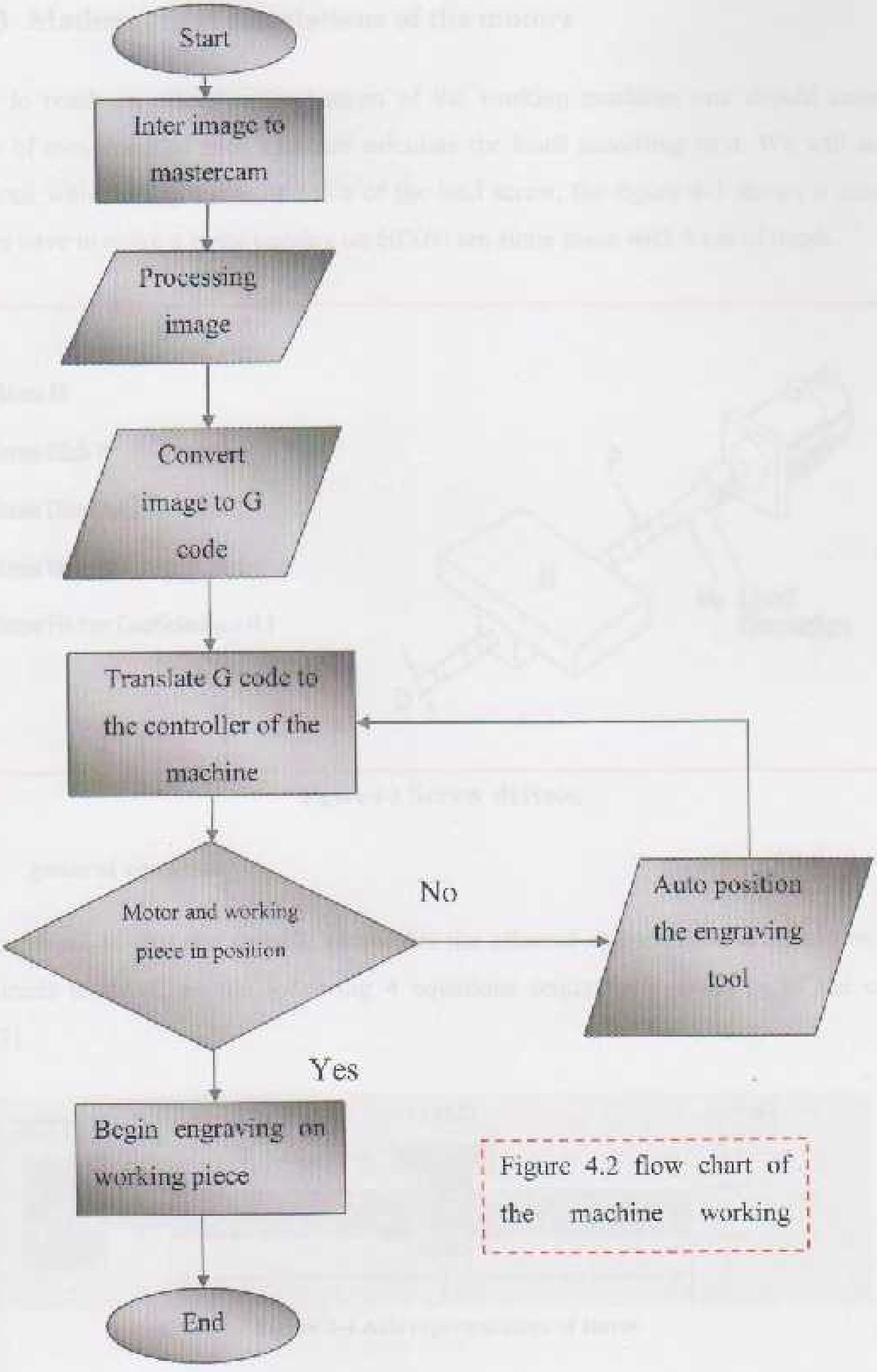



Figure 4.2 flow chart of the machine working

## 4.3 Mathematical calculations of the motors

In order to reach an effective mechanism of the working machine, one should consider the formulas of movement of each axis and calculate the loads according to it. We will start these calculations with finding the axial force of the lead screw, the figure 4-3 shows a sample of it where we have to make a stone carving on 60X60 cm stone piece with 3 cm of depth.

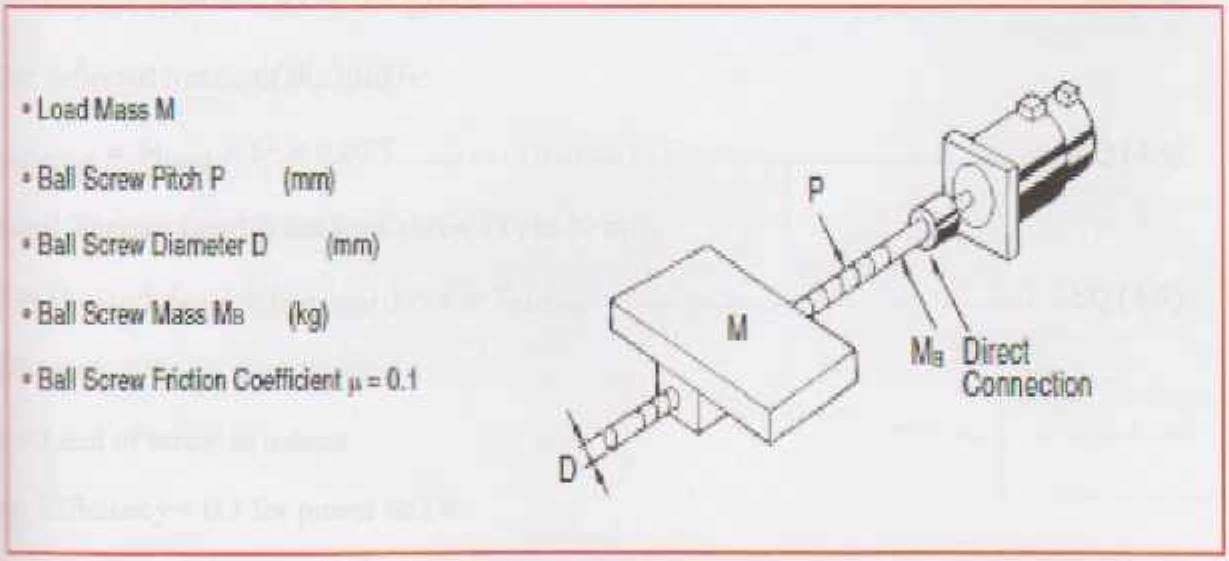



Figure 4-3 **Screw drive**[6]

### 4.3.1 general equation

The calculations to find the suitable torque for the selected motor depends mainly on the load that it needs to drive, so the following 4 equations sequentially leads us to the calculated torque.[7]

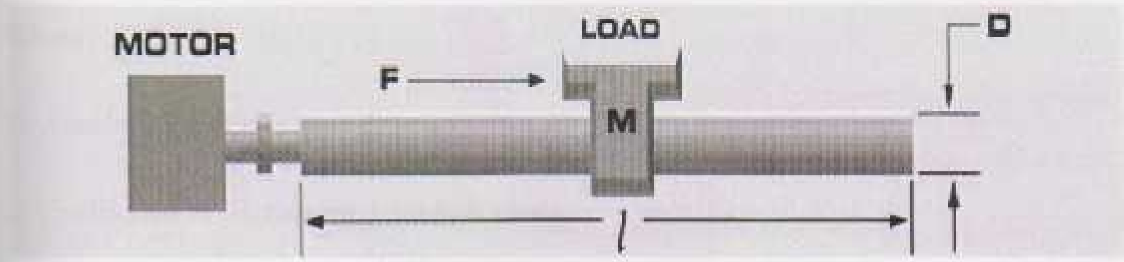



**Figure 4-4 Axis representation of forces**

- Inertia of lead screw load

$$J_{total} = J_{rotor} + J_{steel} + J_{reflected} \text{ .......... EQ (4.1)}$$

$$J_{steel} = D^{-4} \times L \times \frac{\pi}{32} \times \text{Density} \text{ .......... EQ(4.2)}$$

$$\text{Density for steel} = 7.83 \times 10^{6}\ g/m^{3} \text{ .......... EQ(4.3)}$$

The reflected inertia of the load is:

$$J_{reflected} = M_{load} \times L^{2} \times 0.025 \text{ .......... EQ (4.4)}$$

**Total Torque Load from lead screw (T) in N·m:**

$$T = (J_{rotor} + J_{steel} + J_{reflected}) \times a + T_{friction} \text{ .......... EQ (4.5)}$$

Where:

L = Lead of screw in meters

A= Efficiency = 0.3 for power screw.

D: diameter of the power screw.

M: load weight in Kg

a: motor speed in RPM

T: torque in NM

$$T_{friction} = \frac{M \times g \times L \times \mu}{2 \times \pi \times a} \text{ .......... EQ (4.6)[11]}$$

Where:

G: Acceleration due to gravity.

μ: Coefficient of friction =0.1 for ball screw.

We have to calculate the inertia for each axes related to Figure 4-3.

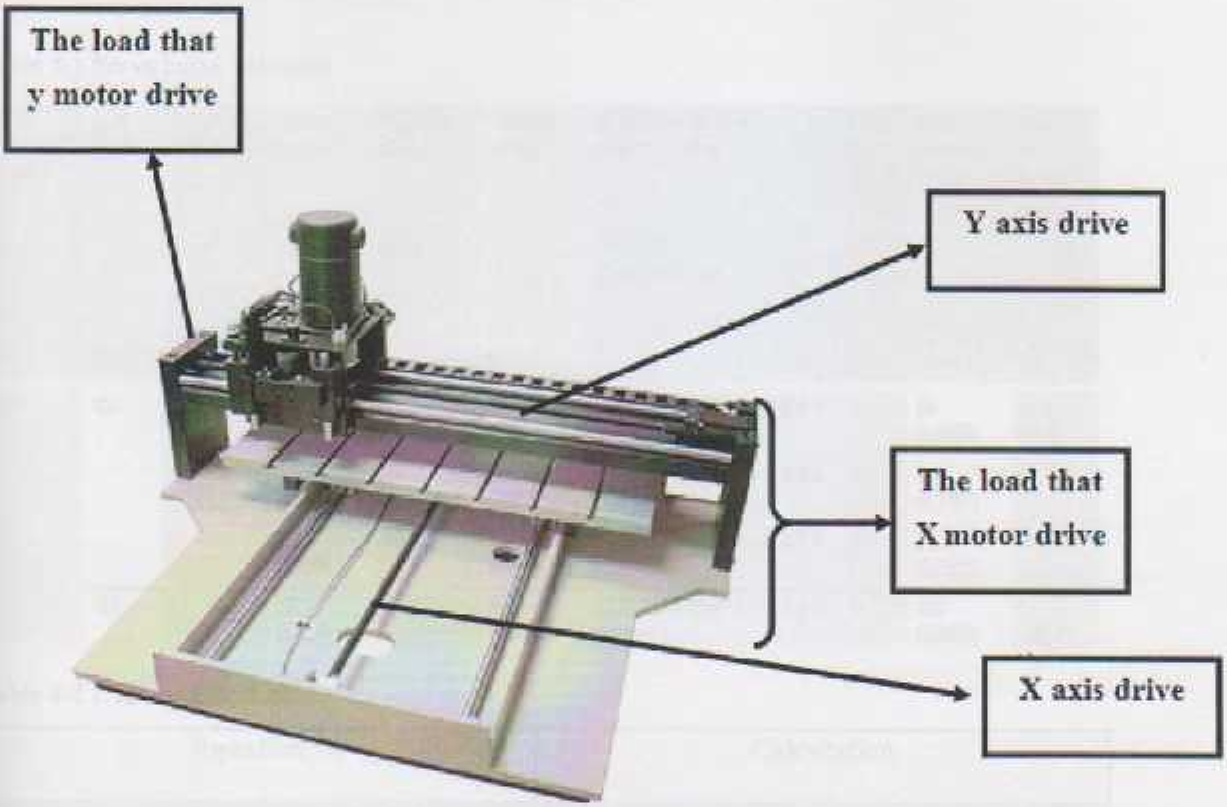



Figure 4-5 machine configuration

### 4.3.2 Motor selection

✓ **Z axis motor selection:**

Each axis has total inertia as we see in previous section which consist of rotor, steel screw, and reflected inertia.

Rotor inertia is from the motor characteristic as shown in the table below. From the following table we have approximately $99 \times 10^{-4}$ kg/$cm^2$ rotor inertia for about 1500 rpm servo motor, we assume 1500 rpm because we don't care about speed as care of position in the machine.

We start from the Z motor (From smallest to the largest motor), because Z motor is a part of X and Y load.

Z motor drive the engraving motor only, which is about 6.1 Kg, and lead screw length of about 40 cm.

Table 4-1 Servo rated value[10]

| Rated Rotational Speed | Shaft Height | Rated Output | Rated Torque 1) | Rated Current | Standstill Torque | 1FT6 Servo Motors Natural cooling | Pole Pair Number | Rotor Moment of Inertia (w/o Brake) | Weight (w/o Brake) |
|---|---|---|---|---|---|---|---|---|---|
| $n_{rated}$ | | $P_{rated}$ at $\Delta T$=100 K | $M_{rated}$ at $\Delta T$=100 K | $I_{rated}$ at $\Delta T$=100 K | $M_0$ at $\Delta T$=100 K | Order No. **Standard Model** | | $J$ | |
| rpm | SH | kW (HP) | Nm ($lb_f$-in) | A | Nm ($lb_f$-in) | | | $10^{-4}$ kgm² ($lb_f$-in-s²) | kg (lb) |
| 1500 | 100 | 3.8 (5.09) | 24.5 (216.8) | 8.4 | 27 (239) | 1FT6 102 – 8AB7■ – ■■■■ | 4 | 99 (0.0876) | 27.5 (60.6) |
| | | 6.4 (8.59) | 41 (362.9) | 14.5 | 50 (442.6) | 1FT6 105 – 8AB7■ – ■■■■ | 4 | 168 (0.1487) | 39.5 (87.1) |
| | | 9.6 (12.87) | 61 (539.9) | 20.5 | 70 (619.6) | 1FT6 108 – 8AB7■ – ■■■■ | 4 | 260 (0.2301) | 55.5 (122.4) |
| | 132 | 9.7 (13) | 62 (548.8) | 19 | 75 (663.8) | 1FT6 132 – 6AB71 – ■■■■ | 3 | 430 (0.3806) | 85 (187.4) |

Table 4-2 Z motor calculation

| Equation | Calculation |
|---|---|
| J reflected=$0.025 \times M \times L^2$ | =0.025*6.1*0.5^2=0.038Kg/$cm^2$ |
| J steel screw= $d^{-4} \times l \times \frac{\pi}{32}$*Dens | $= 0.032^{-4} \times 0.5 \times (1500 \div 32) \times 7.83 \times 10^6$kg/$cm^2$ |
| J total= J rotor +J steels crew +J reflected | = 0.0099+0.038+0.587=0.635 kg/$cm^2$ |
| $T_{friction} = \frac{M \times g \times L \times \mu}{2 \times \pi \times a}$ | $T_{friction} = \frac{6.1 \times 9.88 \times 0.5 \times 0.1}{2 \times \pi \times 0.3} = 0.47$ |
| T total=J total *a + Tf | 0.635*0.3+0.47=0.66 NM |

- ✓ **Y axis motor calculation**

As we see in the figure 4.5, y motor drive the following load:

- Head that installs Z motor (5 kg). -
- Z motor (1.78kg)
- Engraving motor = 6.1Kg. -
- Power screw of 1 meter.

**Table 4-3 Y motor calculation**

| Equation | Calculation |
|---|---|
| J reflected=$0.025 \times M \times L^2$ | =0.025*12.88*1^2=0.322Kg/$cm^2$ |
| ×den J steel screw= $d^{-4} \times l \times \frac{\pi}{32}$ | $= 0.032^{-4} \times 1 \times (1500 \div 32) \times 7.83 \times 10^6$=1.17kg/$cm^2$ |
| J total= J rotor +J steels crew +J reflected | = 0.0099+0.322+1.17=1.5 kg/$cm^2$ |
| $T_{friction} = \frac{M \times g \times L \times \mu}{2 \times \pi \times a}$ | $T_{friction} = \frac{12.88 \times 9.88 \times 1 \times 0.1}{2 \times \pi \times 0.3} = 0.67$ |
| T total=J total *a + Td | 1.5*0.3+0.67=1.12 NM |

- ✓ **X axis motor calculation**

As we see in the figure 4.5, X motor drive Iron Bridge, which carries X and Y motors and have:

Table 4-4 X load component

| Component | Weight in Kg | Length in m |
|---|---|---|
| 2 legs stand in the machine body | 13 | 0.3 for each |
| Bridge deck (stand on the legs) | 21.16 | 1 |
| Y motor | 1.78 | — |
| Z motor | 1.78 | — |
| Engraving motor | 6.1 | |
| Part which the y,Z motor is installed | 10 (5 for each ) | — |
| Total | 46.82 | |

Table 4-5 X motor calculation

| Equation | Calculation |
|---|---|
| J reflected= $0.025 \times M \times L^2$ | =0.025*46.82*1.5^2=2.63Kg/$cm^2$ |
| ×den J steel screw= $d^{-4} \times l \times \frac{\pi}{32}$ | $= 0.032^{-4} \times 1.5 \times (1500 \div 32) \times 7.83 \times 10^6$=1.76 kg/$cm^2$ |
| J total= J rotor +J steels crew +J reflected | =0.0099+2.63+1.76=4.4 kg/$cm^2$ |
| $T_{friction} = \frac{M \times g \times L \times \mu}{2 \times \pi \times a}$ | $T_{friction} = \frac{46.82 \times 9.88 \times 1.5 \times 0.1}{2 \times \pi \times 0.3} = 3.6$ |
| T total=J total *a + Td | 4.4*0.3+3.6=3.8NM |

Physically, power is defined as the rate of doing work. For linear motion, power is the product of force multiplied by the distance per unit time. In the case of rotational motion, the analogous calculation for power is the product of torque multiplied by the rotational distance per unit time.

$P = T \times \omega$ ............................................................................................EQ (4.7) [3]

Where:

P: Mechanical power.

ω: Angular velocity.

The most commonly used unit for angular velocity is rev/min (RPM). In calculating rotational power, it is necessary to convert the velocity to units of rad/sec. This is accomplished by simply multiplying the velocity in RPM by the constant (2 x π) /60:

$\omega_{rad} = \omega_{rpm} \times \frac{2\pi}{60}$ ............................................................................................EQ (4.8)

$$\omega_{rad} = 1500_{rpm} \times \frac{2\pi}{60} = 157\frac{rad}{sec}$$

**Now for each axis we have:**

$P_x = T_x \times \omega = 3.8 \times 157 = 596.6\,watt$

$P_Y = T_y \times \omega = 1.12 \times 157 = 175.8\,watt$

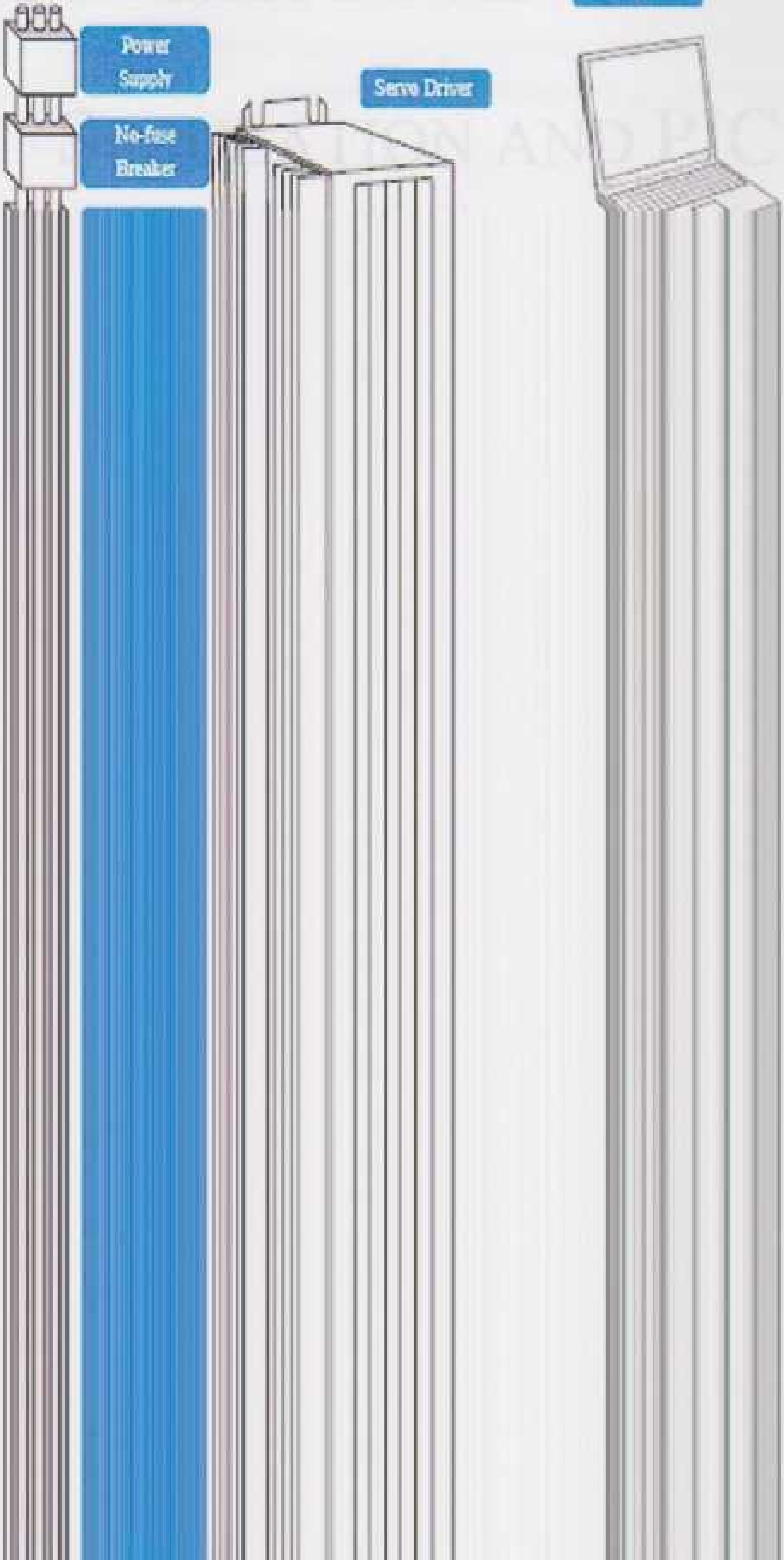
$P_z = T_Z \times \omega = 0.66 \times 157 = 103.6\,watt$

## 4.4 Wiring and protection system

For the motor we have (x, y, z servo and engraving motor) we must protect them from over load and heating. So we must connect a circuit breaker and fuses in the power connection for each

## Wiring

Please refer to this wiring picture:



# CHAPTER FIVE

# SIMULATION AND PIC

**5.1 Introduction**

**5.2 Mastercam**

**5.3 G code conclusion**

**5.4 PIC Microcontroller**

**5.5 PIC Simulation.**

**5.6 proteus application**

**5.7 Mechanical simulation CATIA**

## 5.1 Introduction

In this chapter we manly looking to design full simulation of the machine starting from the production of the G code from the painting using Mastercam program, thin its analysis to get programmable functions can be implement in the microcontrollers as a controller use to drive the 3 axis motors to engrave the painting.

But we can't programming the G code using microcontrollers because it contains a lot of information that need to be programmed and also needs 12 bytes to implement any order of commands.

So we can represent only one case, which means that we can draw any paintings and control it by its own program, thus, we started working on the G code and analyzed as described in Figure 5-1.

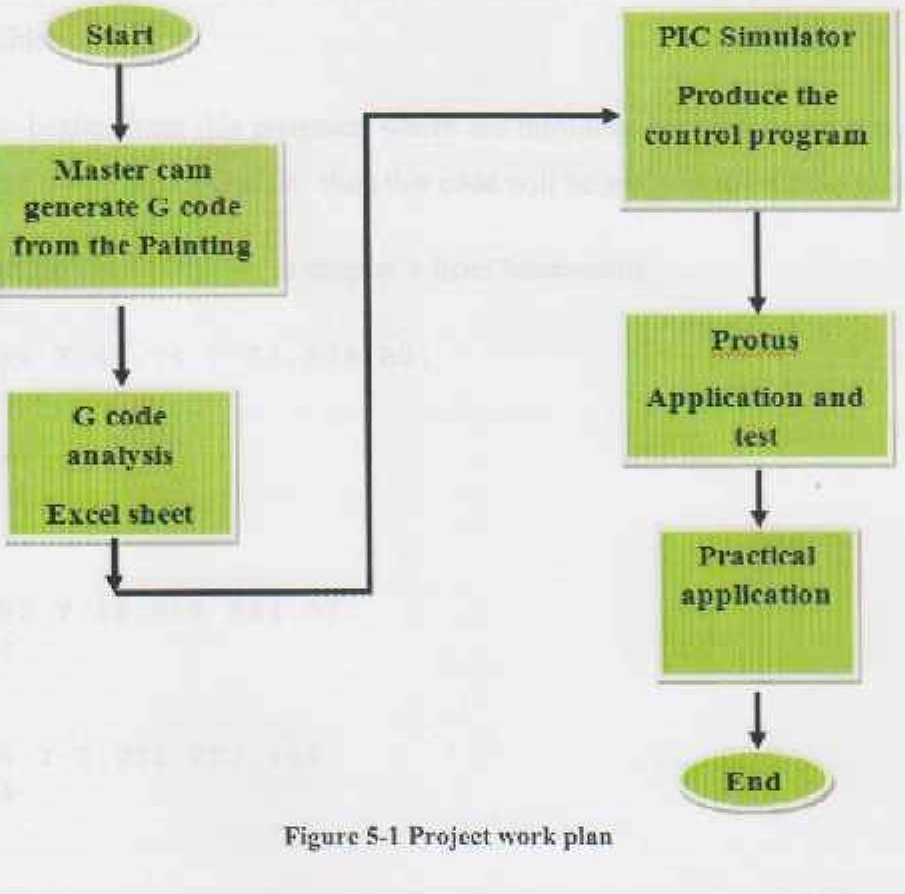



**Figure 5-1 Project work plan**

## 5.2 Mastercam

The latest release for the Mastercam CNC machine tool programs can bring huge benefits to operatives and give them greater control over the machining process, according to developer CNC Software.

Mastercam introduces a unified interface and streamlined workflow for generating multiaxis tool paths in used CNC machine tools, giving manufacturers the ability to fully utilize the full capabilities of their machines.

It gives programmers complete control over three crucial elements of multiaxis machining drill pattern, tool axis control and collision control.

CNC machines use a special programming language called GN-code (technical name: RS274). MasterCAM is software that allows users to create GN-code programs that can be used to drill different geometric shapes and hole on CNC machines. Here we study MasterCAM for CNC engraving machines.

Practically we  begins from this program, where we introduce the image and then analyzed by the program and converted to G code, then this code will be analysis to become as function.

Here is some of the G code we got in chapter 3 from Mastercam:

```
G0 G90 G54 X-69.74 Y-33.398 A0.
G43 Z10.
Z7.
G1 Z-1. F7.2
X69.74
Y-25.976
X32.369
G3 X46.302 Y-18.555 R84.037
G1 X69.74
Y-11.133
X53.501
G3 X56.14 Y-3.711 R22.494
G1 X69.74
Y3.711
```

```
X56.14
G3 X53.501 Y11.133 R22.493
G1 X69.74
Y18.555
X46.302
G3 X32.369 Y25.976 R84.038
G1 X69.74
Y33.398
X-69.74
Y25.976
```

## 5.3 G code conclusion

Because the G code have 12 byte information need to be controlled, which is difficult to made by microcontrollers, We aim to insert a system to control one case on the machine work we want to make this code as function we study it and found that each order of this code consists of four parts as shown in Figure 5-2.

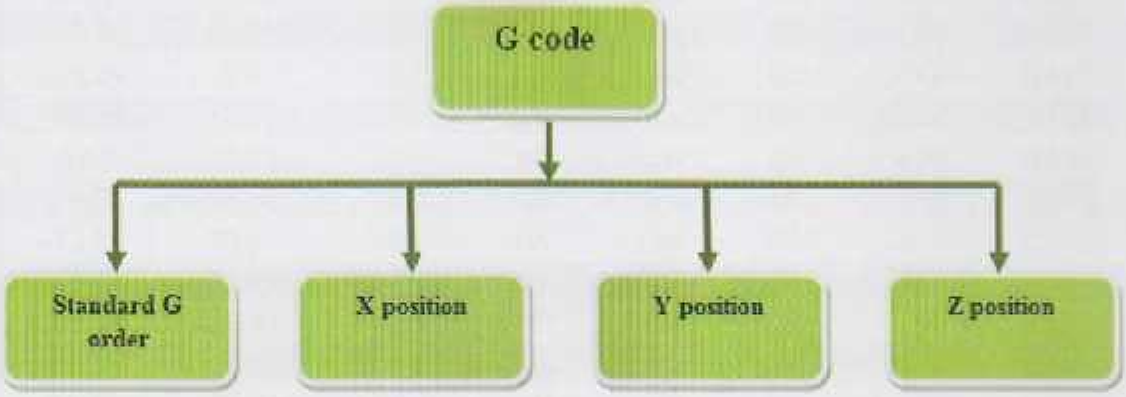



**Figure 5-2 G code contents**

As example if we take one order of the code:

```
G00 X-69.74 Y-33.398  Z10.
```

The G0 is the order of the code.

X -69.74 is the position motor x must move to .

Y -33.398 is the position motor y must move to .

Z 10 is the position motor z must move to.

That means motor x for example should move from position 0.00 to -69.74 cm in conjunction with the speed of the motors, table 5.1 show the details of all orders.

**Table 5-1G code conclusion**

| G order | X position | Y position | Z position | X dir | Y dir | Z dir | X time/s | Y time/s | Z time/s |
|---|---|---|---|---|---|---|---|---|---|
| G00 | 0 | 0 | 0 | off | 0 | Off | 0 | 0 | 0 |
| G00 | -69.74 | -33.4 | 0 | ccw | ccw | Off | 5.8 | 2.78 | 0 |
| G1 | 69.74 | -25.97 | 7 | cw | cw | Cw | 11.62 | 0.615 | 0.5835 |
| G03 | 46.3 | -18.55 | 7 | ccw | cw | Off | 1.95 | 0.615 | 0 |
| G01 | 69.74 | -11.13 | 7 | cw | cw | Off | 1.95 | 0.615 | 0 |
| G03 | 56.14 | -3.7 | 7 | ccw | cw | Off | 1.135 | 0.615 | 0 |
| G01 | 69.74 | 3.7 | 7 | cw | cw | Off | 1.135 | 0.615 | 0 |
| G03 | 53.5 | 11.13 | 7 | ccw | cw | Off | 1.35 | 0.615 | 0 |
| G01 | 69.74 | 18.55 | 7 | cw | cw | Off | 1.35 | 0.615 | 0 |
| G03 | 32.37 | 25.97 | 7 | ccw | cw | Off | 3.1 | 0.615 | 0 |
| G01 | 33.39 | 25.97 | 7 | cw | off | Off | 0.085 | 0 | 0 |
| G03 | -46.3 | 18.55 | 7 | ccw | ccw | Off | 6.6 | 0.615 | 0 |
| G01 | -69.74 | 11.13 | 7 | ccw | ccw | Off | 1.95 | 0.615 | 0 |
| G03 | -56.14 | 3.7 | 7 | cw | ccw | Off | 1.135 | 0.615 | 0 |
| G01 | -69.74 | -3.7 | 7 | ccw | ccw | Off | 1.135 | 0.615 | 0 |
| G03 | -53.5 | -11.13 | 7 | cw | ccw | Off | 1.35 | 0.615 | 0 |
| G01 | -69.74 | -18.55 | 7 | ccw | ccw | Off | 1.35 | 0.615 | 0 |
| G03 | -32.36 | -25.97 | 7 | cw | ccw | Off | 3.1 | 0.615 | 0 |
| G01 | -69.74 | -25.97 | 7 | ccw | off | Off | 3.1 | 0 | 0 |
| G00 | -69.74 | -25.97 | 2 | off | off | Ccw | 0 | 0 | 0.415 |
| G00 | -27.088 | -27.97 | 7 | cw | ccw | Cw | 3.56 | 0.165 | 0.415 |
| G01 | -27.088 | -27.97 | -1 | off | off | Ccw | 0 | 0 | 0.665 |
| G03 | -36.87 | 35.898 | -1 | ccw | cw | Off | 0.815 | 5.3 | 0 |
| G01 | -72.24 | -35.898 | -1 | ccw | ccw | Off | 2.95 | 5.95 | 0 |
| G01 | 72.24 | 35.898 | -1 | cw | cw | Off | 12 | 5.95 | 0 |
| G01 | -1.5 | -36.87 | -1 | ccw | ccw | Off | 6.1 | 6.05 | 0 |
| G03 | -46.87 | 25.898 | -1 | ccw | cw | Off | 3.78 | 5.25 | 0 |
| G01 | -46.87 | 18.17 | -1 | off | ccw | Off | 0 | 0.645 | 0 |
| G00 | -46.87 | 18.17 | 2 | off | off | Cw | 0 | 0 | 0.25 |
| G00 | -67.03 | 17.2 | 7 | ccw | ccw | Cw | 1.68 | 0.08 | 0.415 |
| G01 | -61.26 | 17.2 | 7 | cw | off | Off | 0.45 | 0 | 0 |
| G03 | -47.33 | 14.8 | 7 | cw | ccw | Off | 1.16 | 0.2 | 0 |
| G01 | -47.05 | 15 | 7 | cw | cw | Off | 0.02 | 0.0165 | 0 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| G02 | 47.05 | 15 | 7 | cw | off | Off | 0 | 0 | 0 |
| G01 | 47.6 | 14.6 | 7 | cw | ccw | Off | 7.89 | 0.033 | 0 |
| G02 | -14.13 | 14.6 | 7 | ccw | off | Off | 5.15 | 0 | 0 |
| G01 | 47.6 | -14.6 | 7 | cw | ccw | Off | 5.15 | 2.43 | 0 |
| G02 | 14.13 | -14.6 | 7 | ccw | off | Off | 2.785 | 0 | 0 |
| G01 | -47.61 | 14.6 | 7 | ccw | cw | Off | 5.15 | 2.43 | 0 |
| G00 | -47.61 | 14.6 | 10 | off | off | Cw | 0 | 0 | 0.25 |
| G00 | 0 | 0 | 0 | cw | ccw | Ccw | 3.95 | 1.215 | 0.8335 |

All servo motors are set to move in 60 rad/s, to convert it to liner motion:

$$linear\ speed = rotation\ speed * radius\ of\ rotation$$

$$S\ liner = S\ rot * r$$

$$Sl = 60 * 0.2 = 12\ \frac{m}{s} \qquad for\ 0.4\ cm\ screw\ diameter$$

$$time\ delay = \frac{position}{speed}$$

$$x1\ delay = -\frac{69.74}{12} = 5.8\ s$$

$$y1\ delay = -\frac{33.4}{12} = 2.78s$$

$$Z1\ deelay = \frac{0}{12} = 0s$$

Also we must know the direction of the motors from the position value.

The table above shows the details to start programming in microcontroller frame.

## 5.4 PIC Microcontroller

### 5.4.1 Microcontroller and industry

The microcontrollers have great applications in industry field, if we compare between microcontroller and PLC

✓ **MC VS PLC**

- Microcontrollers (MCU) are complete computer systems on a chip. They combine CPU, memory, timer/counters, serial port, input/output (I/O) ports and a clock oscillator, cheaper than PLC, easy to interface, good for every application, programmable
- Programmable logic controllers (PLC) are the control hubs for automated systems. They contain multiple inputs and outputs that use transistors and other circuitry to simulate switches and relays to control equipment. They're also programmable via standard computer interfaces and proprietary languages and network options, PLC main circuit contain MCU

❖ **Embedded systems**

The main application that we found a great usage for MCU is in embedded systems, which is a system whose principal function is not computational, but which is controlled by a computer embedded within it.

❖ **Microcontroller families**

- There are thousands of different microcontroller types in the world today, made by numerous different manufacturers.
- A manufacturer builds a microcontroller family around a fixed microprocessor core. Different family members are created by using the same core, combining with it different combinations of peripherals and different memory sizes.

### 5.4.2 PIC microcontrollers today

- There are literally hundreds of different devices, offered in different packages, for different applications.
- all PIC microcontrollers are low-cost, self-contained, 8-bit/16-bit/32-bit, Harvard structure, pipelined, RISC, single accumulator (the Working or W register), with fixed reset and interrupt vectors, full documented, easy to programming.
- In 8-bit Microcontrollers, Microchip ranked to be #1.
- The most common used family are PIC16 and PIC18.

### 5.4.3 PIC18 FAMILY

- The PIC 18 Series microcontrollers dramatically enhance the PIC core, making it suitable for advanced embedded projects. Despite many features which are new, it has been designed to make upwards migration from a 16 Series device easy.
- We will try to get familiar with PIC18F4550.

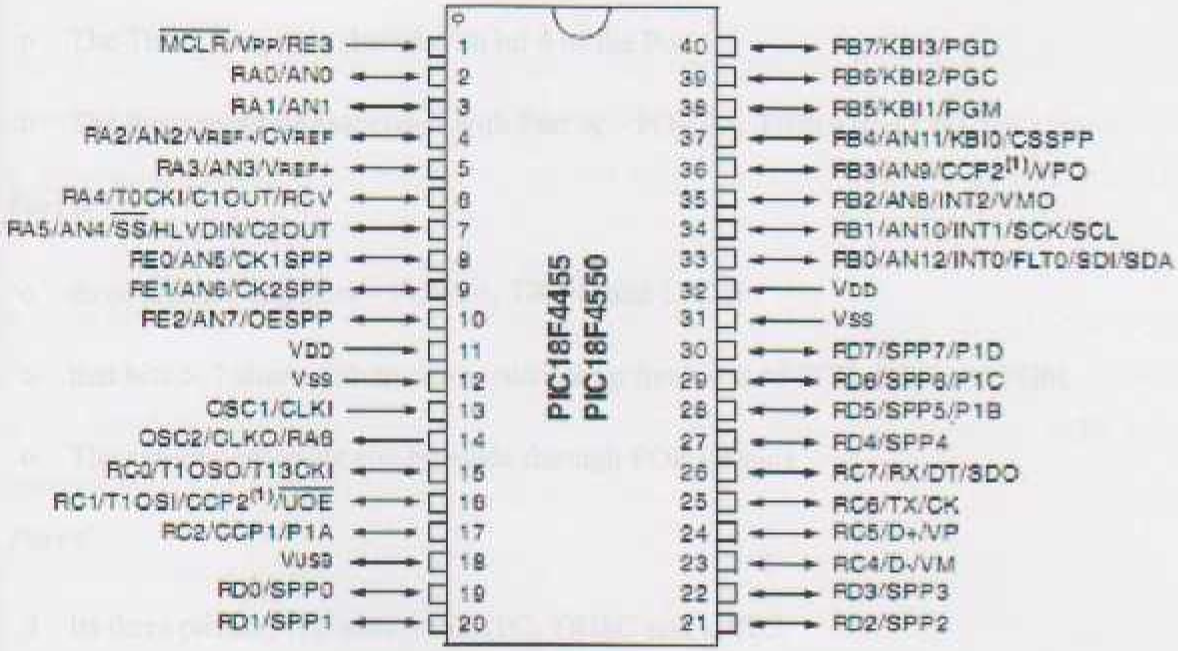



**Figure 5-3 PIC 18F4550**

### 5.4.4 The PIC 18F4550 peripherals

We will talk about the common used peripheral

- The PIC18F4550 have 5 port A,B,C,D and E and it described as follow
- Each PORT have three registers associated for his operation and these registers is PORTX, TRISX and LATX
- The Port data itself appears in the PORTX
- The data direction is determined by the bit values set in the (control registers) TRISX
- The LATX is used to read the output data back (not input read)

1- *Port A*

- The port can be used for general-purpose bi-directional digital data. It is also shared with the Analog functions
- The Timer 0 input is shared with bit 4 of the Port
- The three registers associated with Port A – PORTA, TRISA and LATA

2- *Port B*

- three primary registers – PORTB, TRISB and LATB
- that bits 5–7 share with the in-circuit debug functions of PGD, PGC and PGM
- The external interrupt can be made through PORTB pins

3- *Port C*

- its three primary registers – PORTC, TRISC and LATC
- this port shares its pins with the serial ports and the CCP functions, while bit 0 is shared with the Timer 1 input

4- The parallel slave port (PORTD)

The parallel port itself is Port D, with 3 bits of Port E being available for handshaking.

- o The timers
- o The 18F4550 have 5 programmable timers, as well as a Watchdog Timer, the general used counting and timing.

## 5.5 PIC Simulators

PIC Simulator is powerful application that supplies PIC developers with user-friendly graphical development environment for Windows with integrated simulator (emulator), Basic compiler, assembler, disassembler and debugger.

The program helps the user to view the internal microcontroller architecture. It has features such as FLASH program memory editor, variable simulation rate and a powerful PIC basic compiler. It features code debugging using breakpoints manager.

To solve the purpose of proper communication with other devices it features a PC's serial port terminal. It is bundled with many signal generator simulation tools along with an Oscilloscope. The program has many color themes to make it user-friendly. It supports external simulation modules and extensive program options.

The users can find great improvements than its earlier version. It is easy to use and helps in quick PIC programming. The free upgrades and additional features have made the program a bundle of utilities. The basic compiler saves a lot of time as it is very powerful. It can be fairly easy to operate even for a novice.

PIC Simulator main features:

- Main simulation interface showing internal microcontroller architecture.

- FLASH program memory editor, EEPROM data memory editor, hardware stack viewer.

- Microcontroller pin out interface for simulation of digital I/O and analog inputs.

- Variable simulation rate, simulation statistics.

- Breakpoints manager for code debugging with breakpoints support.

- PIC assembler, interactive assembler editor for beginners, PIC disassembler.

From the features of this program we start programming in the PIC chip to control the machine depending on the values of the table as described below.

```
output_high(pin_b0);

output_high(pin_b2);

output_high(pin_b4);

delay_ms(2870);

output_low(pin_b4);

delay_ms(2930);

output_low(pin_b2);
```

This code is to describe the first order of the G code, which enable the engraving motor directly when the input switch is active, then activate pin2 which activate the second relay of X motor and activate the motor in counter clock wise direction, then activate pin 4 which activate the second relay of Y motor and activate the motor in counter clock wise direction, after the first delay is complete, the pin4 must stop according to the G code to get the painting in correct form, then after the second time delay is complete, the pin2 reach its time and stop active.

And so we complete the first order of the G code. The all program that controls the painting we have inserted in Mastercam is shown in the appendix, which is implemented in proteus to tests the result and make sure that the system is correct.

## 5.6 proteus application

Proteus is simulation software which is very essential for every electronics engineers and students. Especially electronics engineers will find this software very useful for academic purpose.

This is the perfect tool for engineers to test their microcontroller designs before constructing a physical prototype in real time. This program allows users to interact with the design using on-screen indicators and/or LED and LCD displays and, if attached to the PC, switches and buttons. One of the main components of Proteus 7.0 is the Circuit Simulation, a product that uses a SPICE3f5 analog simulator kernel combined with an event-driven digital simulator that allow users to utilize any SPICE model by any manufacturer.

Proteus comes with extensive debugging features, including breakpoints, single stepping and variable display for a neat design prior to hardware prototyping.

In summary, Proteus 7.0 is the program to use when you want to simulate the interaction between software running on a microcontroller and any analog or digital electronic device connected to it.

## 5.7 Mechanical simulation CATIA

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Dassault Systems product lifecycle management software suite, CATIA is one of the world's leading high-end integrated CAD/CAM/CAE systems. CATIA V5 is a state of art solid modeling software used in automotive and aerospace industry by companies like: Chrysler, Toyota, BMW, Bombardier, Lockheed and Boeing. It is extensively used by many mold making, tool and die, and sheet metal companies. The emphasis of this training is on the graphical communication of solutions to mechanical engineering design problems. This training should provide a solid background for solid modeling and assembly for digital product development. By the end of this CATIA Fundamental Training, participants should be able to apply the fundamentals of solid modeling including feature based parametric CAD by completing a three dimensional part; explain the engineering design process and the role of engineering graphics in digital design and analysis; create a 3D assembly model, including a bill of materials; demonstrate the management of CAD data files and integrated data management documentations; and understand the product lifecycle management (PLM).

Features and Benefits:

- User-friendly environment
- Fast design-analysis loops
- Multidiscipline collaboration
- Knowledge-based optimization
- Industry-proven performance

From catia we design the mechanical parts of the machine and activate an animation for the movable parts to show the mechanism of action as shown in figure 5.4.

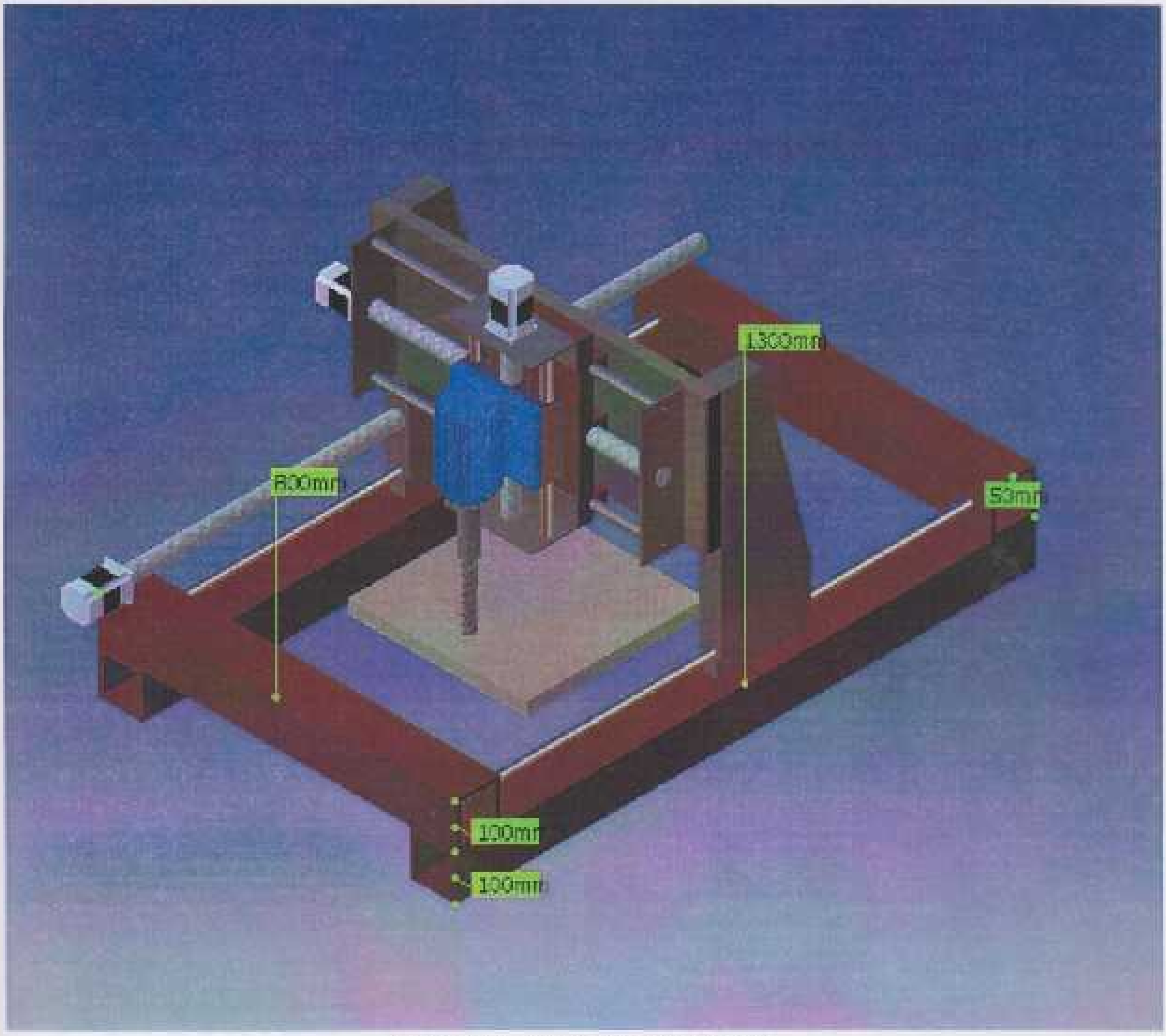



**Figure 5-4 mechanical design in catia**

# CHAPTER SIX

# SIMULATION DESIGN

**6.1 Mastercam Simulation.**

**6.2 G code conclusion.**

**6.3 PIC Simulator.**

**6.4 Proteus application.**

**6.5 Catia simulation.**

## 6.1 Mastercam

One of the forms that Mastercam can import is image that we want to engrave. Here the procedure that we follow shown in figures below sequentially.

1. Inter the image that we need to engrave on it

From main menu→ Art → trace image

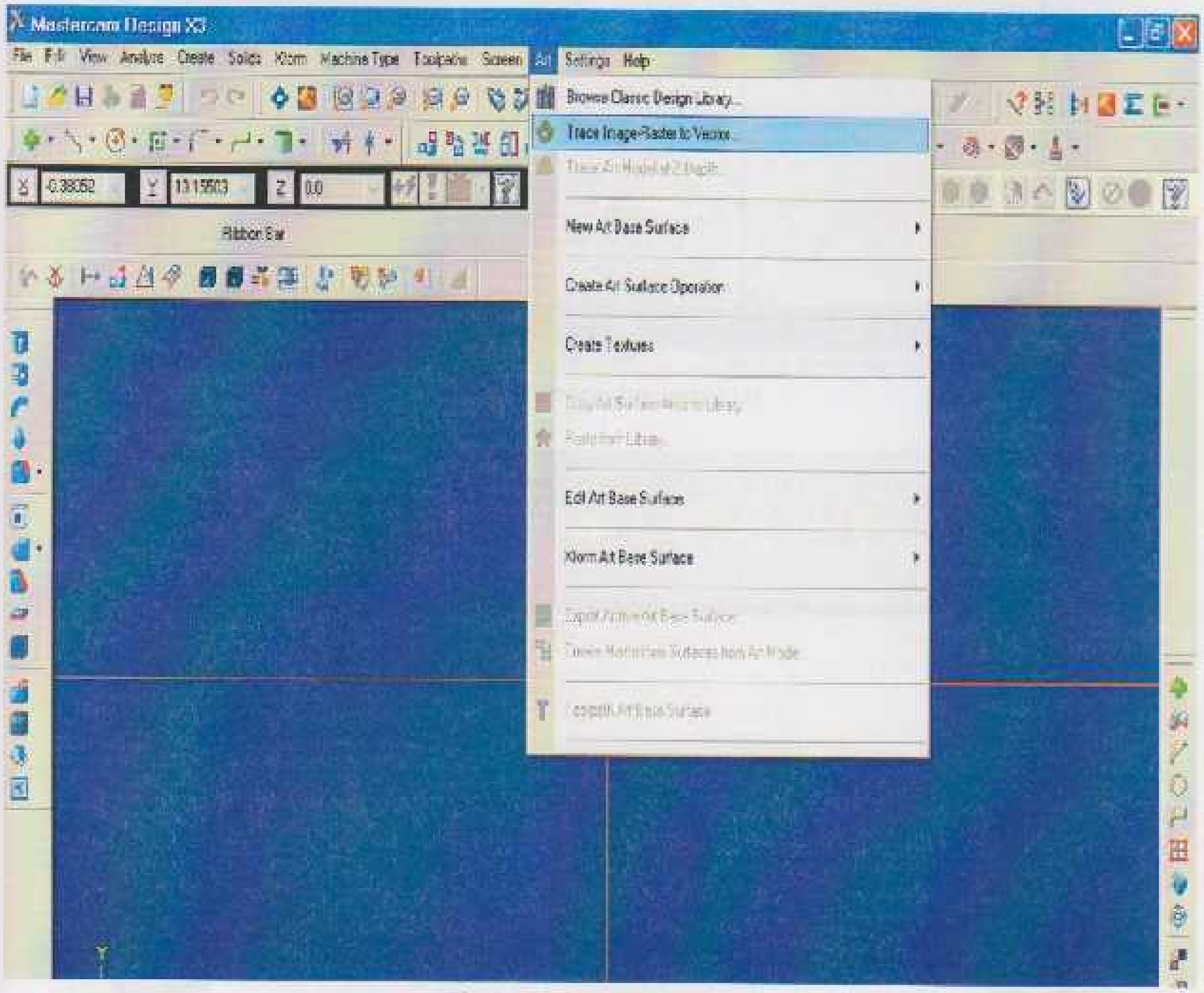



**Figure 6-1 Interring image**

2. Processing image (Select the resolution for the image

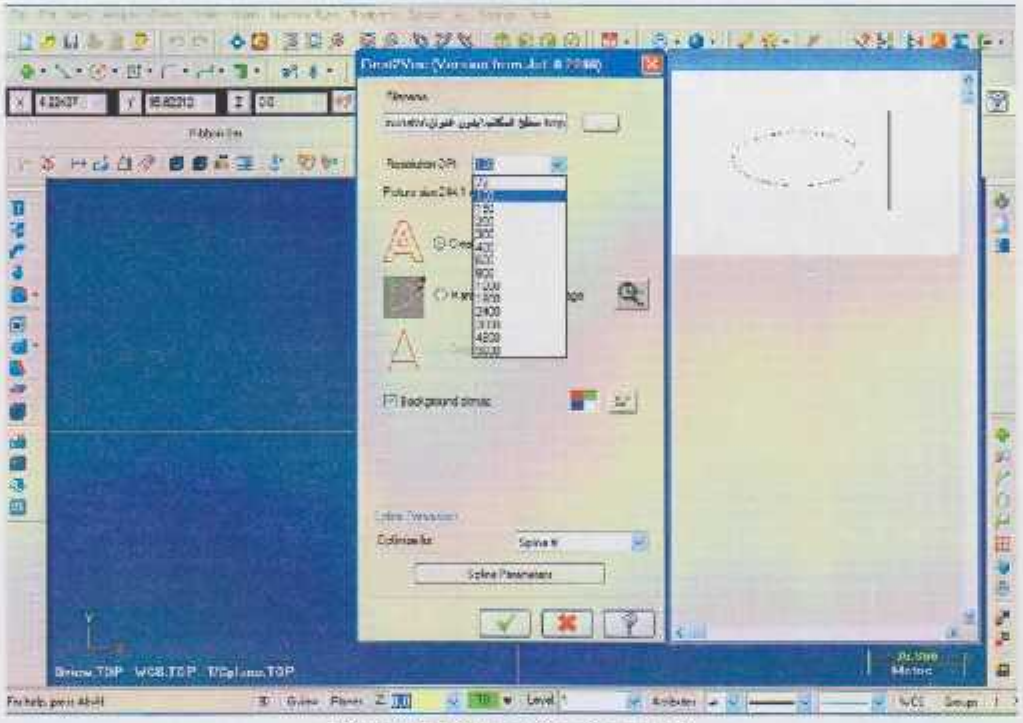


Figure 6-2 Processing image (1)

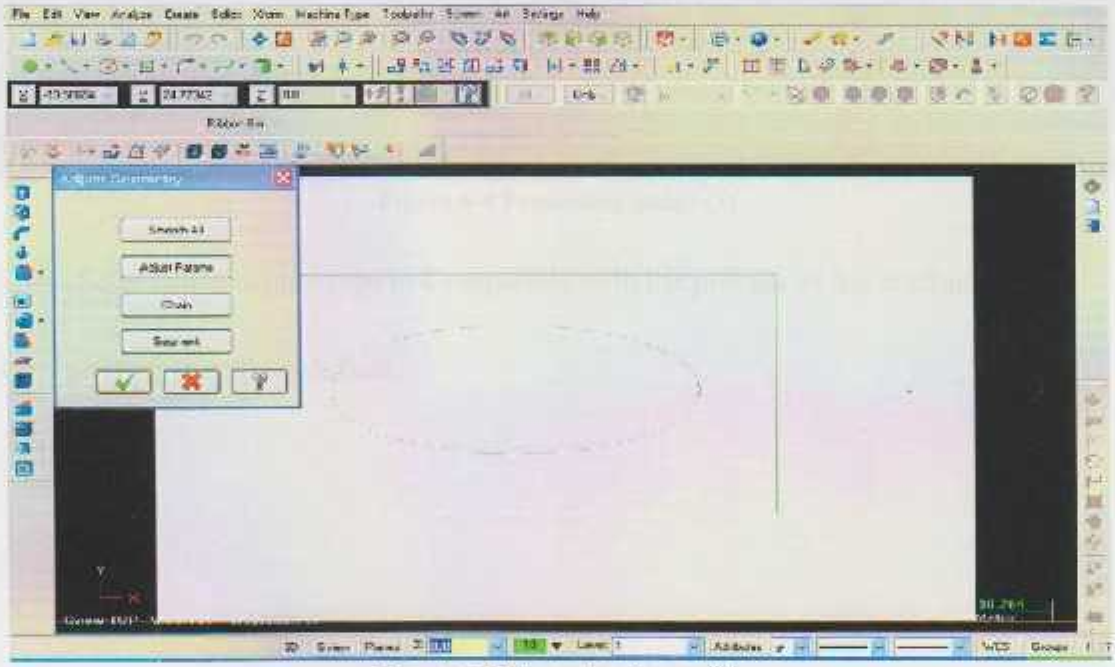


Figure 6-3 Processing image (2)

3. Remove open lines and excess lines because it held the machine accuracy work.

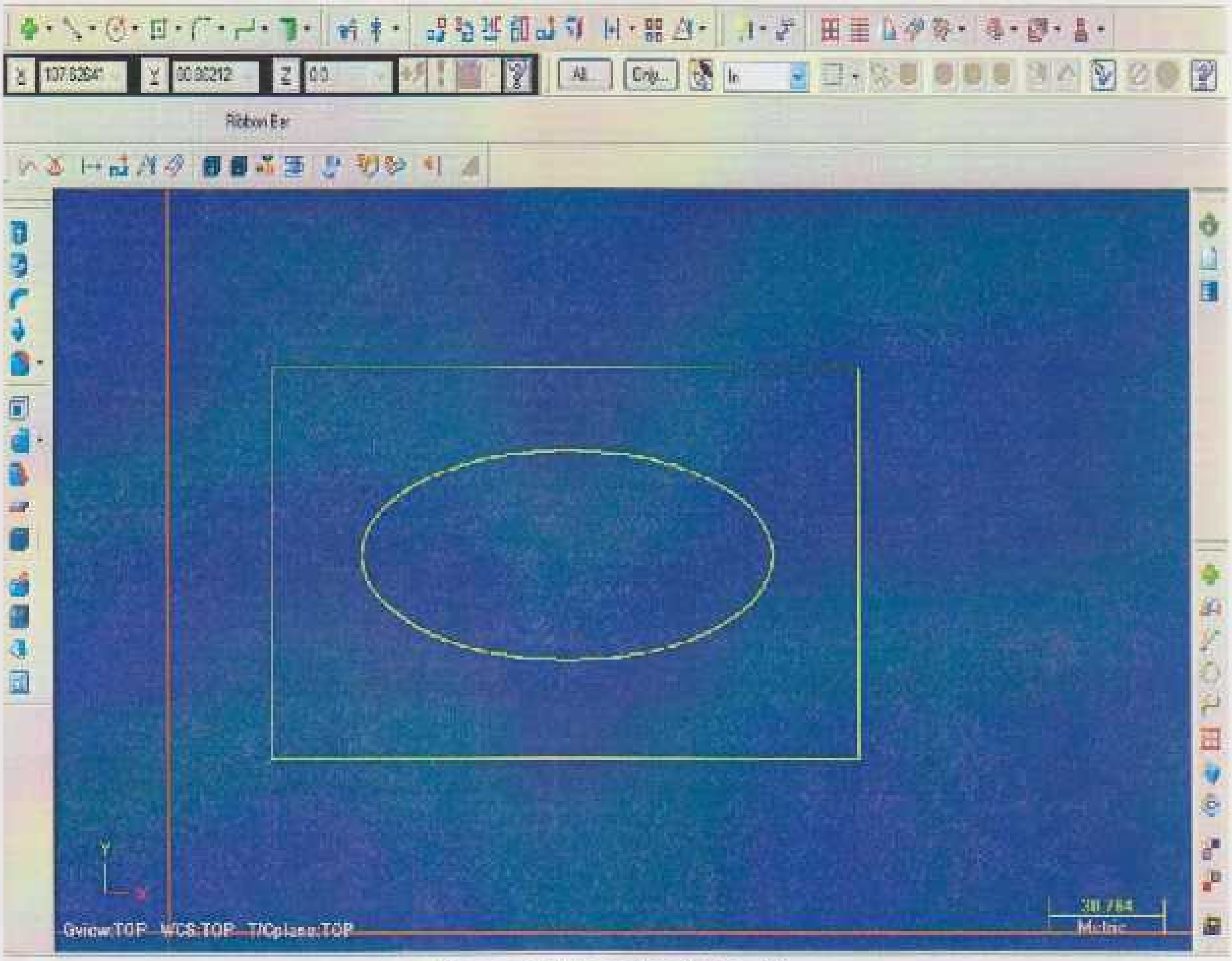



**Figure 6-4 Processing image (3)**

4. Select the machine type to Compatible with the process of the machine, from:

Machine type→ mill→ default.

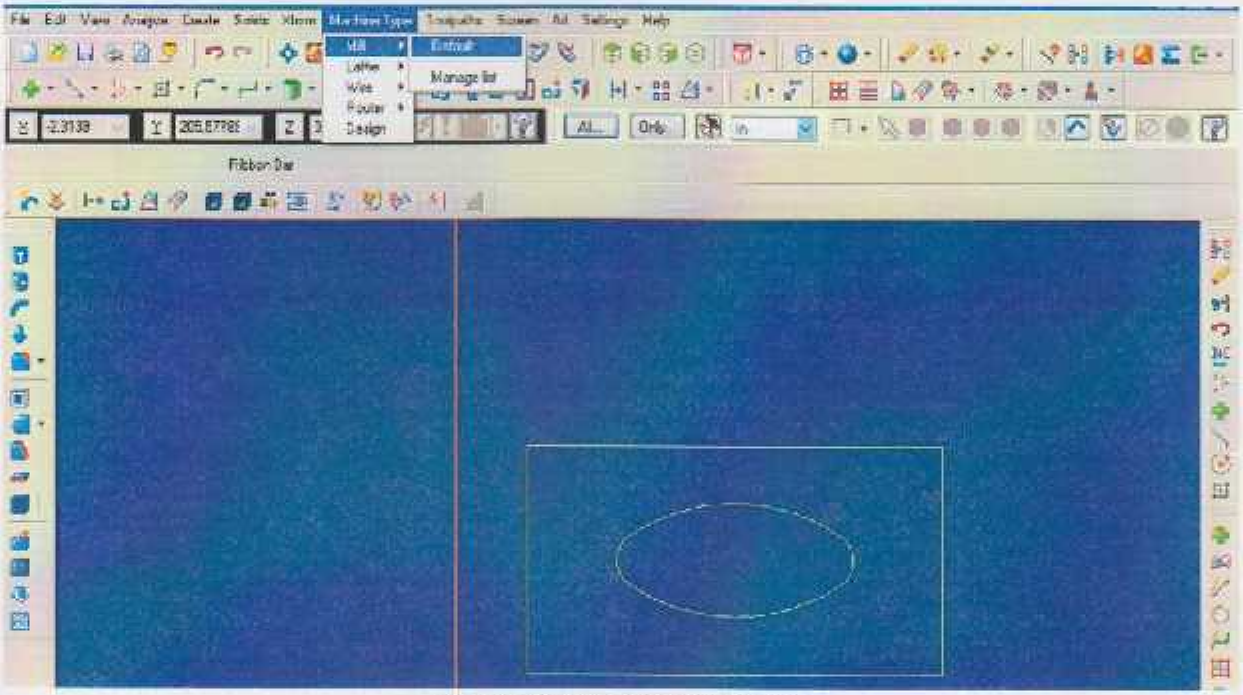


Figure 6-5 Select of machine type

5. Select the type of the process (engraving) from tool path-pocket

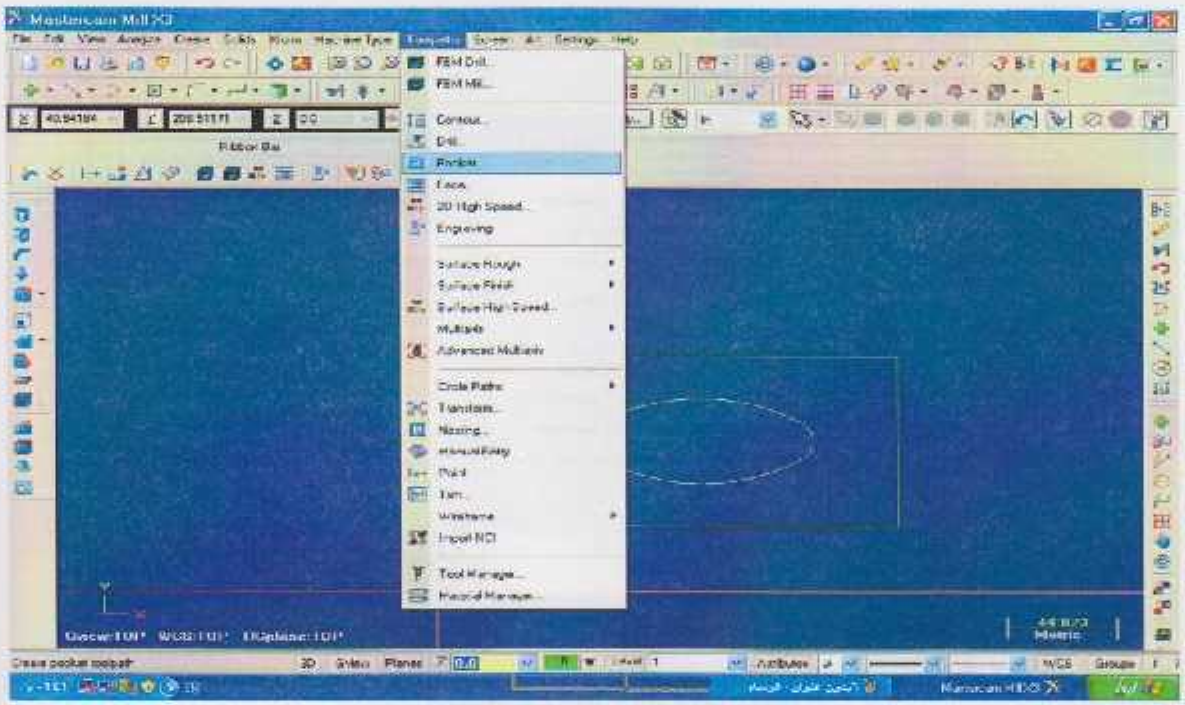


Figure 6-6 Select type of processes

6. Track drill motor from point-to-point and locate the beginning and the end.

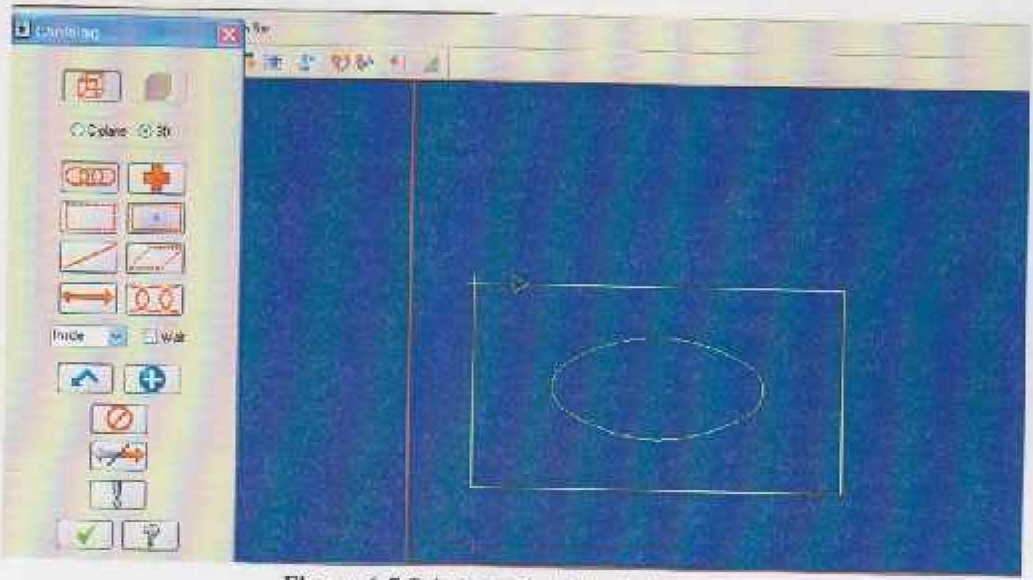


**Figure 6-7 Select track of the dril motor**

7. Select the parameter of the tool path (tool#, head#, diameter…etc).

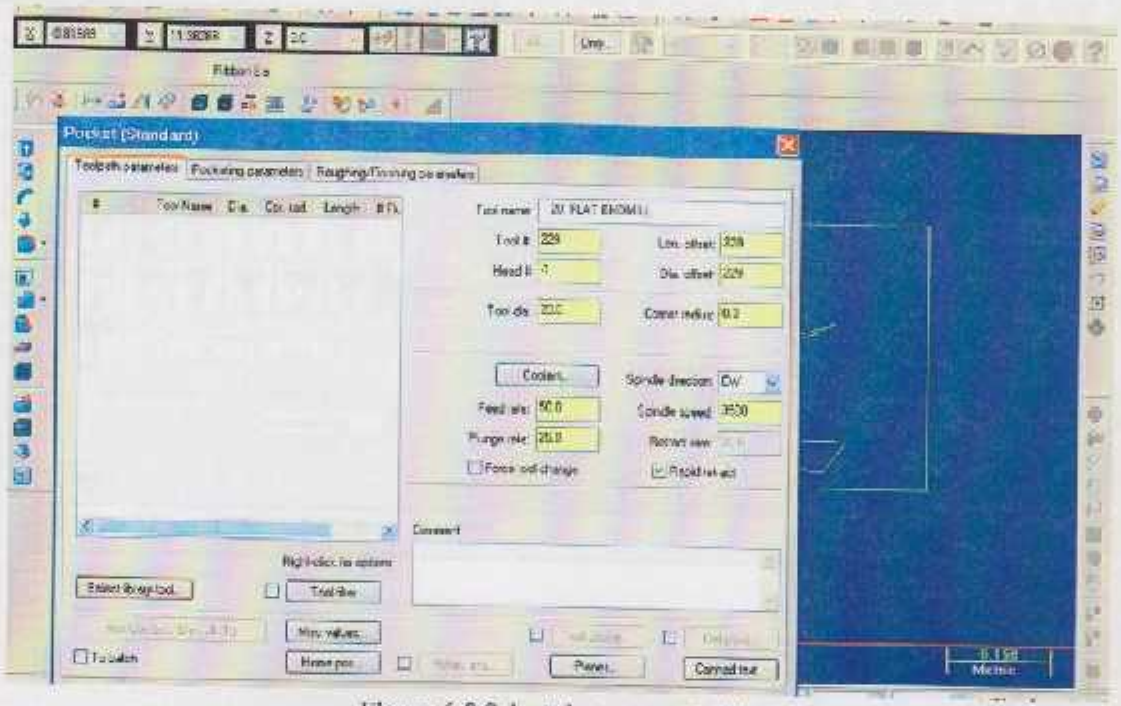


**Figure 6-8 Select the parameter(1)**

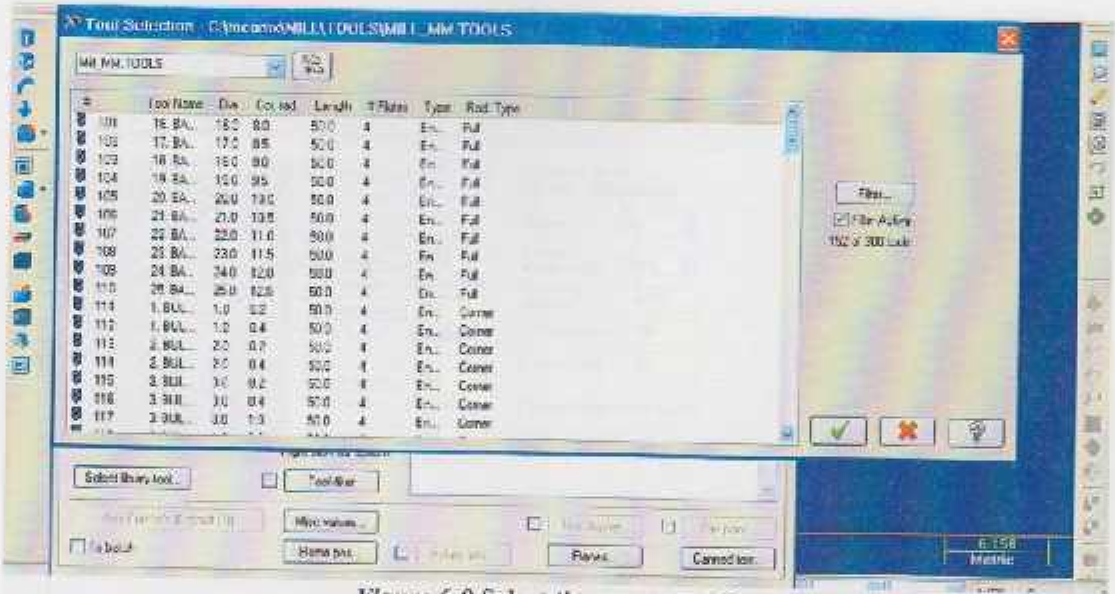


**Figure 6-9 Select the parameter(2)**

8. Select the spindle type (for engrave), and it's characteristic.

**Figure 6-10 Spindle selection(1)**

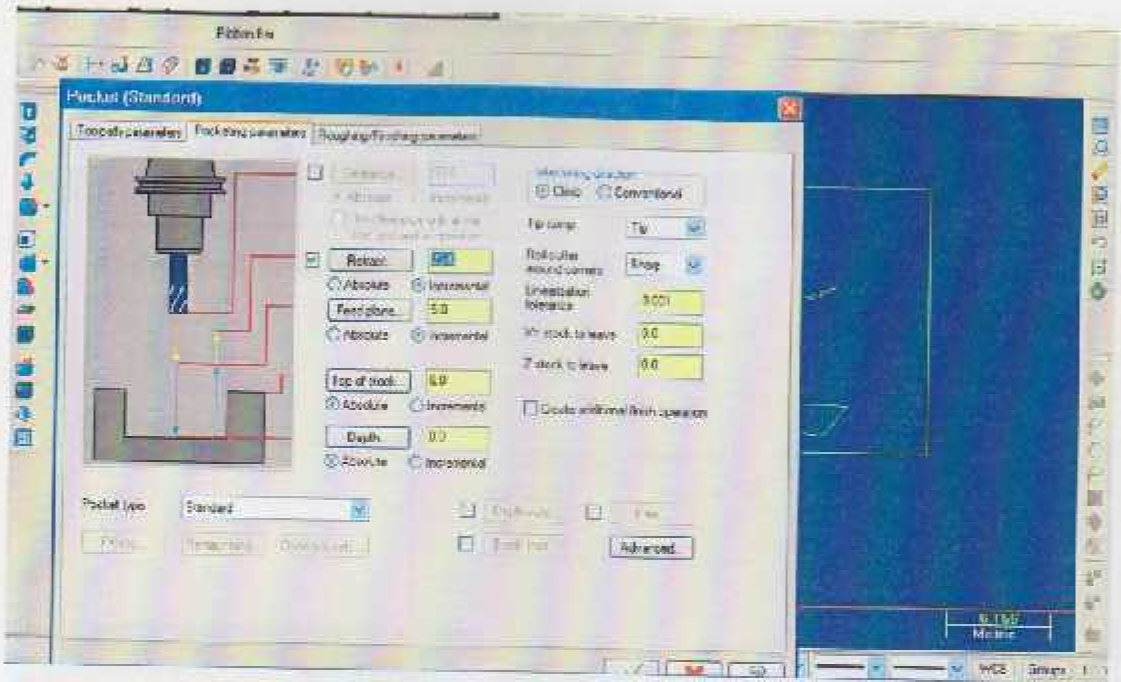


**Figure 6-11 Spindle selection(2)**

9. Determine the direction of rotation as (zigzag) so going Spindle from the beginning of the cheek continuously until the end.

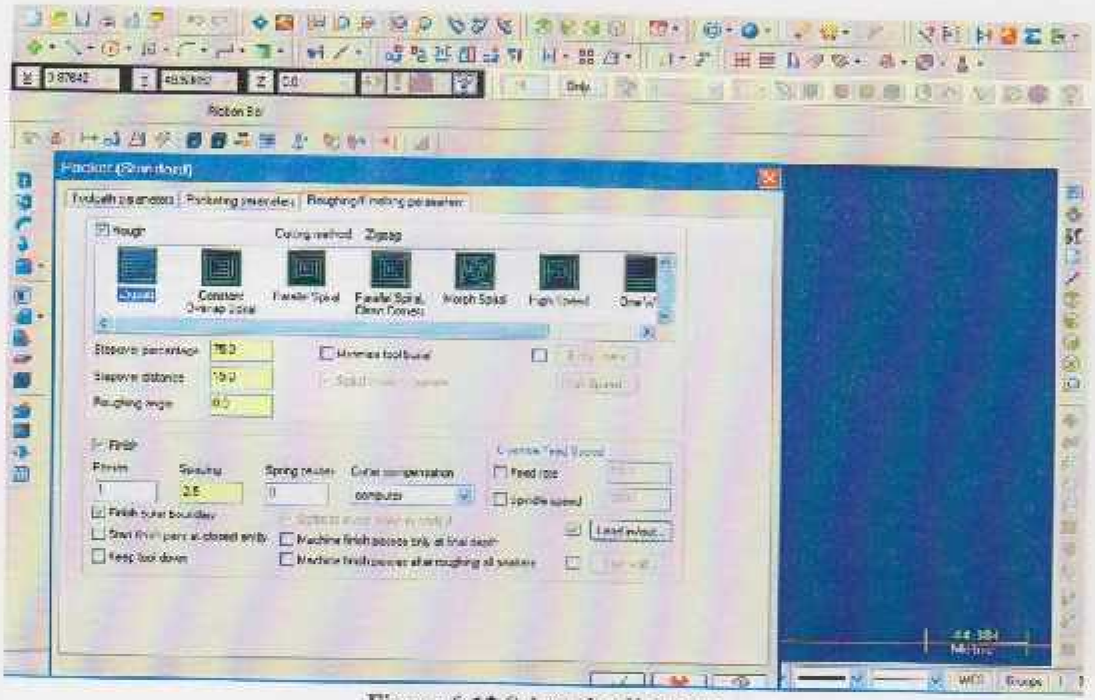


**Figure 6-12 Select the diriction**

10. Determine the speed of the spindle (as the engraving motor we have).

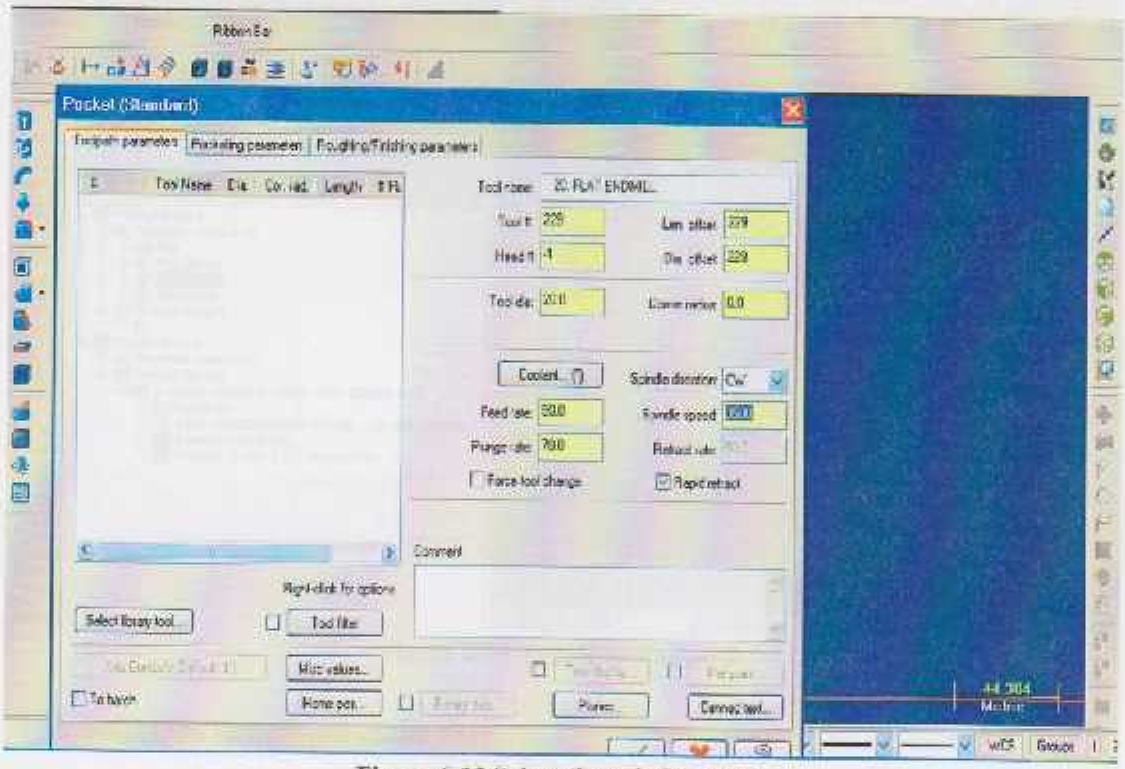


**Figure 6-13 Select the spindel speed**

11. From (view) select Toggle operation manager to manage the engraving process.

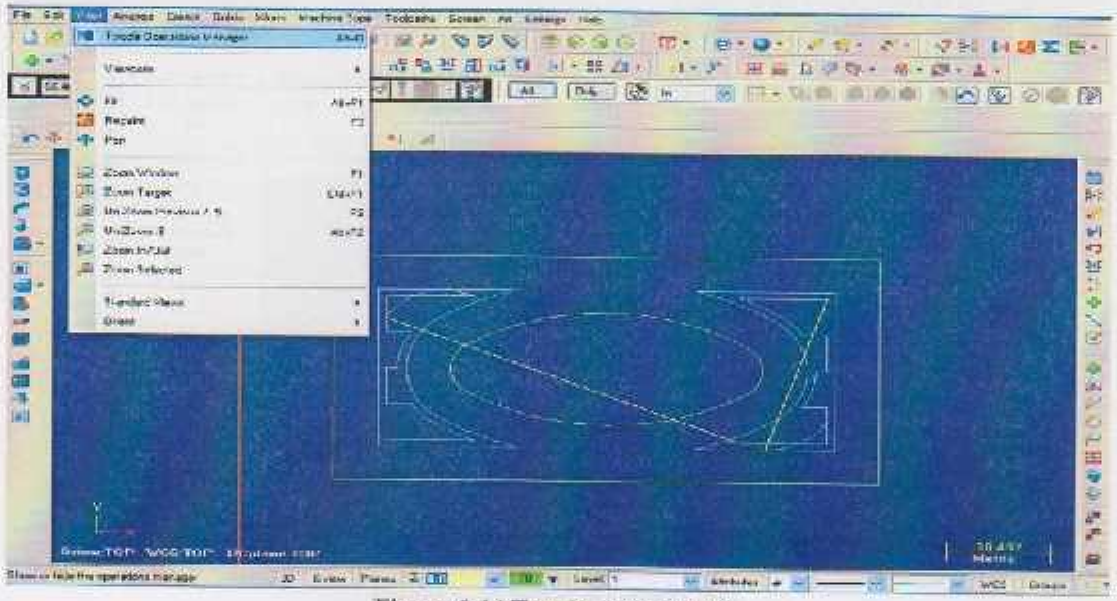


**Figure 6-14 Toggle operation(1)**

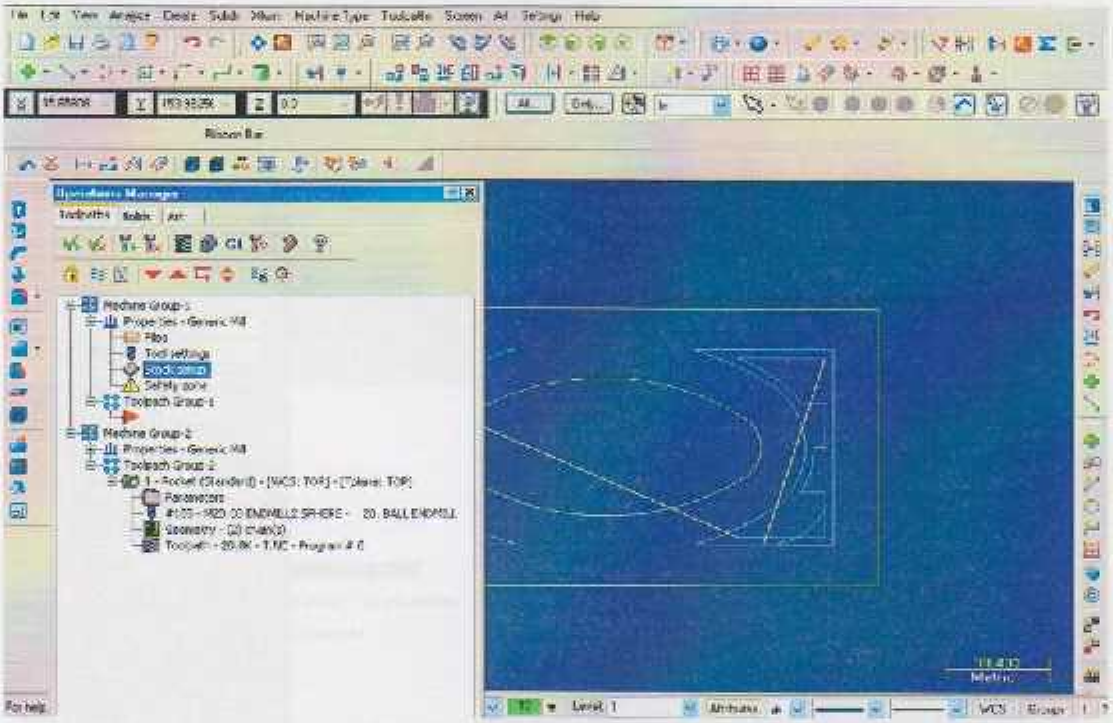


Figure 6-15 Toggle operation(2)

12. Select the dimension of the axes

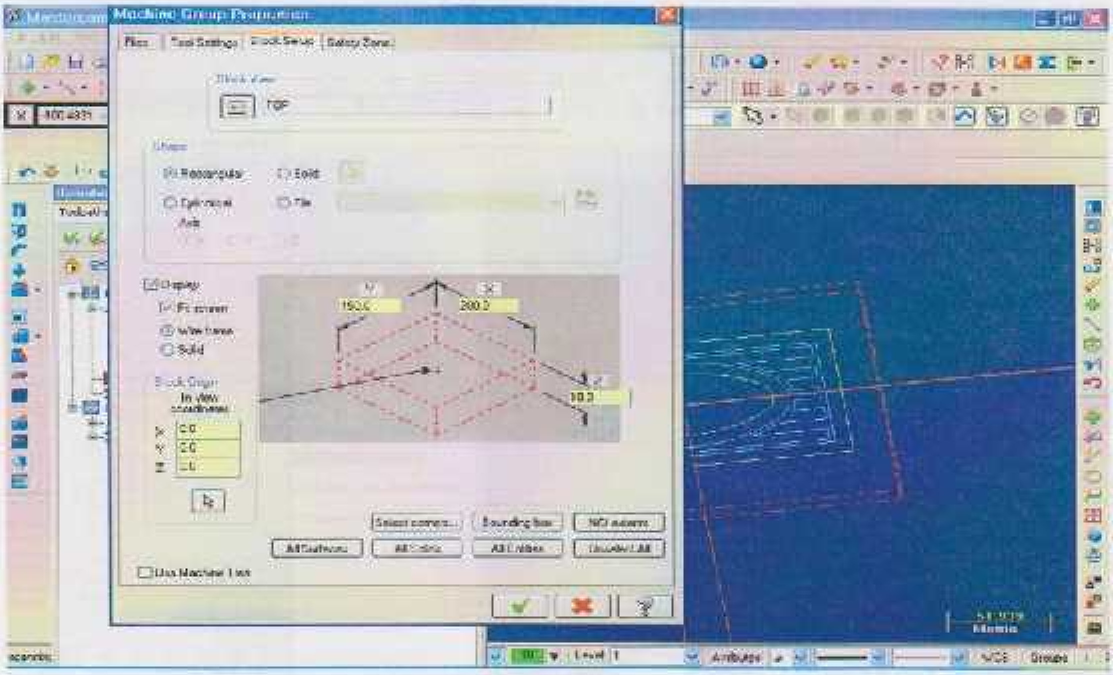


Figure 6-16 Select the dimension

13. To see how it work and chick the axes dimensions from (verity and machine).

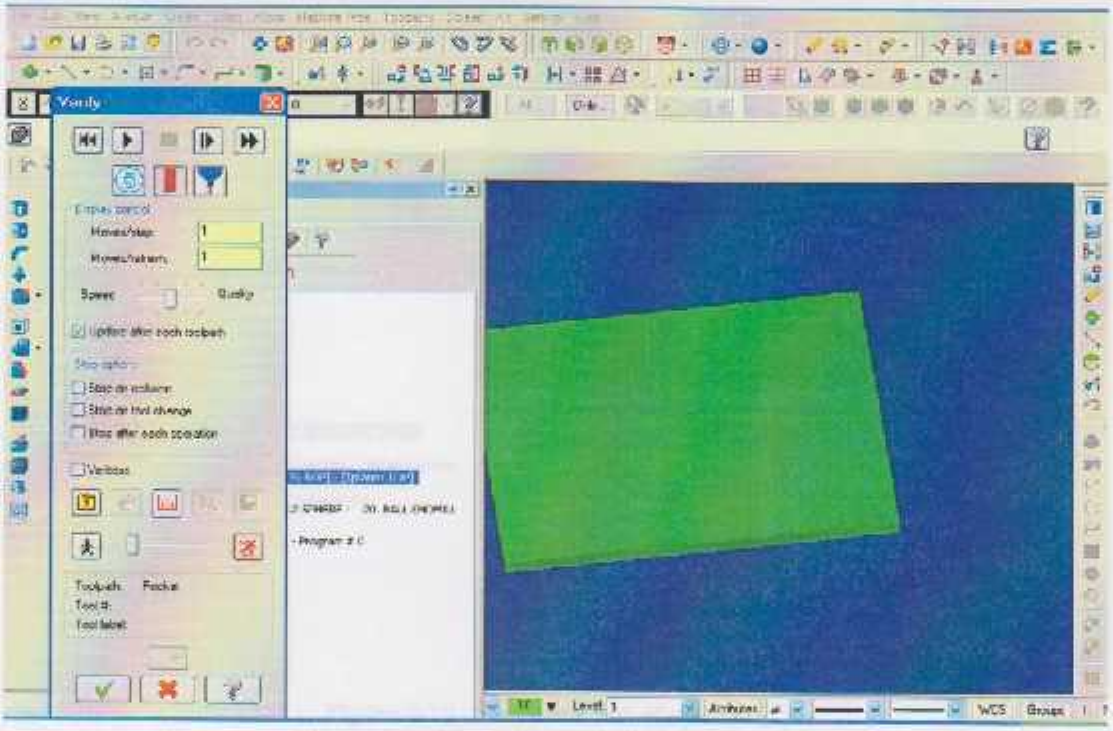


Figure 6-17 Check the work of the spindle (1)

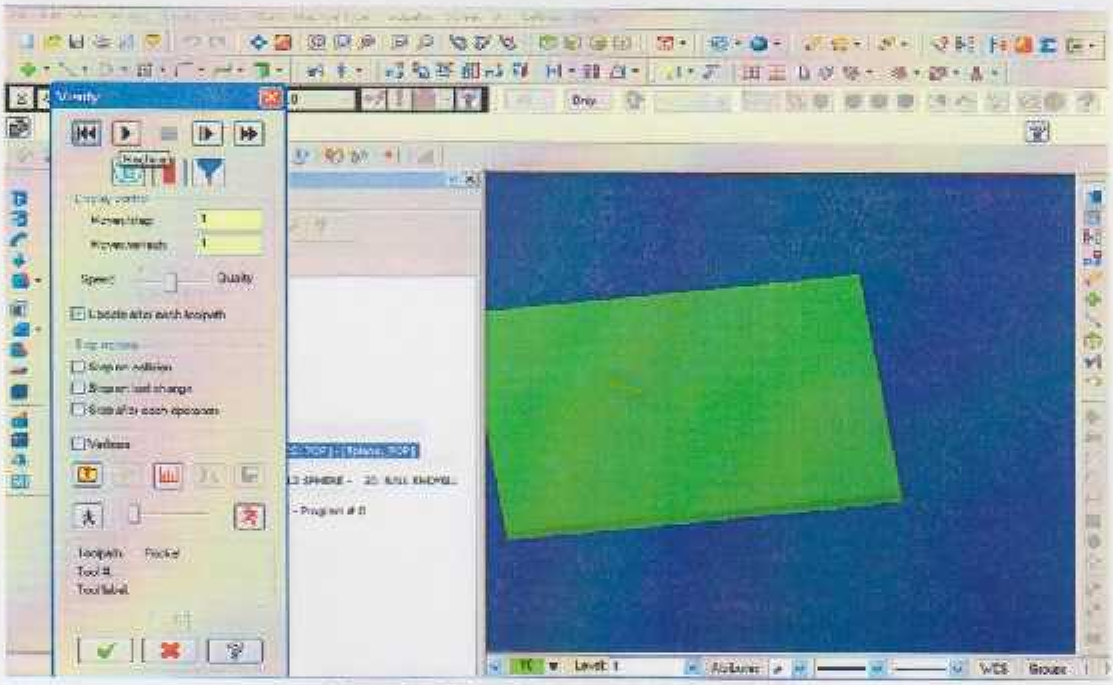


Figure 6-18 check the work of spindle (2)

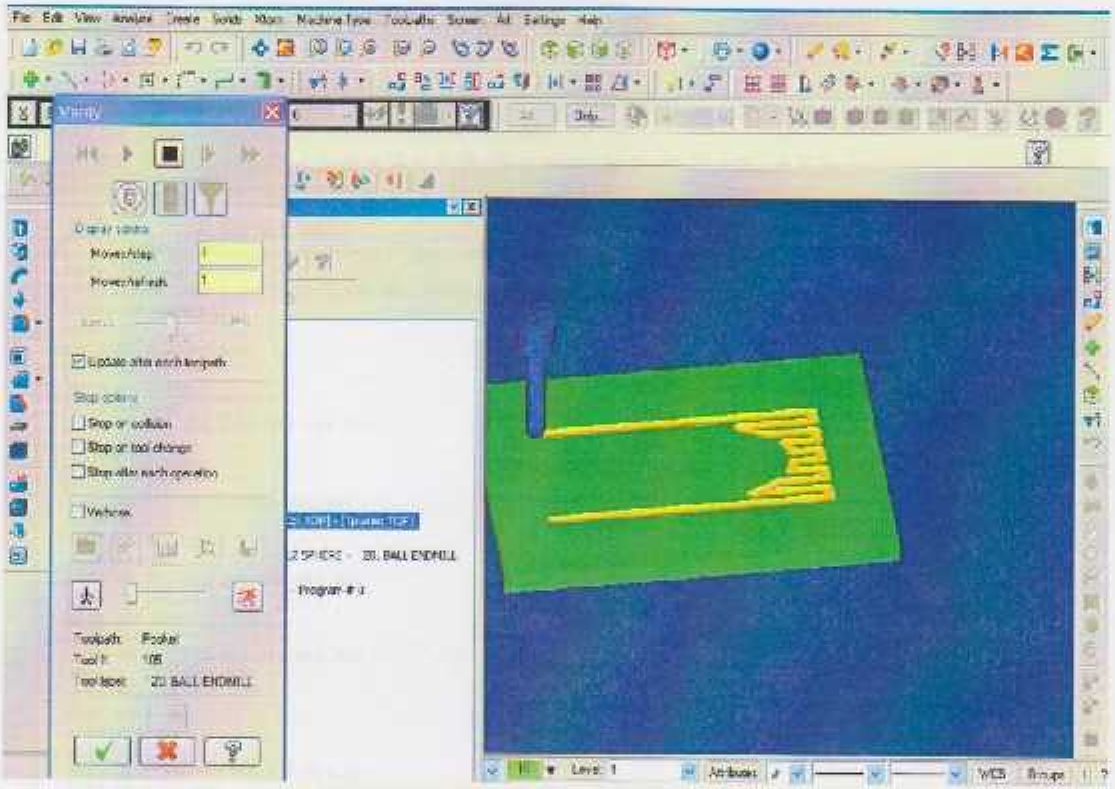



**Figure 6-19 check the work of spindle (3)**

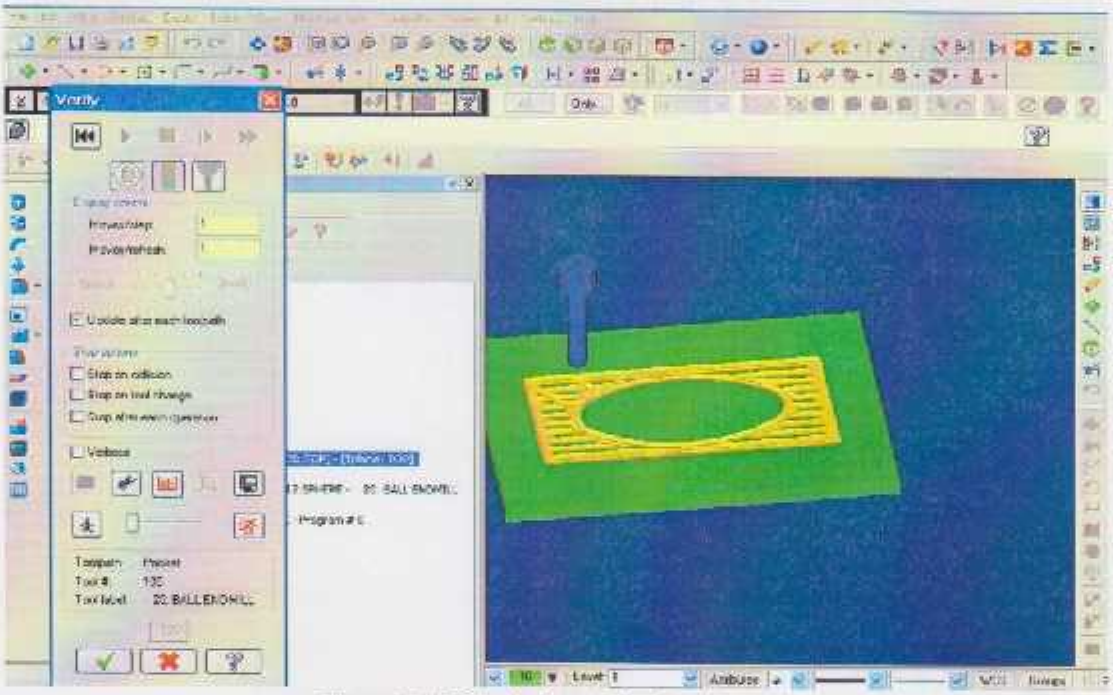



**Figure 6-20 Check the work of spindle (4)**

14. To create the G code (from G1 and post processing operation)

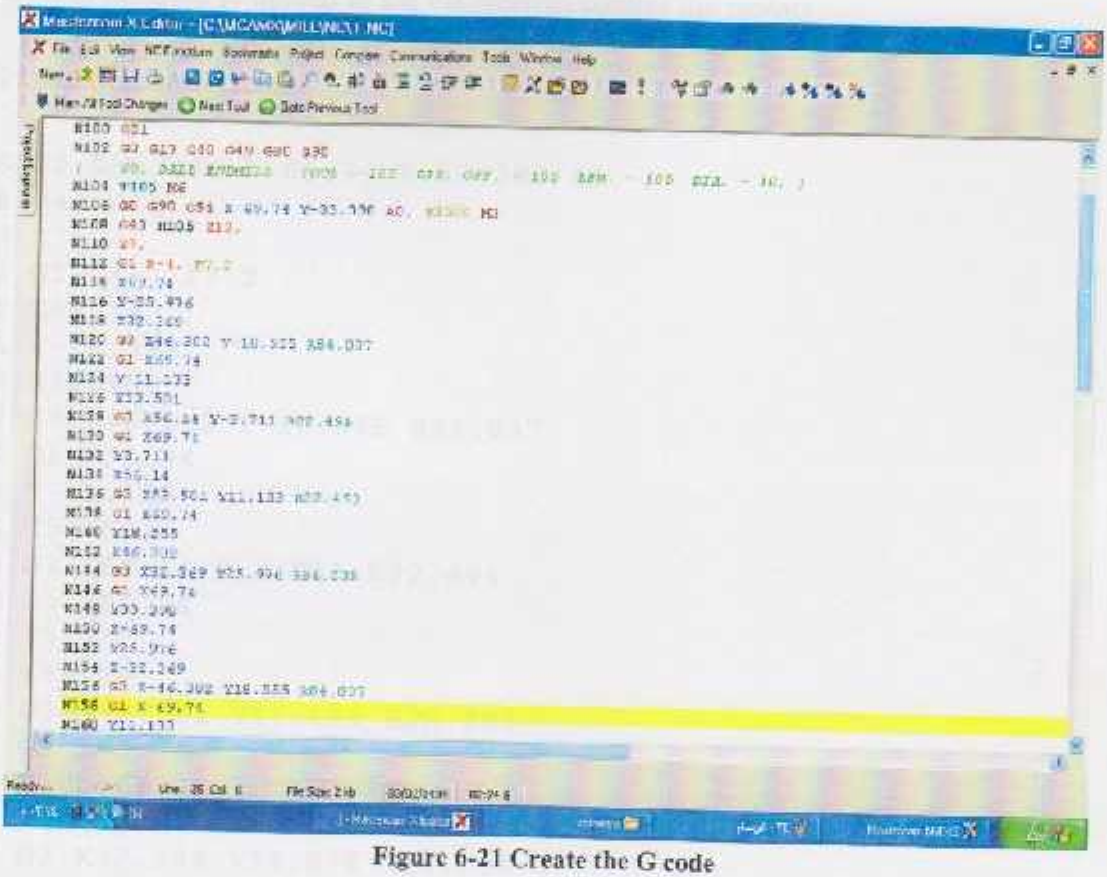


Figure 6-21 Create the G code

## 6.2 G code conclusion

Mastercam produce G code to upload it to the machine, but here we want to study the code and convert it to program to upload to the PIC chip to control the motors.

All G code from mastercam:

```
N106 G0 G90 G54 X-69.74 Y-33.398 A0.
N108 G43 Z10.
N110 Z7.
N112 G1 Z-1. F7.2
N114 X69.74
N116 Y-25.976
N118 X32.369
N120 G3 X46.302 Y-18.555 R84.037
N122 G1 X69.74
N124 Y-11.133
N126 X53.501
N128 G3 X56.14 Y-3.711 R22.494
N130 G1 X69.74
N132 Y3.711
N134 X56.14
N136 G3 X53.501 Y11.133 R22.493
N138 G1 X69.74
N140 Y18.555
N142 X46.302
N144 G3 X32.369 Y25.976 R84.038
N146 G1 X69.74
N148 Y33.398
N150 X-69.74
N152 Y25.976
N154 X-32.369
N156 G3 X-46.302 Y18.555 R84.037
N158 G1 X-69.74
N160 Y11.133
N162 X-53.501
N164 G3 X-56.14 Y3.711 R22.494
N166 G1 X-69.74
N168 Y-3.711
N170 X-56.14
N172 G3 X-53.501 Y-11.133 R22.493
N174 G1 X-69.74
N176 Y-18.555
N178 X-46.302
N180 G3 X-32.369 Y-25.976 R84.038
```

```
N182 G1 X-69.74
N184 G0 Z2.
N186 Z7.
N188 X-27.088 Y27.975
N190 G1 Z-1.
N192 G3 X-36.87 Y35.898 R10.
N194 G1 X-72.24
N196 Y-35.898
N198 X72.24
N200 Y35.898
N202 X-1.5
N204 X-36.87
N206 G3 X-46.87 Y25.898 R10.
N208 G1 Y18.176
N210 G0 Z2.
N212 Z7.
N214 X-67.039 Y25.381
N216 G1 Z-1.
N218 X-61.269 Y17.214
N220 G3 X-47.331 Y14.818 R10.
N222 G1 X-47.052 Y15.015
N224 G2 X47.052 R81.538
N226 G1 X47.61 Y14.621
N228 X48.092 Y14.138
N230 G2 Y-14.138 R19.993
N232 G1 X47.61 Y-14.621
N234 X47.052 Y-15.015
N236 G2 X-47.052 R81.538
N238 G1 X-47.61 Y-14.621
N240 X-48.092 Y-14.138
N242 G2 Y14.138 R19.993
N244 G1 X-47.61 Y14.621
N246 X-47.331 Y14.818
N248 G3 X-44.935 Y28.755 R10.
N250 G1 X-48.215 Y33.398
N252 G0 Z10.
N256 G91 G28 Z0.
N258 G28 X0. Y0. A0.
```

And as shown in table 5.1 the codes are converted to values and information needs to be programmed by a pic simulator.

## 6.3 PIC simulator:

Here we start to programming using the data on the table until we reached to the following code:

```
void main()
{

  setup_adc_ports(NO_ANALOGS|VSS_VDD);
  setup_adc(ADC_OFF);
  setup_psp(PSP_DISABLED);
  setup_spi(FALSE);
  setup_wdt(WDT_OFF);
  setup_timer_0(RTCC_INTERNAL);
  setup_timer_1(T1_DISABLED);
  setup_timer_2(T2_DISABLED,0,1);
  setup_comparator(NC_NC_NC_NC);
  setup_vref(FALSE);
  setup_oscillator(False);

  // TODO: USER CODE!!
if(input(pin_e0)==1){
output_high(pin_b0);
output_high(pin_b2);
```

```
output_high(pin_b4);
delay_ms(2870);
output_low(pin_b2);
delay_ms(2930);
output_low(pin_b4);

output_high(pin_b1);
output_high(pin_b3);
output_high(pin_b5);
delay_ms(615);
output_low(pin_b3);
output_low(pin_b5);
delay_ms(11000);
output_low(pin_b1);

output_high(pin_b2);
output_high(pin_b3);
delay_ms(615);
output_low(pin_b3);
delay_ms(1335);
output_low(pin_b2);
output_high(pin_b1);
```

```
output_high(pin_b3);
delay_ms(615);
output_low(pin_b3);
delay_ms(1335);
output_low(pin_b1);

output_high(pin_b2);
output_high(pin_b3);
delay_ms(615);
output_low(pin_b3);
delay_ms(520);
output_low(pin_b2);

output_high(pin_b1);
output_high(pin_b3);
delay_ms(615);
output_low(pin_b3);
delay_ms(520);
output_low(pin_b1);

output_high(pin_b2);
output_high(pin_b3);
```

```
delay_ms(615);
output_low(pin_b3);
delay_ms(735);
output_low(pin_b2);

output_high(pin_b1);
output_high(pin_b3);
delay_ms(615);
output_low(pin_b3);
delay_ms(735);
output_low(pin_b1);

output_high(pin_b2);
output_high(pin_b3);
delay_ms(615);
output_low(pin_b3);
delay_ms(2485);
output_low(pin_b2);

output_high(pin_b2);
delay_ms(85);
```

```
output_low(pin_b2);
output_high(pin_b2);
output_high(pin_b4);
delay_ms(615);
output_low(pin_b4);
delay_ms(5985);
output_low(pin_b2);
output_high(pin_b2);
output_high(pin_b4);
delay_ms(615);
output_low(pin_b4);
delay_ms(1335);
output_low(pin_b2);
output_high(pin_b1);
output_high(pin_b4);
delay_ms(615);
output_low(pin_b4);
delay_ms(520);
output_low(pin_b1);
```

```
output_high(pin_b2);
output_high(pin_b4);
delay_ms(615);
output_low(pin_b4);
delay_ms(520);
output_low(pin_b2);

output_high(pin_b1);
output_high(pin_b4);
delay_ms(615);
output_low(pin_b4);
delay_ms(735);
output_low(pin_b1);

output_high(pin_b2);
output_high(pin_b4);
delay_ms(615);
output_low(pin_b4);
delay_ms(735);
output_low(pin_b2);
```

```
output_high(pin_b1);
output_high(pin_b4);
delay_ms(615);
output_low(pin_b4);
delay_ms(2485);
output_low(pin_b1);

output_high(pin_b1);
delay_ms(3100);
output_low(pin_b1);
output_high(pin_b6);
delay_ms(415);
output_low(pin_b6);
output_high(pin_b1);
output_high(pin_b4);
output_high(pin_b5);
delay_ms(165);
output_low(pin_b4);
delay_ms(250);
output_low(pin_b5);
```

```
delay_ms(3145);
output_low(pin_b1);
output_high(pin_b6);
delay_ms(656);
output_low(pin_b6);
output_high(pin_b2);
output_high(pin_b3);
delay_ms(815);
output_low(pin_b2);
delay_ms(4485);
output_low(pin_b3);
output_high(pin_b2);
output_high(pin_b4);
delay_ms(2950);
output_low(pin_b2);
delay_ms(3000);
output_low(pin_b4);
output_high(pin_b1);
```

```
output_high(pin_b3);
delay_ms(5950);
output_low(pin_b3);
delay_ms(6050);
output_low(pin_b1);

output_high(pin_b2);
output_high(pin_b4);
delay_ms(6050);
output_low(pin_b2);
delay_ms(50);
output_low(pin_b4);

output_high(pin_b2);
output_high(pin_b3);
delay_ms(3780);
output_low(pin_b2);
delay_ms(1470);
output_low(pin_b3);

output_high(pin_b4);
delay_ms(645);
```

```
output_low(pin_b4);
output_high(pin_b5);
delay_ms(250);
output_low(pin_b5);
output_high(pin_b2);
output_high(pin_b4);
output_high(pin_b5);
delay_ms(80);
output_low(pin_b4);
delay_ms(335);
output_low(pin_b5);
delay_ms(1265);
output_low(pin_b2);

output_high(pin_b1);
delay_ms(450);
output_low(pin_b1);
output_high(pin_b1);
output_high(pin_b4);
```

```
delay_ms(200);
output_low(pin_b4);
delay_ms(940);
output_low(pin_b1);

output_high(pin_b2);
output_high(pin_b4);
delay_ms(16.5);
output_low(pin_b2);
delay_ms(3.5);
output_low(pin_b4);

output_high(pin_b1);
delay_ms(7860);
output_low(pin_b1);

output_high(pin_b1);
output_high(pin_b4);
delay_ms(33);
output_low(pin_b1);
delay_ms(45.8);
output_low(pin_b4);
```

```
output_high(pin_b2);
delay_ms(5150);
output_low(pin_b2);

output_high(pin_b1);
output_high(pin_b4);
delay_ms(2430);
output_low(pin_b4);
delay_ms(2720);
output_low(pin_b1);

output_high(pin_b2);
delay_ms(2785);
output_low(pin_b2);

output_high(pin_b2);
output_high(pin_b3);
delay_ms(2430);
output_low(pin_b3);
delay_ms(2720);
output_low(pin_b2);
```

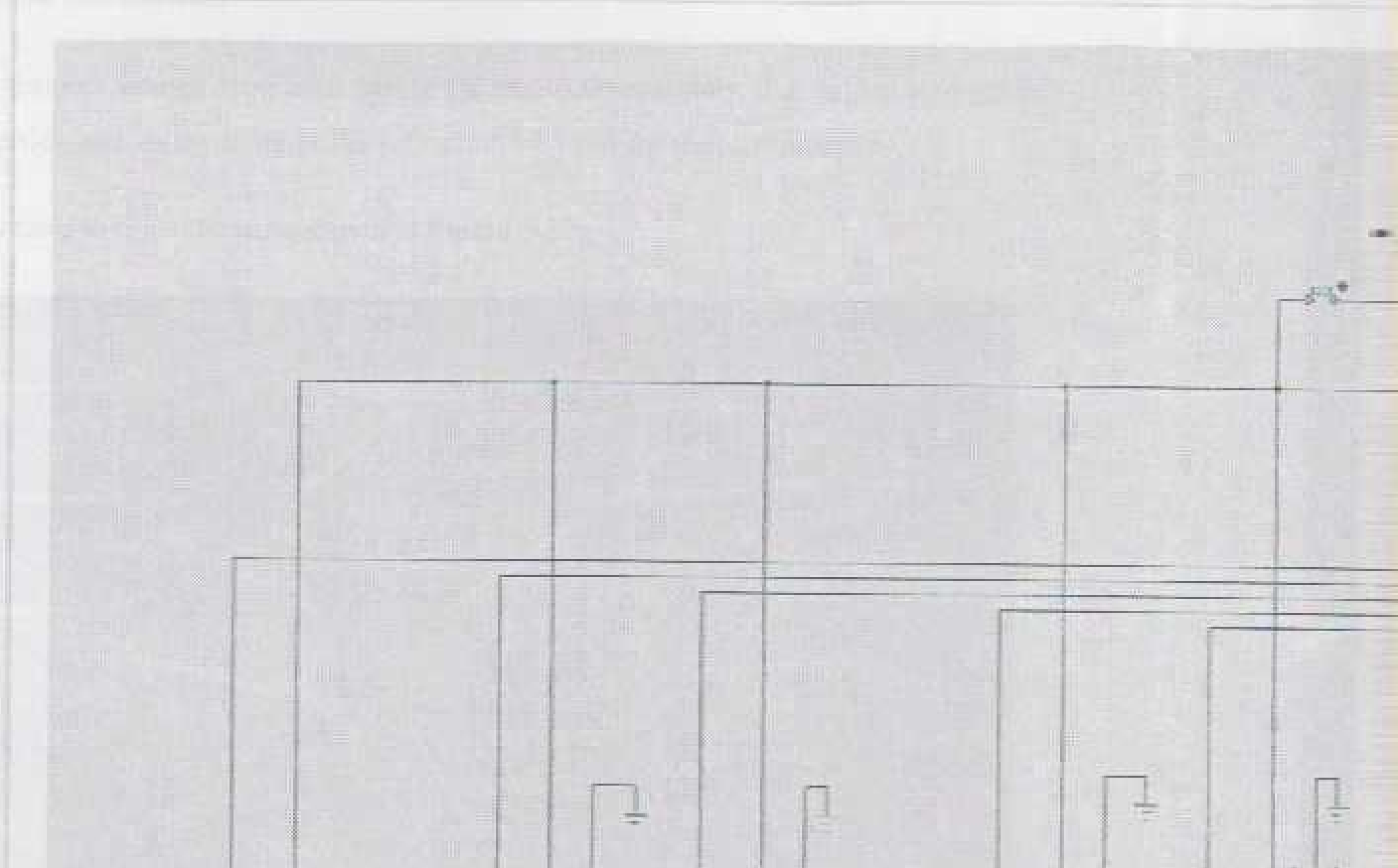
```
output_high(pin_b5);
delay_ms(250);
output_low(pin_b5);

output_high(pin_b1);
output_high(pin_b4);
output_high(pin_b6);
delay_ms(833);
output_low(pin_b4);
delay_ms(382);
output_low(pin_b6);
delay_ms(2735);
output_low(pin_b1);

}
```

These program in c language is qualifies us to make tests on the proteus application program.

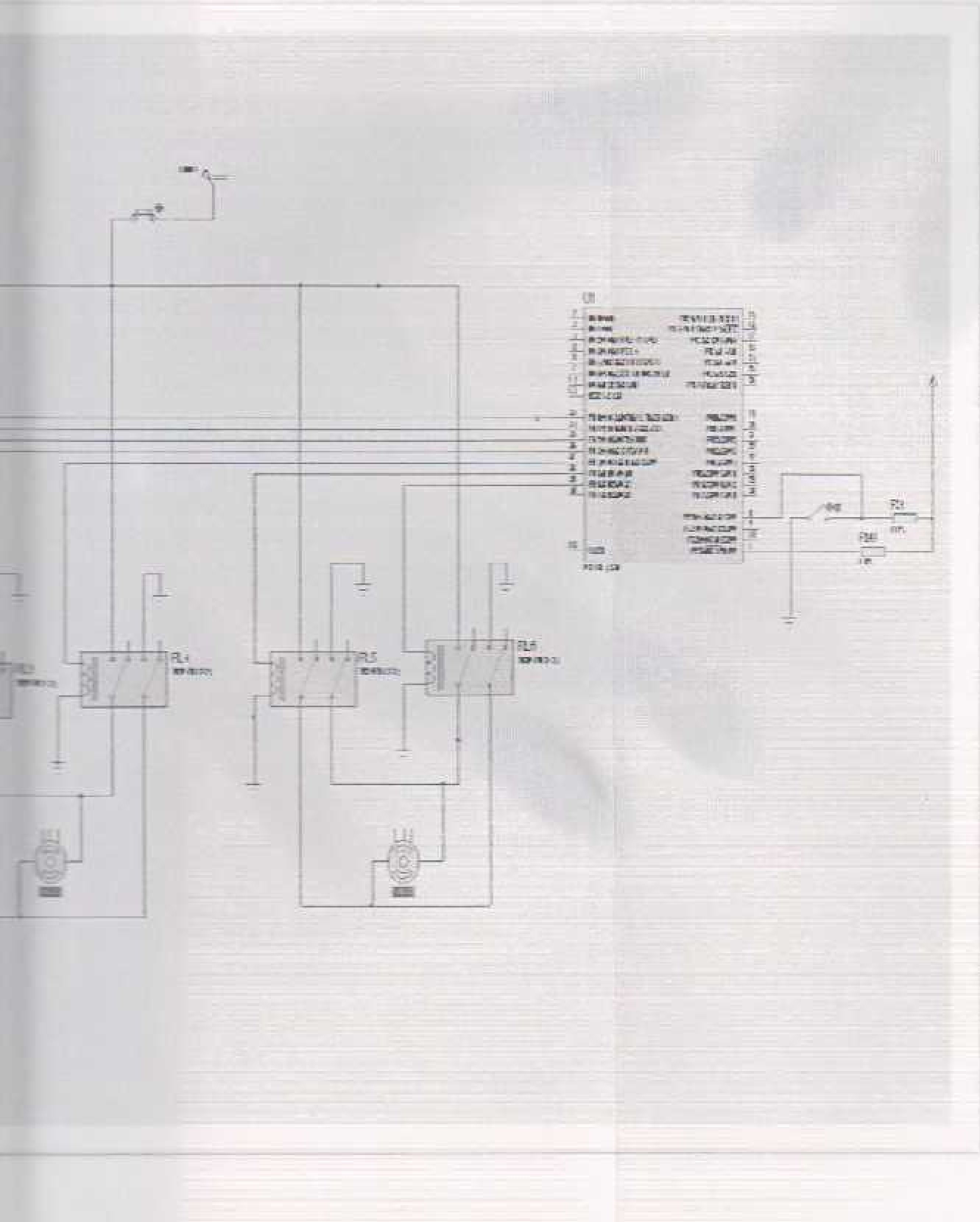
## 6.4 Proteus application

As shown in the Scheme B below, the connection of the pic input and output, when the input switch is on, the pic start the program contents step by step with the delay times.

Scheme B Proteus project conn



oteus project connection



The output pins is connected to relays to translate power from low voltage from pic and high voltage from the single phase to motors.

## 6.5 Catia simulation

From CATIA features we can draw each part of the machine separately, thin collect it to get full machine properties, and ability to make the animation we need for the movable parts.

We are mainly used [illegible]

The output pins is connected to relays to translate power from low voltage from pic and high voltage from the single phase to motors.

## 6.5 Catia simulation

From CATIA features we can draw each part of the machine separately, thin collect it to get full machine properties, and ability to make the animation we need for the movable parts.

We are mainly need to draw the parts shown in Figure 6-22.

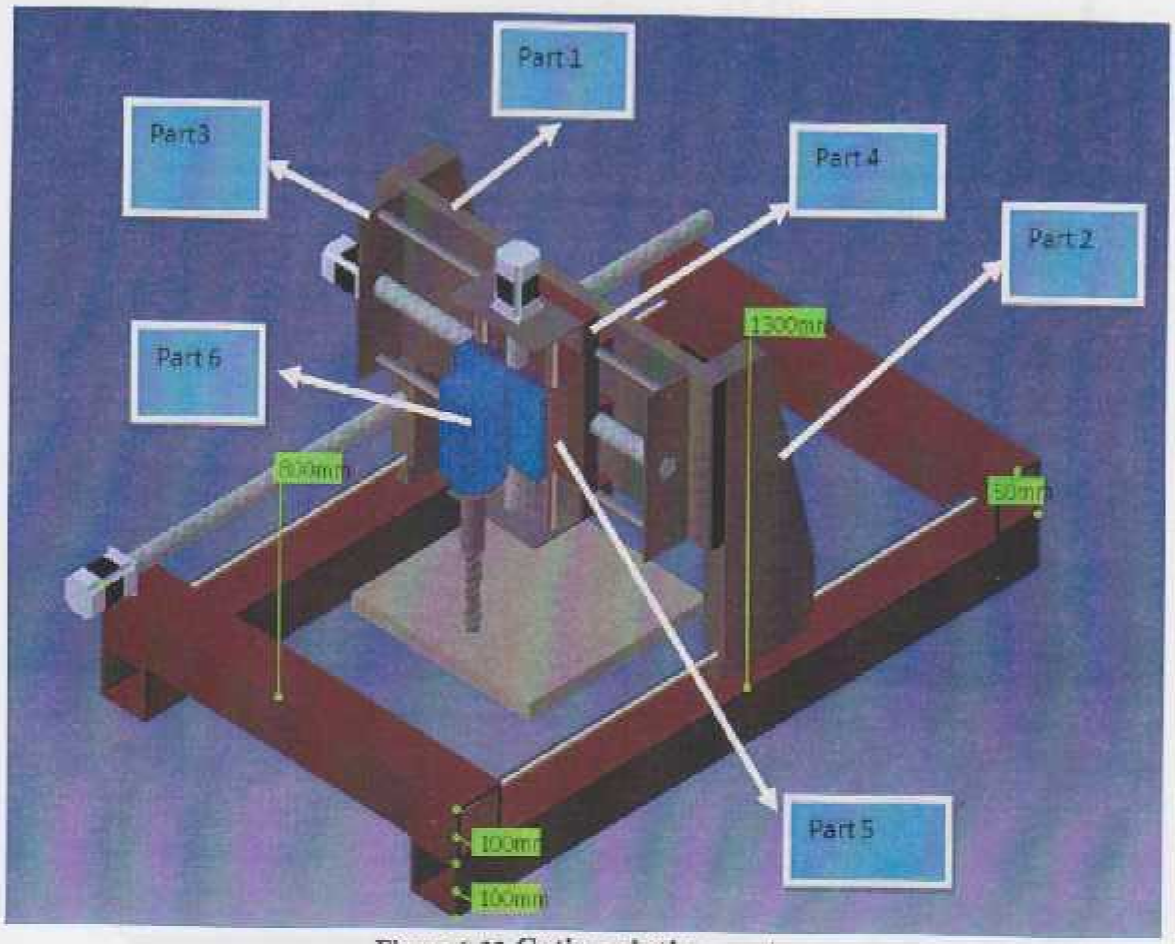



**Figure 6-22 Catia painting parts**

### 1) Part one

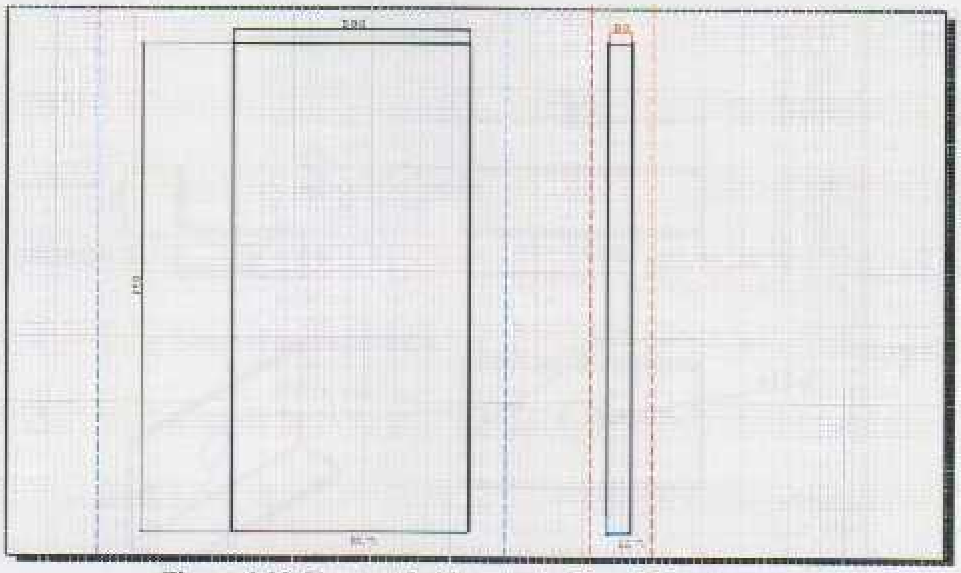


**Figure 6-23 Constant bridge carries Y and Z motor**

### 2) Part two

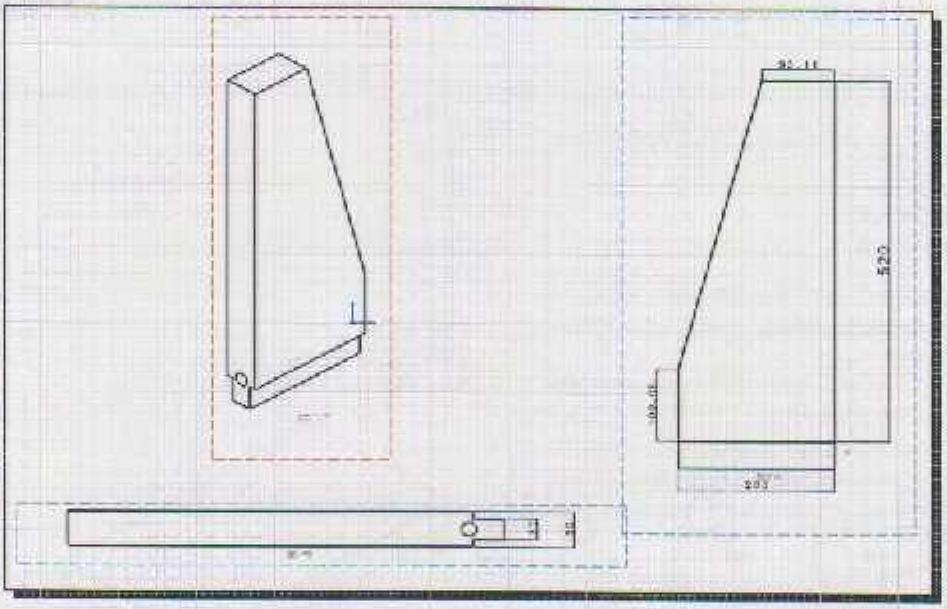


**Figure 6-24 Columns carries the fixed bridge**

3) Part three

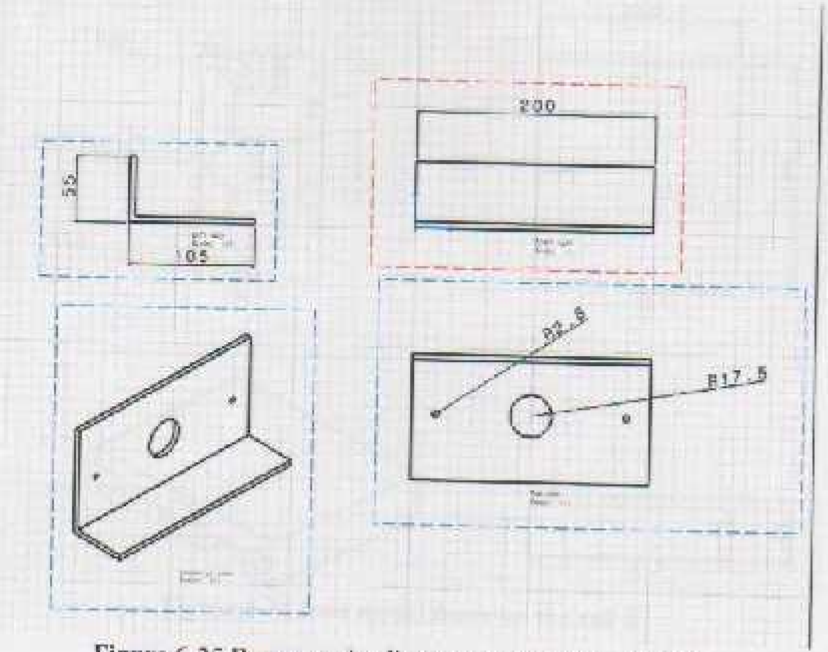



Figure 6-25 Beams and rail carry Z motor component

4) Part four

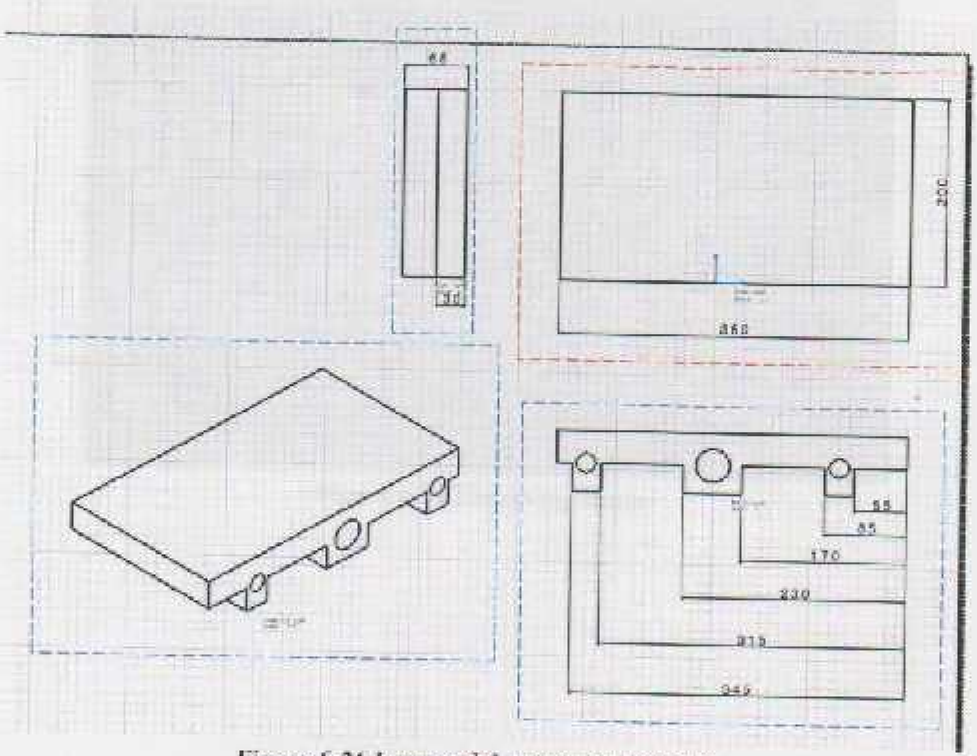
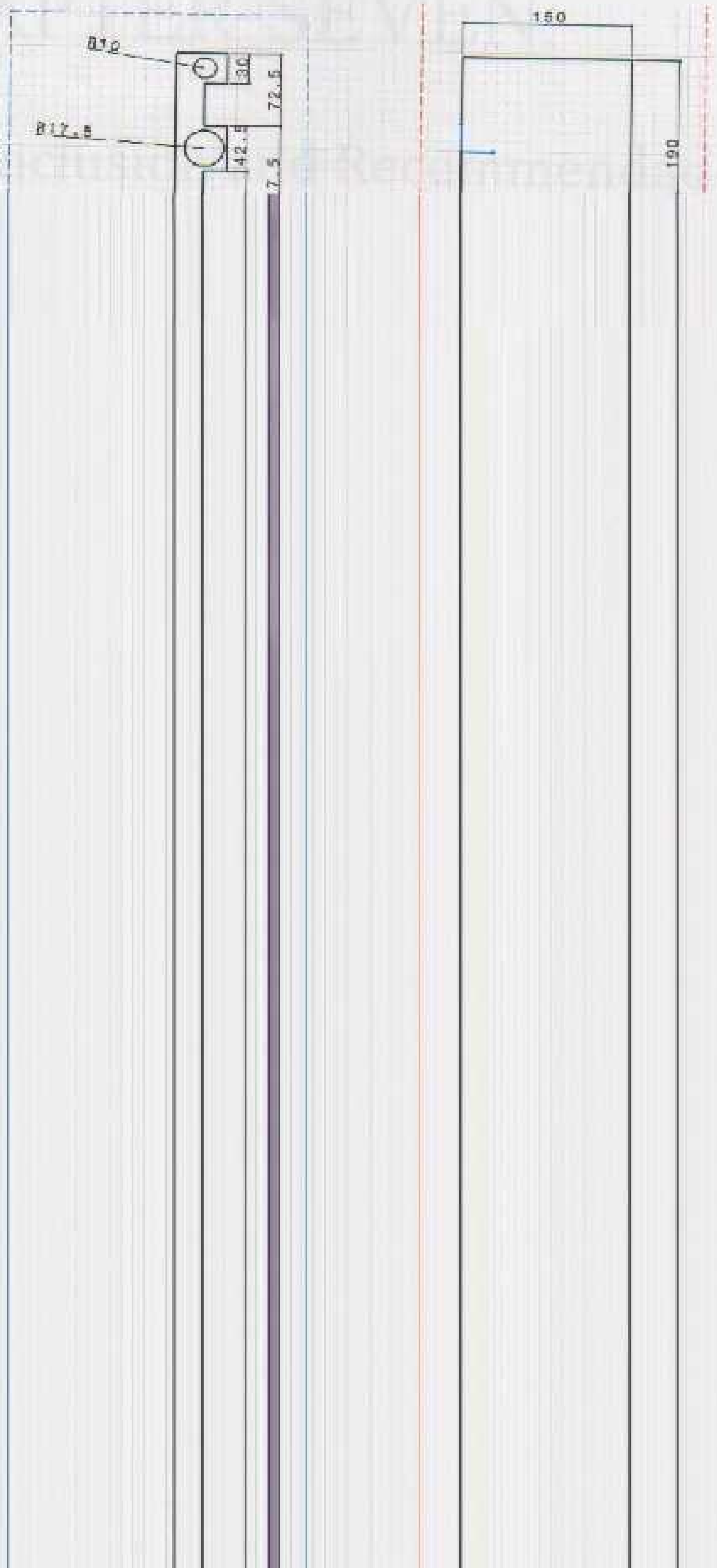



Figure 6-26 Iron model move up the rail Y

5) Part five



5) **Part five**

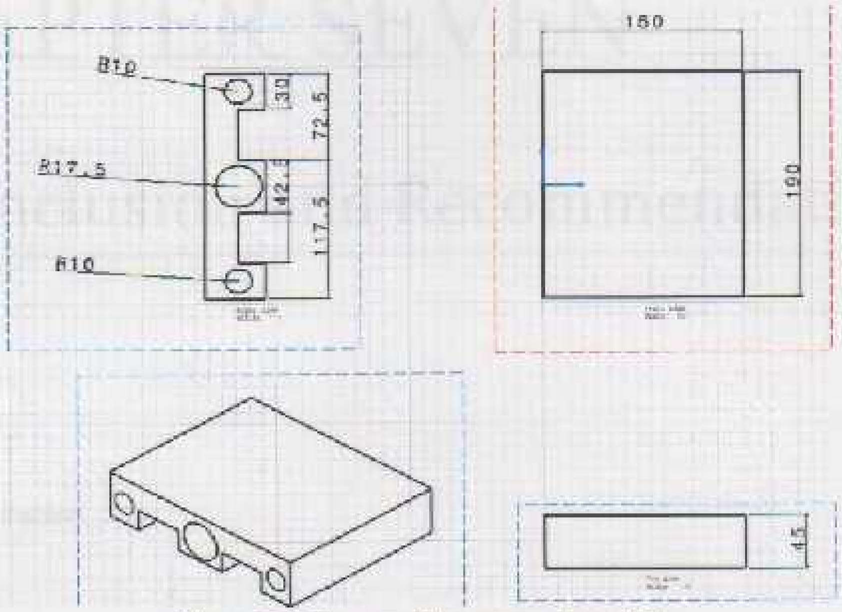



**Figure 6-27 Iron model move up the rail Z**

6) **Part six**

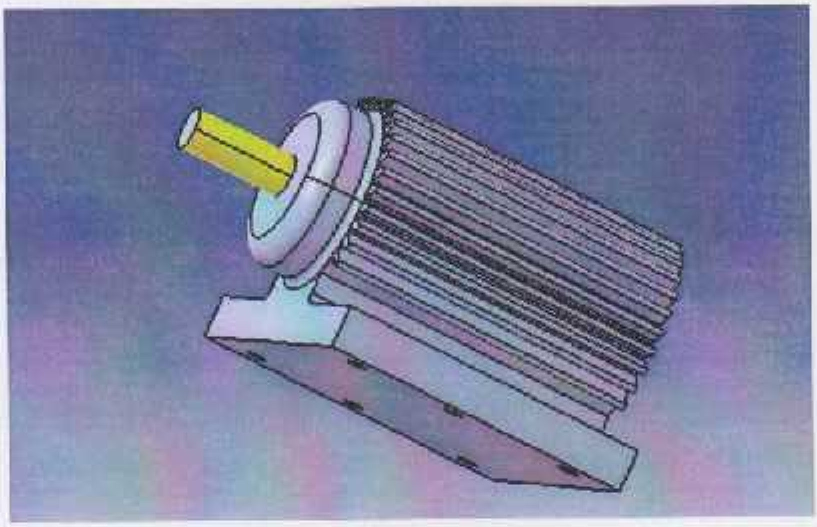


**Figure 6-28 Engraving motor**

# CHAPTER SEVEN

## Conclusion and Recommendation

**7.1 Conclusion**

**7.2 Recommendation**

## 7.1 Conclusion

After the search in this project we conclude the following:

1. We can implement the system with the component with spatial controllers for CNC machine, which is prohibited in our land.
2. Mk1 CNC controllers has spatial component sense the G code, we can't realize it easily.
3. To design the machine we aim to implement we need three servo motors with the following power values:
   - Motor X with 596.6 watt
   - Motor Y with 175.8 watt
   - Motor Z with 103.6 watt
4. We can replace the CNC controllers with microcontrollers but with the toughest conditions.
5. Microcontrollers can just representation one case of CNC engraving machine.
6. We can test the microcontrollers chip in proteus application system, and connection procedure with its features.
7. Practically we can implement a module to prove the system work.

## 7.2 Recommendations

- ❖ To implement this project practically when support is available.
- ❖ Give a chance for computers engineers to find a software solutions for the project, through a complete programming contain any G code can be extracted from different paintings, with the participation of some electrical engineers.
- ❖ To find a controller with high response with CNC machine to prevent the interrupts that may occurs as in microcontrollers.

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