A PROJECT REPORT
ON

"CNC PLASMA CUTTING MACHINE"

Submitted to

DEPARTMENT OF MECHANICAL ENGINEERING
AIKTC

UNDER THE GUIDANCE OF
PROF. YUSUF KHAN

ANJUMAN-I-ISLAM'S KALSEKAR
TECHNICAL CAMPUS
SCHOOL OF ENGINEERING & TECHNOLOGY

2020-2021

AFFILIATED TO
UNIVERSITY OF MUMBAI

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In Partial Fulfillment of the Requirement for the Award of BACHELOR'S DEGREE IN MECHANICAL ENGINEERING

BY

KHAN ALTAMASH	17ME25
KHAN FAIZAN AHMED	17ME31
KHAN HIFZURREHMAN	17ME38
KHAN MUTASSIM	17ME40

UNDER THE GUIDANCE OF
PROF. YUSUF KHAN

DEPARTMENT OF MECHANICAL ENGINEERING
Anjuman-I-Islam's Kalsekar Technical Campus
SCHOOL OF ENGINEERING & TECHNOLOGY
Plot No. 2 3, Sector - 16, Near Thana Naka,
Khandagaon, New Panvel - 410206

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Department of Mechanical Engineering
SCHOOL OF ENGINEERING & TECHNOLOGY
Plot No. 2 3, Sector - 16, Near Thana Naka,
Khandagaon, New Panvel - 410206

CERTIFICATE

This is to certify that the project entitled

"CNC PLASMA CUTTING MACHINE"

Submitted by

KHAN ALTAMASH	**17ME25**
KHAN FAIZAN AHMED	**17ME31**
KHAN HIFZURREHMAN	**17ME38**
KHAN MUTASSIM	**17ME40**

Is a record of bonafide work carried out by them, in the partial fulfillment of the requirement for the award of Degree of Bachelor of Engineering (Mechanical Engineering) at ***Anjuman-I-Islam's Kalsekar Technical Campus, Navi Mumbai*** under the University of Mumbai. This work is done during year 2020-2021, under our guidance.

Date: / /

(Prof. YUSUF KHAN)
Project Guide

(Prof. ZAKIR ANSARI)
HOD, Mechanical Department

DR. ABDUL RAZAK HONNUTAGI
Director

FORWARDING LETTER

Anjuman-I-Islam's Kalsekar Technical Campus,
New Panvel,
Navi Mumbai,
410206

Dear Reader,

We the students of BEME01 assigned with the below mentioned group code are submitting the report entitled "CNC PLASMA CUTTING MACHINE".

Yours Sincerely,
BEME01

ACKNOWLEDGEMENTS

Our first experience of project has been successful, thanks to the supporting staff, my friends and college with gratitude. We wish to acknowledge all of them however we wish to make special mention of following.

First of all we are thankful to our project guide **Prof. YUSUF KHAN** Assistant Professor, Department of Mechanical Engineering, AIKTC, School of Engineering, and New Panvel under whose guidance we were able to complete our project. We are wholeheartedly thankful to him for giving his valuable time and attention and providing a systematic way for completing all projects in time.

We would like to express our sincerest appreciation towards **Dr. ABDUL RAZAK HONUTAGI,** Director, AIKTC, New Panvel, **Prof. Zakir Ansari**, Head of Department of Mechanical Engineering and **Prof. YUSUF KHAN**, Project Coordinator whose valuable assistance supported us to complete this project.

We must express sincere gratitude to all the staff members of mechanical engineering who helped us directly or indirectly during the course of work.

KHAN ALTAMASH 17ME25
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Project I: Approval for Bachelor of Engineering

This project entitled ***"CNC PLASMA CUTTING MACHINE "by*** **ALTAMASH KHAN, KHAN FAIZAN AHMED, KHAN HIFZURREHMAN, KHAN MUTASSIM** is approved for the degree of ***Bachelor of Engineering in the department of Mechanical Engineering.***

Examiners

1.....

2.....

Supervisors

1.....

2.....

Chairman

.....

DECLARATION

We hereby declare that the project work entitled "CNC PLASMA CUTTING MACHINE ", is a record of an original work done by us under the guidance of Prof. Yusuf khan, assistant professor, Mechanical department, AIKTC, New Panvel and this project work is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering in Mechanical Engineering.

The results embodied in this project report have not been submitted to any other university or institution for the award of any degree or diploma.

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ABSTRACT

In the developing stages of all conventional machining processes there is a special and most important type of non-conventional machining has been developed during early years of mechanical era. The most important and reliable development is the plasma arc cutting machine due to its high rate of cutting speed and greater accuracy lead to the development of this machining process. The most important aspect of this type is that it can cut any type of harder material through hot jet of plasma. Another main and most important is cost parameter because of material used in this machine is of low cost efficient compared to any other machining processes in the market. The modern framework and body frame of mechanical components has become the heart of the any industry. This book illustrates the design of plasma cutting machine through set of design considerations. The rapid developing technology i.e., plasma cutting machine plays an important role in the industry, the plasma cutting machine uses jet of hot plasma to cut metal pieces using some set of components they are CNC machine, controllers, machine table and most 2D software which used to convert images to some set of CNC codes to operate in specified coordinates.

Keywords: Oxyfuel, Plasma CNC machine, Gantry, CNC Controller, grbl software.

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INTRODUCTION

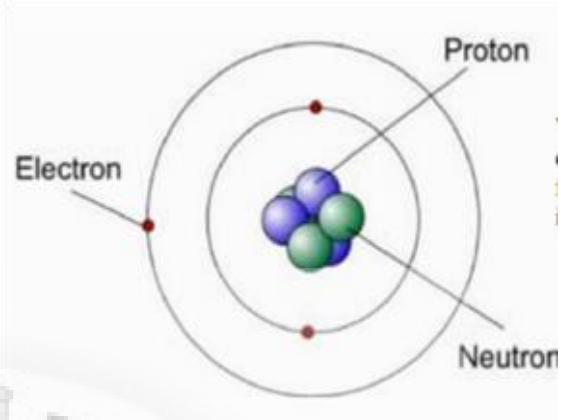
Introduction

Plasma cutting torch is a commonly used tool for cutting metals for a wide variety of purposes. A hand-held plasma torch is an excellent tool for quickly cutting through sheet metal, metal plates, straps, bolts, pipes, etc. Hand-held plasma torches also make an excellent gouging tool, for back-gouging weld joints or removing defective welds. A hand torch can be used for cutting small shapes from steel plate, but it's impossible to get good enough part accuracy or edge quality for most metal fabrication. That is why a CNC plasma is necessary. Once the programming is put into the machine, a CNC machine will operate on its own. The speed and position of machinery and involved tools are run through software. CNC machines operate like robots. "CNC plasma" system is a machine that carries a plasma torch, and can move that torch in a path directed by a computer. The term "CNC" refers to "Computer Numerical Control", which means that a computer is used to direct the machines motion based on numerical codes in a program. The plasma cutting is a process of cutting in which it uses a jet of plasma through electrically conducting materials, the material includes steel aluminum and other metals. The positive and negative terminals create path between current to pass through a nozzle of varying shape constrict a passage of highly ionized gas i.e., air, oxygen and inert gas. The low amps and low cost create more and more research in the process. The ability to cut metals and to attain higher accuracy and finish, the plasma arc cutting process has useful advantages compared to other machining processes thus it is being carried in industries from large CNC operated machines to small scale industries.

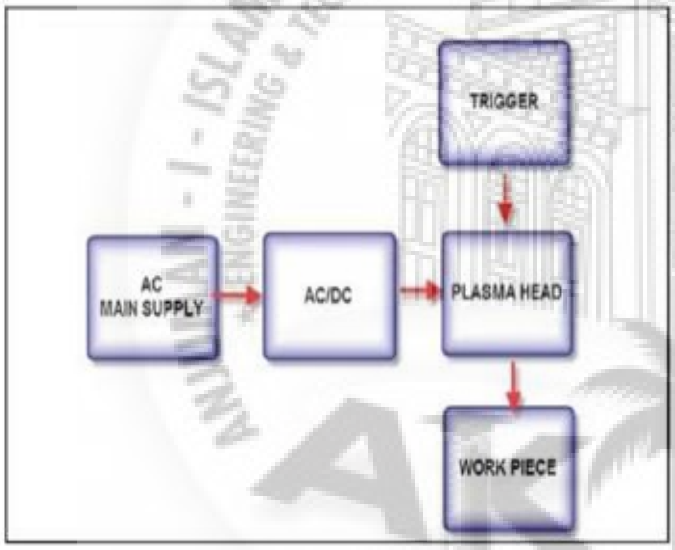
Plasma cutting is a process that cuts through electrically conductive materials by means of an accelerated jet of hot plasma. Typical materials cut with a plasma torch include steel, stainless steel, aluminum, brass and copper, although other conductive metals may be cut as well. Plasma cutting is often used in fabrication shops, automotive repair and restoration, industrial construction, and salvage and scrapping operations. Due to the high speed and precision cuts combined with low cost, plasma cutting sees widespread use from large-scale industrial CNC applications down to small hobbyist shops.

What is plasma?

- Plasma is a fourth state of matter.
- The other three states of matter are Solids, Liquids, & Gases
- When the gas is heated to above saturated temperature the resulted matter is known as PLASMA.



Plasma cutting basics:



The plasma cutter includes more & more units the below fig. shows the basic idea of plasma cutter unit.

The exchange of molecules creates heat that generated heat is then ionized and passed to the torch lifter and then to narrow restricted passage where highly ionized gas transfers into the work piece and removes the metal to the required shape. Around 28.7% of the gas is used to cut the metal and remaining 71.3% is used to remove metal and cooling. Plasma is the utilization of electricity to expand an ionized gas through space create heat to come up to a temperature that will cut directly through metal.

The plasma cutter utilizes compressed air or gas to ionize and create plasma. Once the compressed air or gas make contact with the electrode, it ionizes and creates more pressure, resulting in a stream of pure plasma. This is hot enough to cu directly through materials.
The figure shows the components of plasma head.

i Plasma gas.
ii Electrode which is connected to the negative DC power supply.
iii Nozzle which is container that focuses the plasma gas around the electrode.

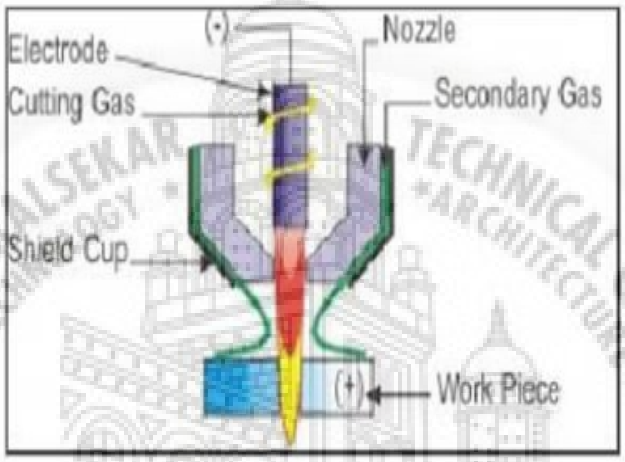


Fig. 3. Plasma head

The plasma cutter circuit includes three major classifications

a. Power circuit
b. Trigger circuit
c. Control circuit

LITERATURE REVIEW

Literature Review

CNC machining is a manufacturing process in which pre-programmed computer software dictates the movement of factory tools and machinery. The process can be used to control a range of complex machinery, from grinders and lathes to mills and routers. With CNC machining, three-dimensional cutting tasks can be accomplished in a single set of prompts. A CNC machine allows for three-dimensional cutting tasks to be accomplished with a single set of prompts. This means that it requires very little input from human operators. Plasma cutting is a process that is used to cut steel and other metals (or Sometimes other materials) using a plasma torch. In this process, an inert gas (Argon) is blown at high speed out of a nozzle and at the same time an electrical arc is formed through that gas from the nozzle to the surface being cut, turning some of that gas to plasma. The plasma is sufficiently hot to melt the metal being cut and moves sufficiently fast to blow molten metal away from the cut. Plasma can also be used for plasma arc welding and other applications. Plasma is typically an ionized gas. Plasma is considered to be a distinct state of matter, apart from gases, because of its unique properties. Ionized refers to presence of one or more free electrons, which are not bound to an atom or molecule. The free electric charges make the plasma electrically conductive so that it responds strongly to electromagnetic fields. The Arc type uses a two cycle approach to producing plasma. First, a High-voltage, low current circuit is used to initialize a very small high intensity spark within the torch body, thereby generating a small pocket of plasma gas. This is referred to as the pilot arc. The pilot arc has a return electrical path built into the torch head. The pilot arc will maintain until it is brought into proximity of the work piece where it ignites the main plasma cutting arc. Plasma arcs are extremely hot and are in the range of 15,000 degrees Celsius. Oxy fuel cuts by burning, or oxidizing, the metal it is severing. It is therefore limited to steel and other ferrous metals which support the oxidizing process. Metals like aluminum and stainless steel form an oxide that inhibits further oxidization, making conventional oxy-fuel cutting impossible. Plasma cutting, however, does not rely on oxidation to work, and thus it can cut aluminum, stainless and any other conductive material. While different gasses can be used for plasma cutting, most people today use compressed air for the plasma gas. In most shops, compressed air is readily available, and thus plasma does not require fuel gas and compressed oxygen for operation. Plasma cutting is typically easier for the novice to master, and on thinner materials, plasma cutting is much faster than oxy-fuel cutting. However, for heavy sections of steel (1inch and greater), oxy-fuel is still preferred since oxy-fuel is typically faster and, for heavier plate applications, very high capacity power supplies are required for plasma cutting applications.

WORKING

Working

CNC Machine and Mechanical Setup

The most important aspect in the machine is design of some useful structures, the main understandings include linear motions & linear bearings. The solid works inventor application is used in the design of this structures.

Linear motion (LM) plays a vital role in all linear CNC machines; it is responsible for three primary tasks.

a. Support machine components.
b. Guide the machine in a precise linear motion with minimal friction.
c. Support lateral loads.

An LM system is composed of some type of linear bearing and the linear bearing guides.

The most famous types of bearings and guides are in figure below:

(a) Rail &guide (b) rod & bushing (c) v-groove

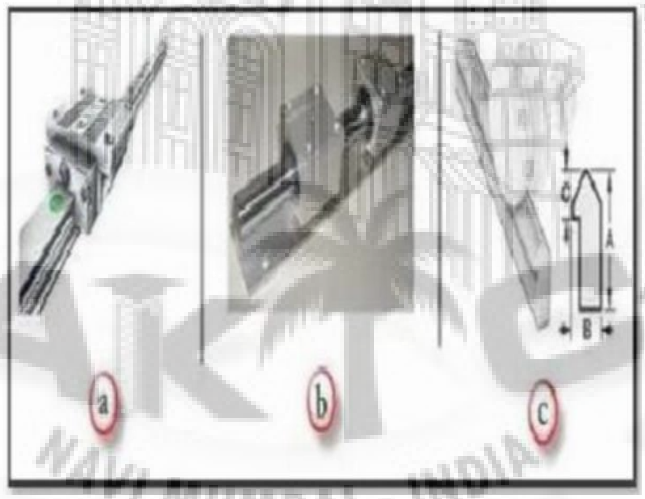


Fig. 4. Types of linear motion systems

Rods and bushings system is selected for our machine because of it is high load capacity, low friction coefficient, good accuracy, low cost and easy maintenance.

A bearing is a device used to allow constrained relative motion between two or more parts, typically rotation or linear movement.

Types of bearing used are as follows,

1. Ball bearing
2. Thrust bearing
3. Linear bearing

Mechanical parts:

The mechanical parts are designed by using solid works inventor software and it includes following parts.

1. Table
2. Y-axis
3. X-axis
4. Z-axis
5. Plasma head holder

Y-axis:

In the Y-axis, Ball bearing is used to facilitate the linear motion and rack and pinion is used to drive the axis. As shown in the figure below.

It have many advantages:

a. Minimum backlash
b. Good accuracy
c. Easy to replace
d. Minimum cost

X-Axis:

Linear motions for rods and bushing are carried out in X-axis. It makes use of rack and pinion setup for driver.

Z-axis:

The main part of the machine is the z-axis motion hence it is needed to be carefully & precisely designed.

CNC Controller:

The CNC controller has played an important role in the development of this plasma arc cutting gantry because any motion that we carry out requires lot more control over the equipment and hence this can be done through stepper motor placed inside it. It carries out the motions in required amount through number of steps say 200 and specially designed synchronous, brushless electric that convert pulses into mechanical shaft rotations.

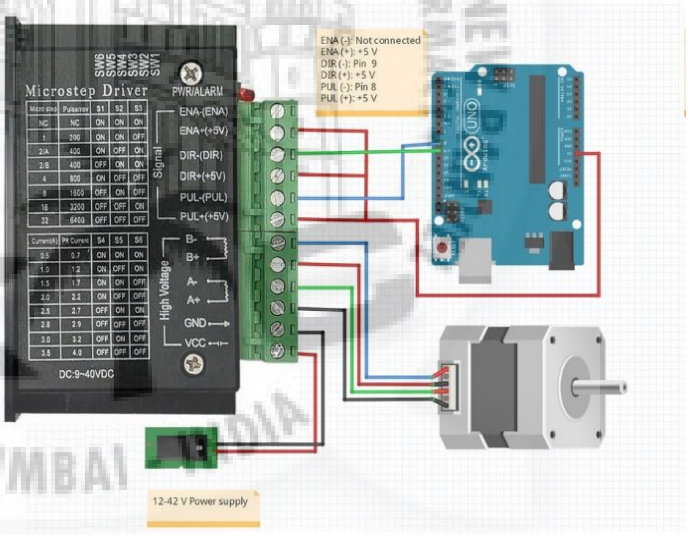
TECHNICAL DETAILS

Technical Details

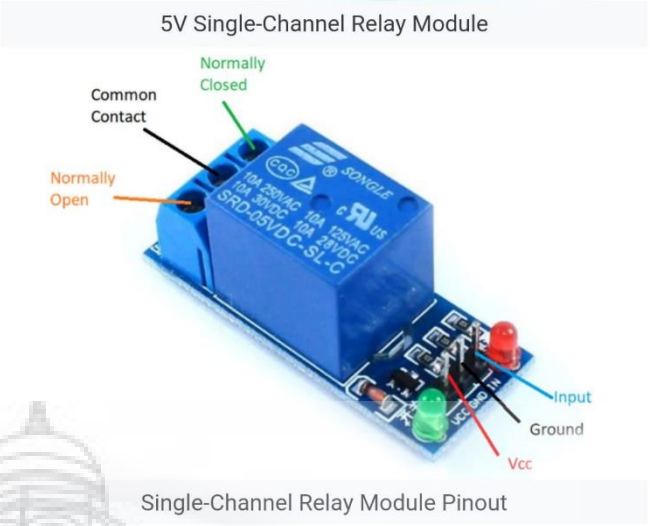
1] Nema 23: Nema 23 is a stepper motor with a 2.3 x 2.3 inch faceplate. It is suitable for 3d printer, robot arm, cnc machine, etc. In low-speed applications, the stepper motor can be driven at the desired speed without missing a single step.

This stepper motor has different torque, the max torque is 3 Nm. We provide nema 23 stepper motor datasheet and torque curve. The torque is different for each operating speed, but decreases as the stepping speed increases. The reason is the operating principle of the stepper motor. The drive signal of the stepper motor generates a magnetic field in the coil of the motor to generate a step force. The time it takes for the magnetic field to reach its maximum intensity depends on the inductance of the coil, the drive voltage and current limit. As the drive speed increases, the coil maintains its full strength for a shorter period of time and the torque that the motor can produce decreases.

2] Motor Driver: TB6600 arduino Stepper Motor Driver is an easy-to-use professional stepper motor driver, which could control a two-phase stepping motor. It is compatible with Arduino and other microcontrollers that can output a 5V digital pulse signal. TB6600 arduino stepper motor driver has a wide range power input, 9~42VDC power supply. And it is able to output 4A peak current, which is enough for the most of stepper motors. The stepper driver supports speed and direction control. You can set its micro step and output current with 6 DIP switch. There are 7 kinds of micro steps (1, 2 / A, 2 / B, 4, 8, 16, 32) and 8 kinds of current control (0.5A, 1A, 1.5A, 2A, 2.5A, 2.8A, 3.0A, 3.5A) in all. And all signal terminals adopt high-speed optocoupler isolation, enhancing its anti-high-frequency interference ability. As a professional device, it is able to drive 57, 42-type two-phase, four-phase, hybrid stepper motor.



3] Relay: A power relay module is an electrical switch that is operated by an electromagnet. The electromagnet is activated by a separate low-power signal from a micro controller. When activated, the electromagnet pulls to either open or close an electrical circuit.



A simple relay consists of wire coil wrapped around a soft iron core, or solenoid, an iron yoke that delivers a low reluctance path for magnetic flux, a movable iron armature and one or more sets of contacts. The movable armature is hinged to the yoke and linked to one or more set of the moving contacts. Held in place by a spring, the armature leaves a gap in the magnetic circuit when the relay is de-energized. While in this position, one of the two sets of contacts is closed while the other set remains open.

When electrical current is passed through a coil, it generates a magnetic field that in turn activates the armature. This movement of the movable contacts makes or breaks a connection with the fixed contact. When the relay is de-energized, the sets of contacts that were closed, open and breaks the connection and vice versa if the contacts were open. When switching off the current to the coil, the armature is returned, by force, to its relaxed position. This force is usually provided by a spring, but gravity can also be used in certain applications. Most power relays are manufactured to operate in a quick manner.

4] Limit Switch: In electrical engineering a limit switch is a switch operated by the motion of a machine part or presence of an object.

They are used for controlling machinery as part of a control system, as a safety interlocks, or to count objects passing a point. A limit switch is an electromechanical device that consists of an actuator mechanically linked to a set of contacts. When an object comes into contact with the actuator, the device operates the contacts to make or break an electrical connection.

5] Rack & pinion:

A rack and pinion is a type of linear actuator that comprises a circular gear (the pinion) engaging a linear gear (the rack), which operate to translate rotational motion into linear motion. Driving the pinion into rotation causes the rack to be driven linearly. Driving the rack linearly will cause the pinion to be driven into a rotation. A rack and pinion drive can use both straight and helical gears. Helical gears are preferred due to their quieter operation and higher load bearing capacity. The maximum force that can be transmitted in a rack and pinion mechanism is determined by the tooth pitch and the size of the pinion.

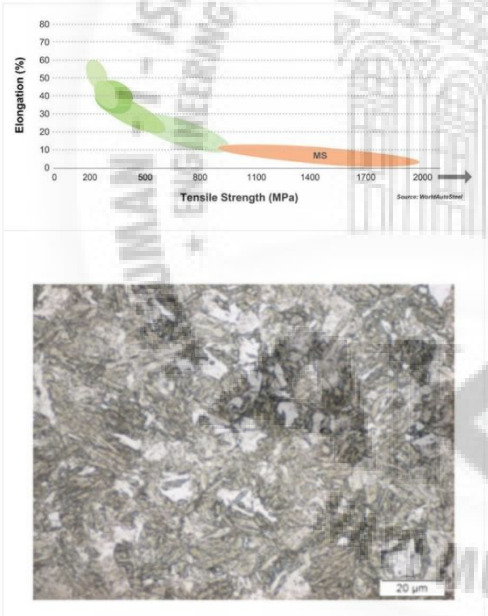


Figure 2-12: Microstructure for MS 950/1200

For our gantry, we used a 1.5mm module with 4.5mm of pitch and 1000mm length for each rack. The pinion is 42mm in diameter, considering the dynamic load, speed and working load of the machine we used MS material (for better reliability and high working load use hardened steel rack and pinion).

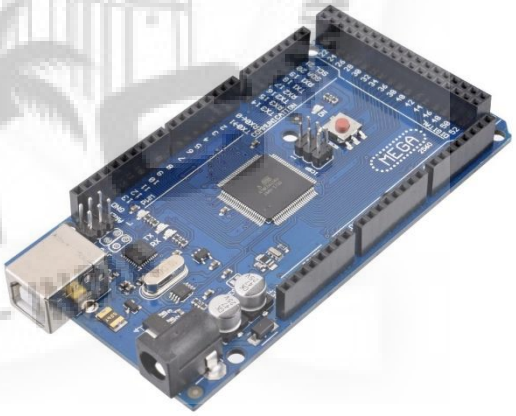
The MS steels are characterized by a martensitic matrix containing small amounts of ferrite and/or bainite. Within the group of multiphase steels, MS steels show the highest tensile strength level. This structure also can be developed with post-forming heat treatment. MS steels provide the highest strengths, up to 1700 MPa ultimate tensile strength. MS steels are often subjected to post-quench tempering to improve ductility and can provide adequate formability even at extremely high strengths.

6]Bearings : Bearings are mechanical assemblies that consist of rolling elements and usually inner and outer races which are used for rotating or linear shaft applications, and there are several different types of bearings, including ball and roller bearings, linear bearings, as well as mounted versions that may use either rolling element bearings or plain bearings. Ball bearings have spherical rolling elements and are used for lower load applications, while roller bearings use cylindrical rolling elements for heavier load carrying requirements. Linear bearings are used for linear movements along shafts and may also have rotational capabilities.

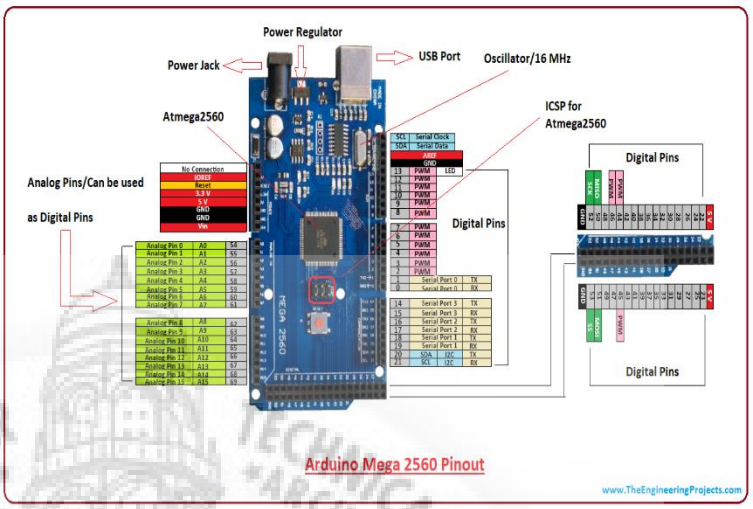
Linear Bearings

Linear Bearings are mechanical assemblies that consist of ball or roller elements captured in housings and used to provide linear movement along shafts. Linear bearings are used primarily in machinery that requires linear movement and positioning along shafts. They also may have Secondary rotational features depending on the design. Considerations include Lower friction and higher accuracies compared with bushings Costlier and more complex than bushings See Thomas Supplier Discover Platform for Suppliers of Linear Bearings. Linear bearings are used exclusively in linear applications such as slide tables.

7] Arduino: Arduino Mega 2560 is a Microcontroller board based on Atmega2560. It comes with more memory space and I/O pins as compared to other boards available in the market. There are 54 digital I/O pins and 16 analog pins incorporated on the board that make this device unique and stand out from others. Out of 54 digital I/O, 15 are used for PWM (pulse width modulation). A crystal oscillator of 16MHz frequency is added on the board. This board comes with USB cable port that is used to connect and transfer code from computer to the board. DC power jack is coupled with the board that is used to power the board. Some version of Arduino board lacks this feature like Arduino Pro Mini doesn't come with DC power jack. ICSP header is a remarkable addition to Arduino Mega which is used for programming the Arduino and uploading the code from the computer.



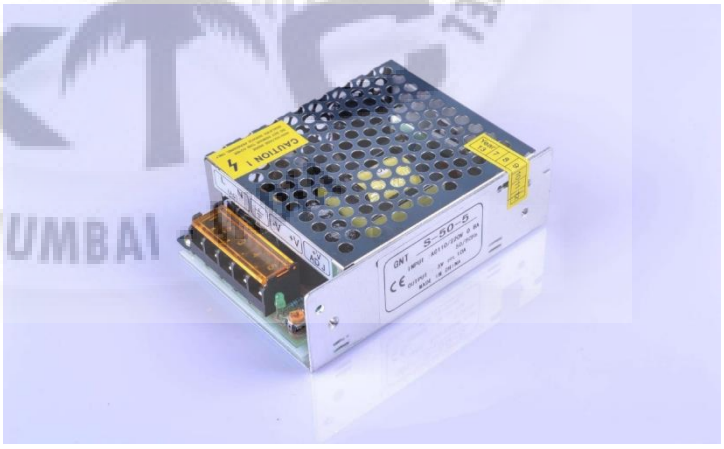
This board comes with two voltage regulator i.e. 5V and 3.3V which provides the flexibility to regulate the voltage as per requirements as compared to Arduino Pro Mini which comes with only one voltage regulator.



There is no much difference between Arduino Uno and Arduino Mega except later comes with more memory space, bigger size and more I/O pins. Arduino software called Arduino IDE is used to program the board which is a common software used for all boards belonged to Arduino family. Availability of Atmega16 on the board makes it different than Arduino Pro Mini which uses USB to serial converter to program the board. There is a reset button and 4 hardware serial port called USART which produces a maximum speed for setting up communication.

Arduino Mega is specially designed for the projects requiring complex circuitry and more memory space. Most of the electronic projects can be done pretty well by other boards available in the market which make Arduino Mega uncommon for regular projects. However, there are some projects that are solely done by Arduino Mega like making of 3D printers or controlling more than one motors, because of its ability to store more instructions in the code memory and a number of I/O digital and analog pins.

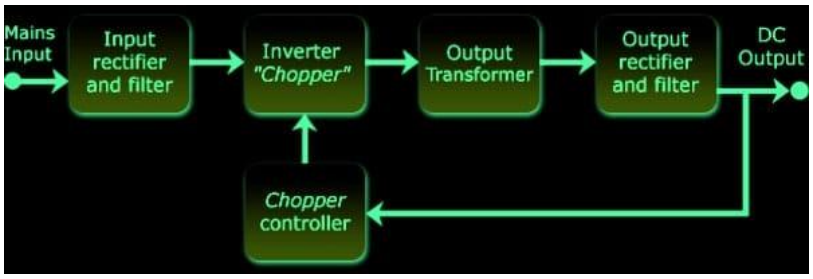
8] Power Supply:



Switched Mode Power Supply uses a switching regulator to convert electric power efficiently. SMPS transfers electric power from a source (AC mains) to the load by converting the characteristics of current and voltage. SMPS always provide a well regulated power to the load irrespective of the input variations. SMPS incorporates a Pass transistor that switches very fast typically at 50Hz and 1 MHz between the on and off states to minimize the energy waste. SMPS regulates the output power by varying the on to off time using minimum voltage so that efficiency is very high compared to the linear power supply.

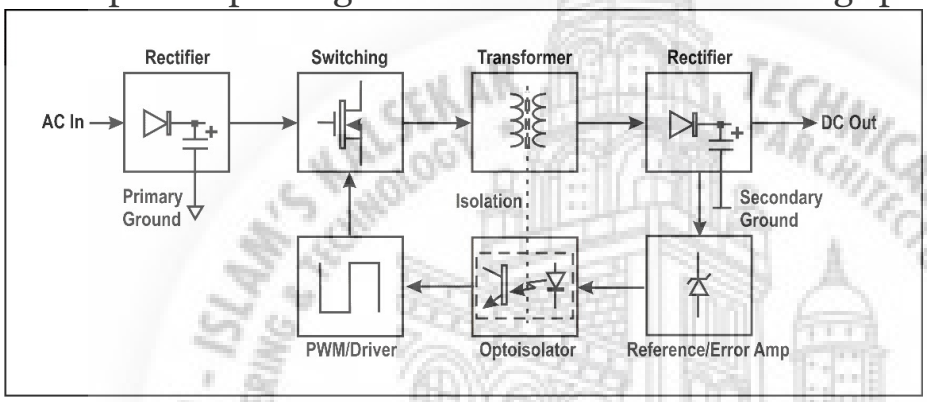
The SMPS essentially has

1. Input rectifier
2. Inverter
3. Voltage converter
4. Output regulator



Input rectifier

The AC input from mains is first rectified in the SMPS using a rectifier to convert it into DC. The rectifier consisting of a full wave diode bridge or module that produces an unregulated DC voltage to the Smoothing capacitor. The input AC passing into the rectifier has AC voltage pulses that may reduce the power factor. So control techniques are used to force the average input current to follow the sine wave.



Inverter

This stage converts the rectified DC into AC using a power oscillator. The power oscillator has a small output transformer with a few windings at the frequency 20-100 kHz. Switching is controlled by a MOSFET amplifier. The output AC voltage is usually isolated optically from the input AC by using an Optocoupler IC for safety reasons.

Components of SMPS Contd...

Voltage converter

This stage has a high frequency transformer and the inverted AC drives its primary windings. This creates the up and down voltage at the output. If DC is required, the output AC is converted to DC using a rectifier circuit using Silicon diodes or Schottky diodes (fast recovery and minimum loss of current and low forward voltage drop).

Output regulator

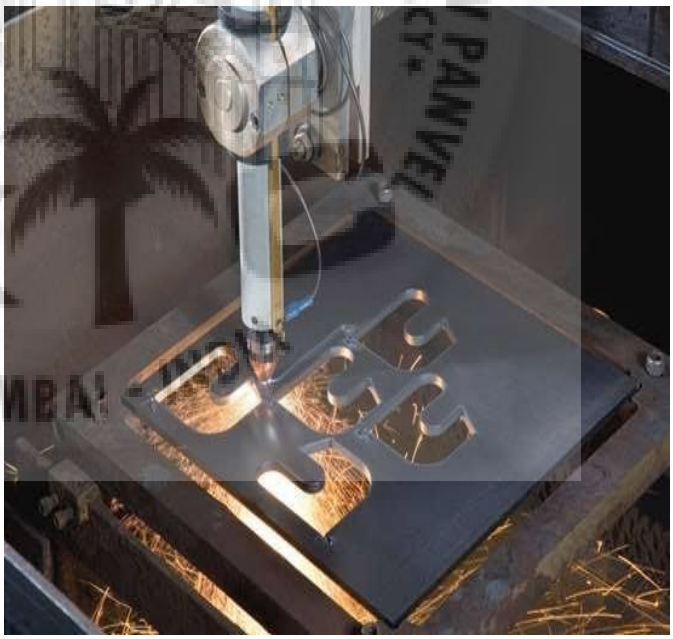
The output stage always monitors the output voltage by comparing with a reference voltage using a feedback system. For safety reasons, the output stage is isolated by an opt isolator as seen in the SMPS of computers. In some SMPS, Open loop regulation is used without feedback circuit and constant voltage is fed to the transformer input.

9] Plasma Cutter:

Plasma cutting is a process that cuts through electrically conductive materials by means of an accelerated jet of hot plasma. Typical materials cut with a plasma torch include steel, stainless steel, aluminum, brass and copper, although other conductive metals may be cut as well. Plasma cutting is often used in fabrication shops, automotive repair and restoration, industrial construction, and salvage and scrapping operations. Due to the high speed and precision cuts combined with low cost, plasma cutting sees widespread use from large-scale industrial CNC applications down to small hobbyist shops.

Specification:

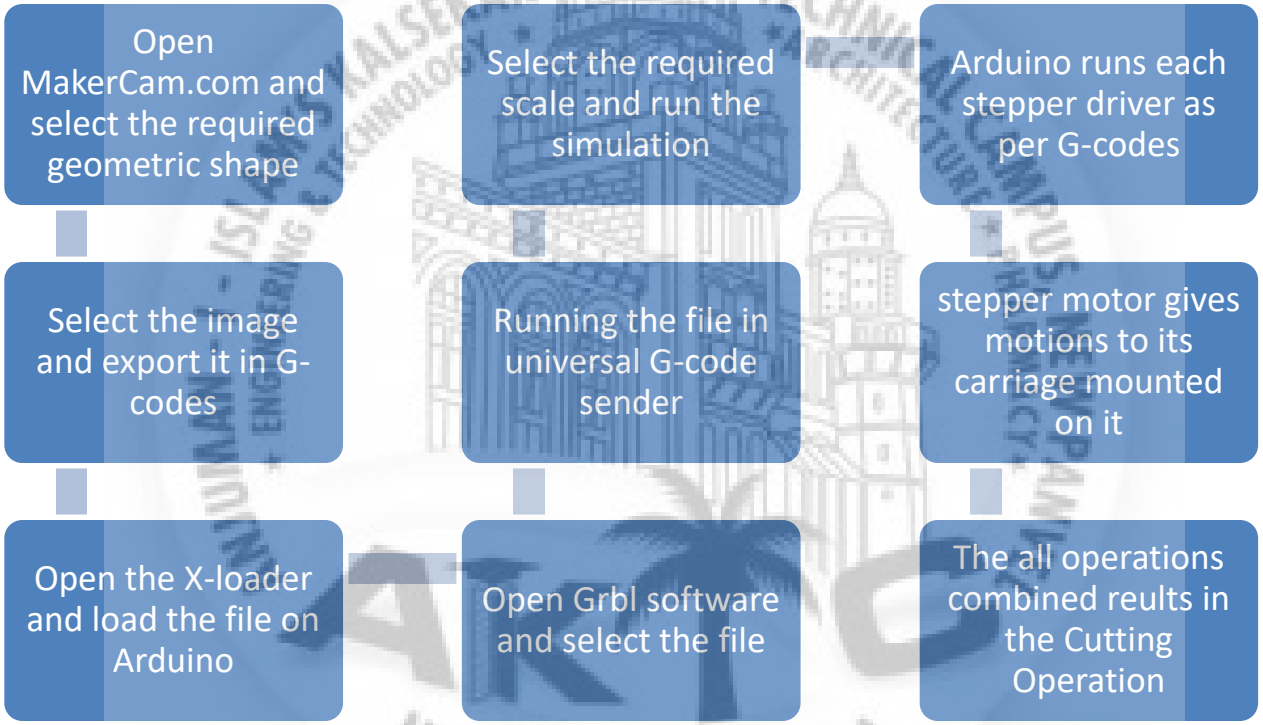
Parameters	Specification
Input Voltage	AC220V+-15% IP
Input Frequency	50/60
Related Input Current	30A
Input Power	6.6KVA
Open Circut Voltage	230V
Current Range	15-40A
Related Output Voltage	96V
Duty Cycle	60%
Efficiency	80%
Power Factor	0.73
Cutting thickness	<= 6mm
Arc initiating	Touch
Air pressure (MPa)	0.4-0.5MPa
Protection Class	IP21
Weight	9KG
Dimensions	395X153X301 mm



10] Linear Shaft Bearing:

Linear shaft bearing is used to assist the transmission with minimum friction and backlash. We used this system particular for x-axis to get more precise movement of torch through X-axis. The other main reason was load on X-axis, this system can handle dynamic load and can easily bear the force or torque. This system is more durable and has more resistance against rust and corrosion. The total length of shaft is 1200mm and 16mm diameter coupled with linear bearing of 50mm x 45mm. The length is intentionally more than the working x-axis considering the future scope of machine.

LIST OF SEQUENCE



SOFTWARE SETUP

Software Setup:

As for the CNC to work, we needed to control our stepper motor by providing it proper command through our microcontroller which is arduino-mega 2560.and for that we choose grbl and universal G-code sender.

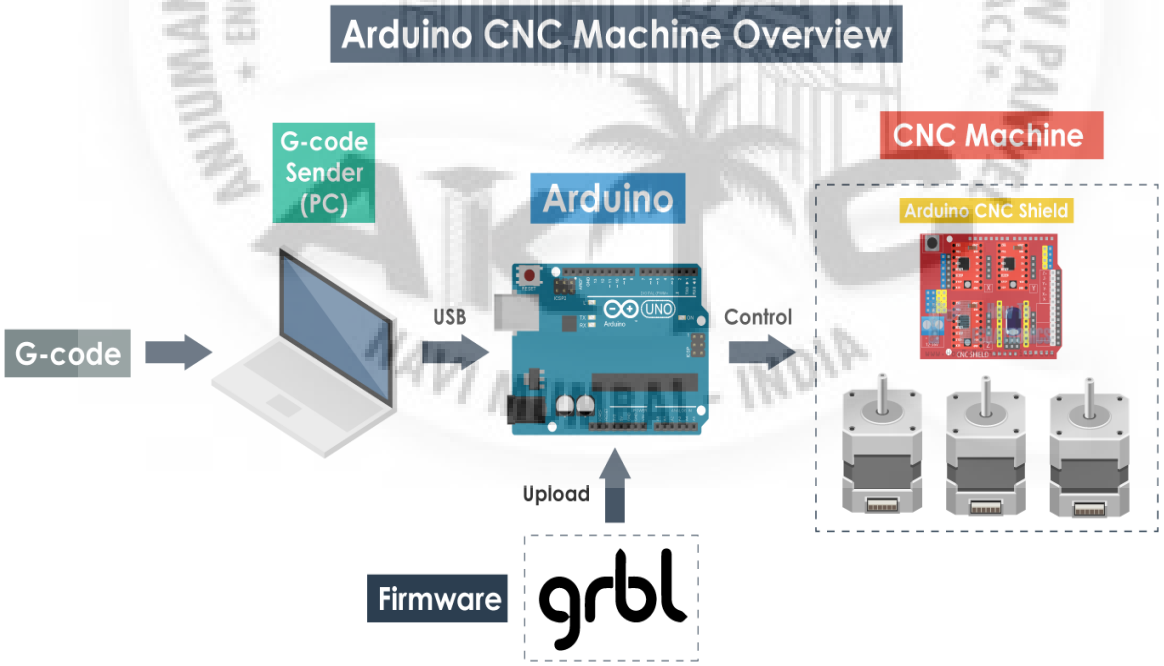
The Reason for choosing this to software particularly is

1. They both are open source and easily available.
2. Their user interface is quite good which make the operator easy to use.
3. They provide markeable precisions so as to get fine cutting.
4. They both work hand-in-hand with our microcontroller.
5. They are universally accepted and has widely used by many of the manufacturing companies.

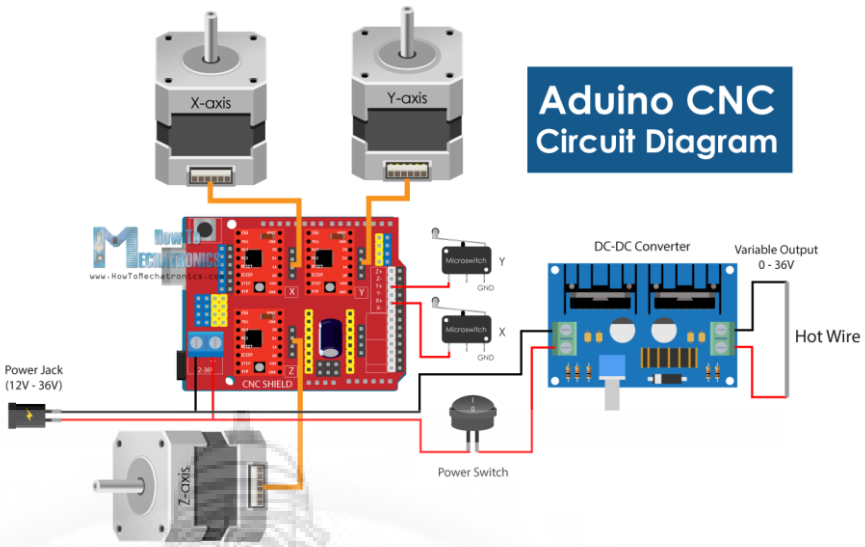
What is GRBL?

GRBL is an open source software or firmware which enables motion control for CNC machines. We can easily install the GRBL firmware to an Arduino and so we instantly get a low cost, high performance CNC controller. The GRBL uses G-code as input, and outputs motion control via the Arduino.

For better understanding, we can take a look at the following diagram:



From the diagram we can see where the GRBL take place in the "big picture" of the working principle of a CNC machine. It's a firmware that we need to install or upload to the Arduino so it can control the stepper motors of the CNC machine. In other words, the function of the GRBL firmware is to translate the G-code into motor movement.



How to Install GRBL

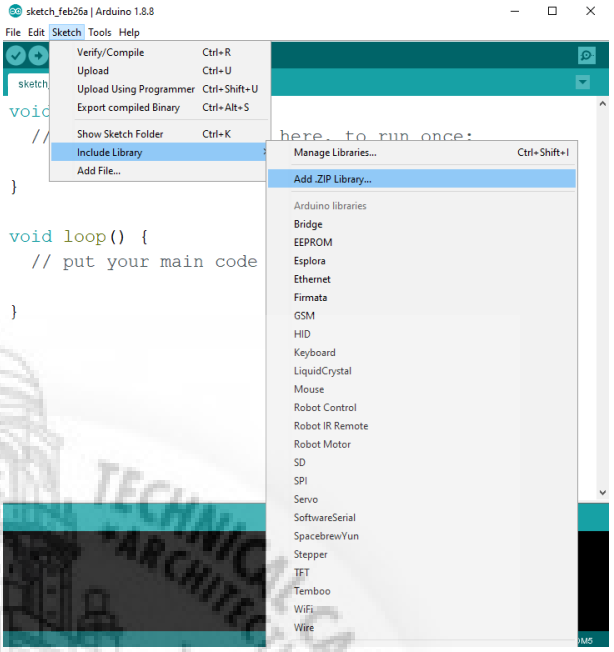
First, in order to be able to install or upload the GRBL to the Arduino we need the Arduino IDE.

Then we can download the GRBL firmware from github.com

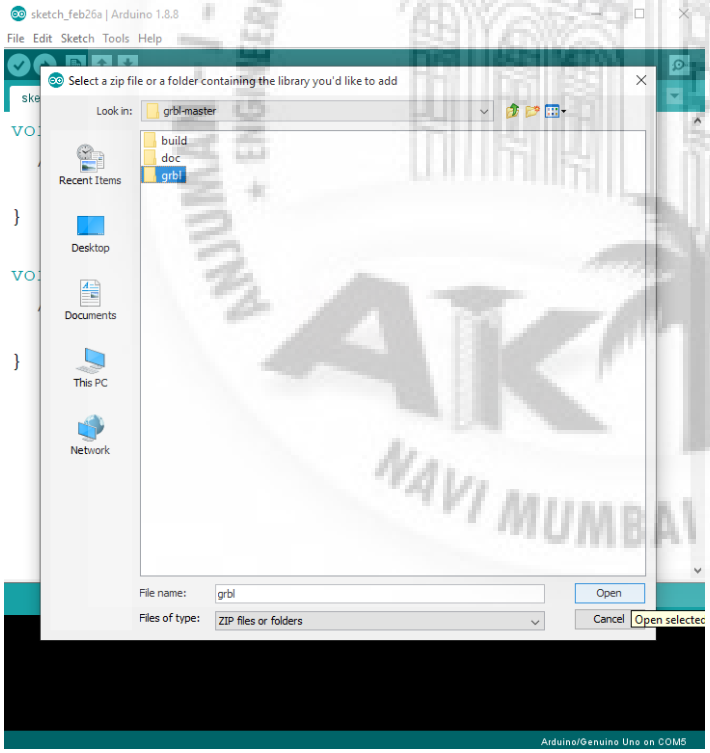
Download it as .ZIP file and then follow these steps:

- Open the grbl-master.zip file and extract the files.

- Open the Arduino IDE, navigate to Sketch > Include Library > Add .ZIP Library...



- Navigate to the extracted folder "grbl-master", in there select the "grbl" folder and click the open file. Now we have to GRBL as an Arduino Library.



- Next, navigate to File > Examples > grbl > grblUpload. A new sketch will open and we need to upload it to the Arduino board. The code might look weird as it's just one lines, but not worries, everything happens in the background in the library. So, we just have to select the Arduino board, the COM port and hit that upload button and we are done.

GRBL Configuration

At this point we should configure or adjust the GRBL to our machine. We can do that via the Serial Monitor of the Arduino IDE. Once we open the Serial Monitor we will get a message like "Grbl 1.1h ['$' for help]". If you cannot see this message, make sure you change the baudrate to 115200.

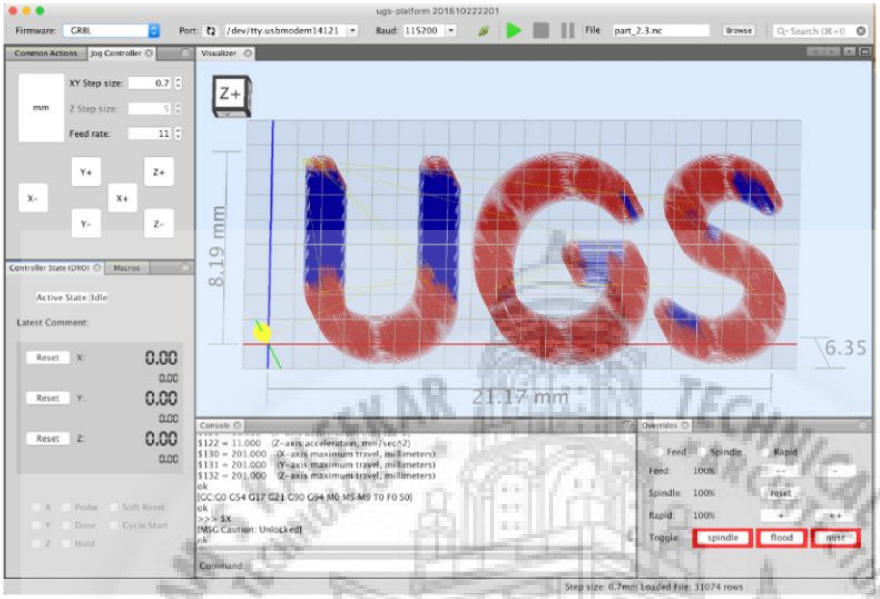
If we type "$$" we will get a list of commands or current settings, and they appear something like this:

$100=250.000 (x, step/mm)
$101=250.000 (y, step/mm)
$102=3200.000 (z, step/mm)
$110=500.000 (x max rate, mm/min)
$111=500.000 (y max rate, mm/min)
$112=500.000 (z max rate, mm/min)
$120=10.000 (x accel, mm/sec^2)
$121=10.000 (y accel, mm/sec^2)
$122=10.000 (z accel, mm/sec^2)

All of these commands can be or should be adjusted according to our CNC machine. For example the with first command, $100=250.000 (x, step/mm), we can adjust the steps per mm of the machine, or we can specify how many steps the motor should make in order our X axis to move 1 mm.

However, I would suggest to leave these settings as they are. There is an easier way to adjust them according to our machine using the controller software, which we will explain in the next section.

GRBL Controller

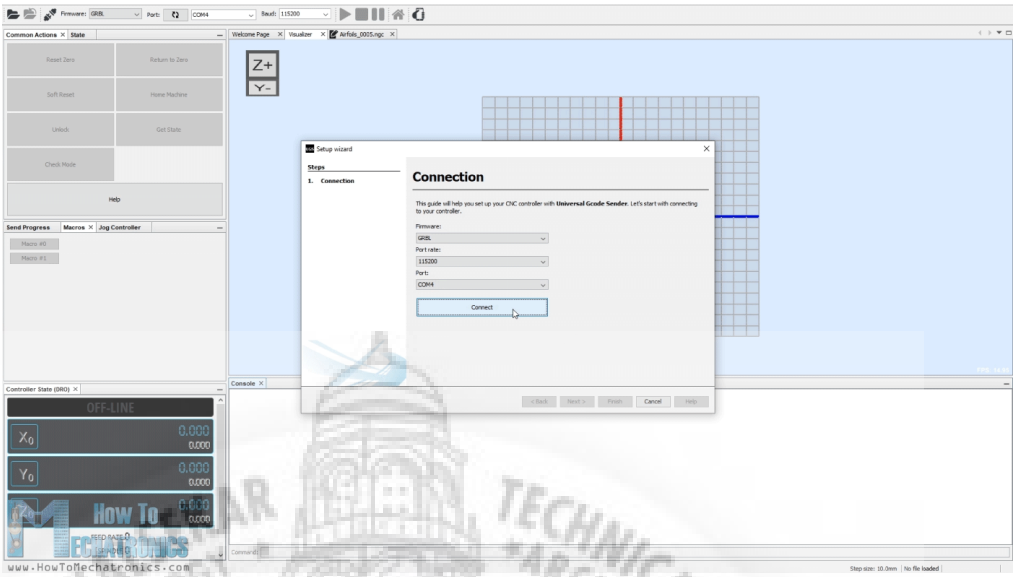


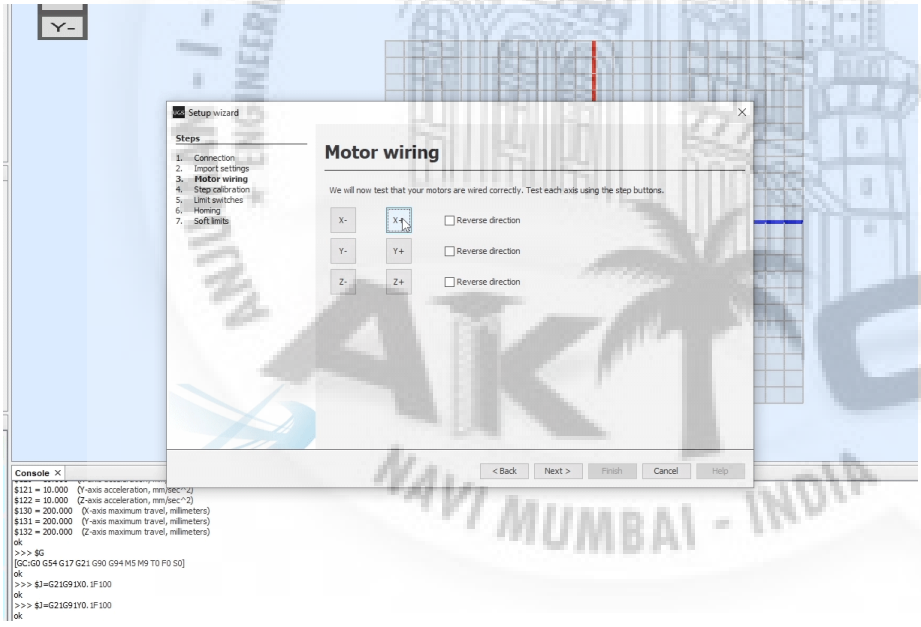
So once we have installed the GRBL firmware, now our Arduino knows how to read G-code and how to control the CNC machine according to it. However, in order to send the G-code to the Arduino we need some kind of interface or a controller software which will tell the Arduino what to do. Actually, there are many both open source and commercial programs for that purpose. Of course, we will stick to open source, so as an example we will use the **Universal G-code Sender.**

How to Use Universal G-code Sender

For this example, I will use the 2.0 Platform version. Once we download it, we need to extract the zip file, go the "bin" folder and open any of the executable "ugsplatfrom" files. This is actually a JAVA program, so in order to be able to run this program, first we need to install JAVA Runtime Environment.

Once we open the Universal G-code sender, first we need to configure the machine, or configure the GRBL parameters shown earlier. For that purpose we will use the UGS Setup Wizard which is much more convenient then manually typing commands through the Serial Monitor of the Arduino IDE.

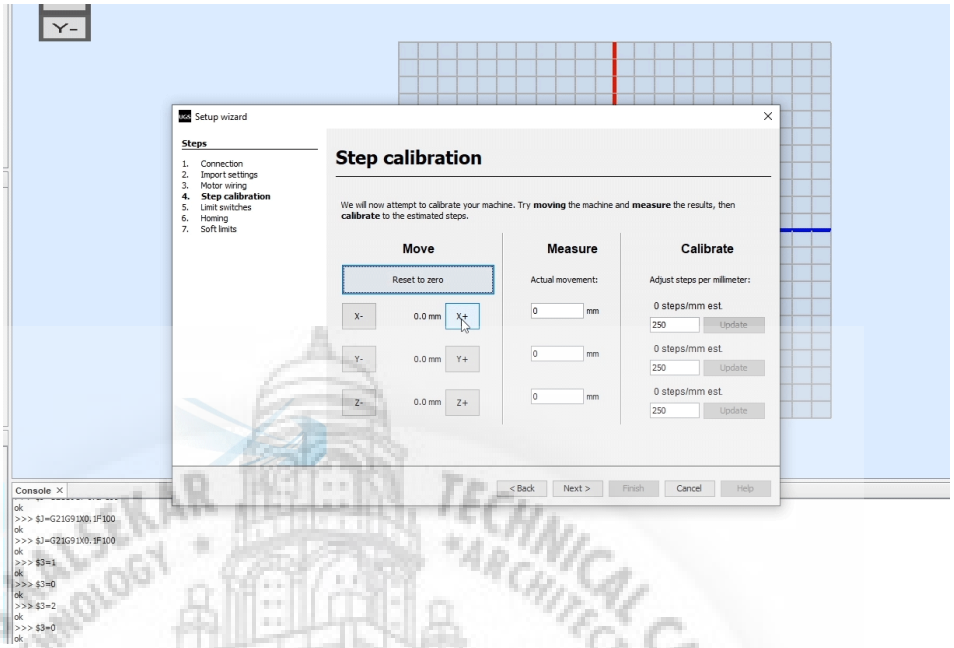


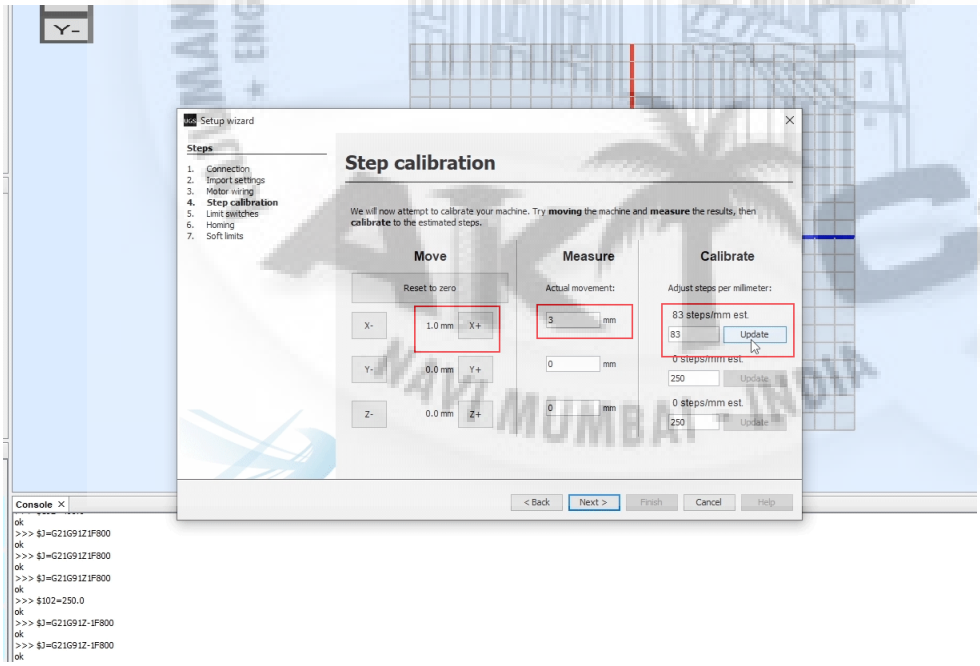


The first step here is to select the baudrate, which should be 115200, and the port to which our Arduino is connected. Once we connect the Universal G-code sender with the Arduino, in the next step we can check the direction of moving of the motors.

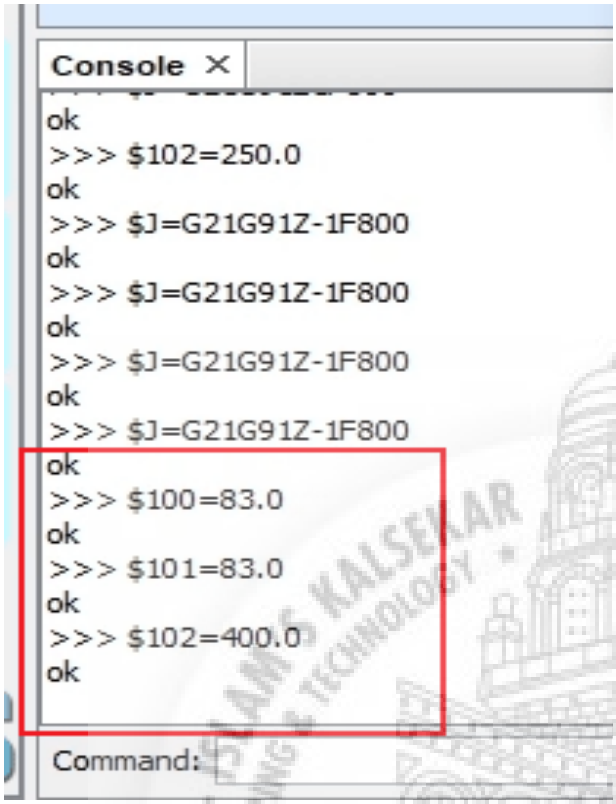
If needed, we can reverse the direction through the wizard, or by manually flipping the connection of the motor on the Arduino CNC Shield

In the next step we can adjust the steps/mm parameter that we mentioned earlier. Here it's much easier to understand how to adjust it because the setup wizard will calculate and tell us to what value we should update the parameter.



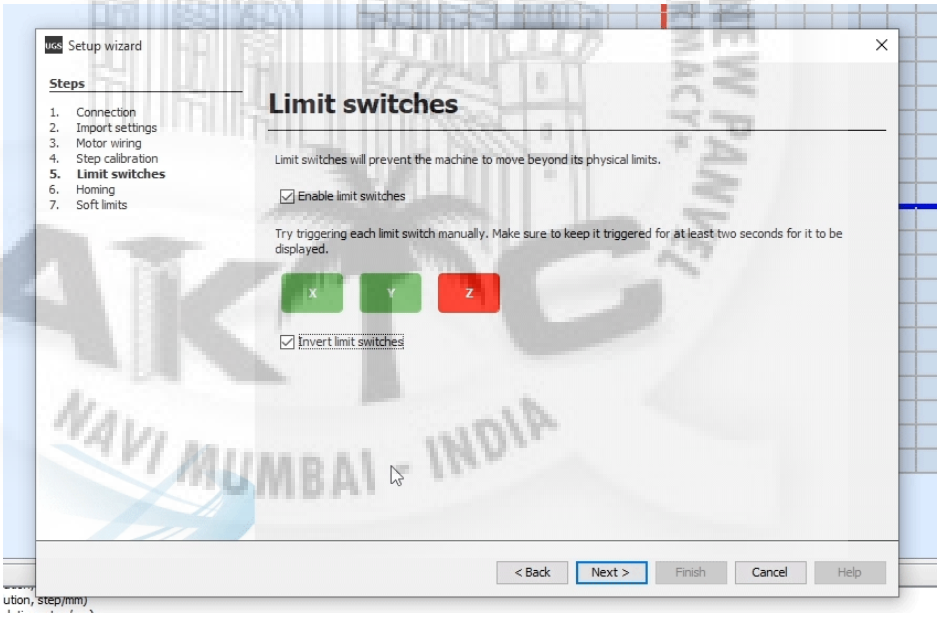


With this value updated the machine now moves correctly, 1 mm in the software mean 1 mm for the CNC machine.



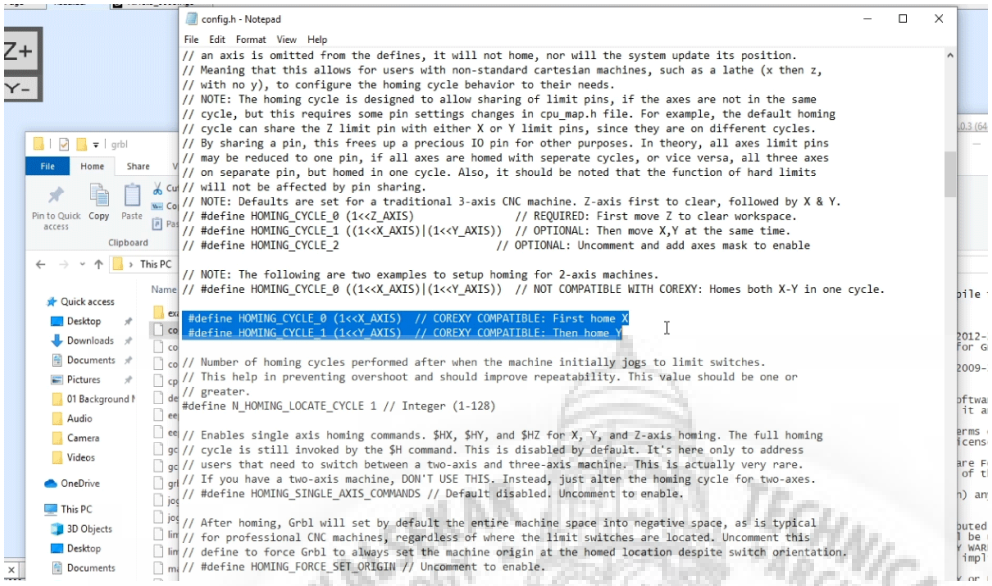
In the UGS console, as we make each action we can see the commands that are executed. We can notice that by updating the steps/mm parameter the UGS program actually sent to the Arduino, or the GRBL firmware the command we mentioned earlier. This was the default value: $100=250.000 (x, step/mm), and now we updated to value of 83 steps per mm: $100=83.

In the next step we can enable the limit switches and test whether they work properly.



Depending whether they are Normally Open or Normally Closed connection, we can also invert them here.

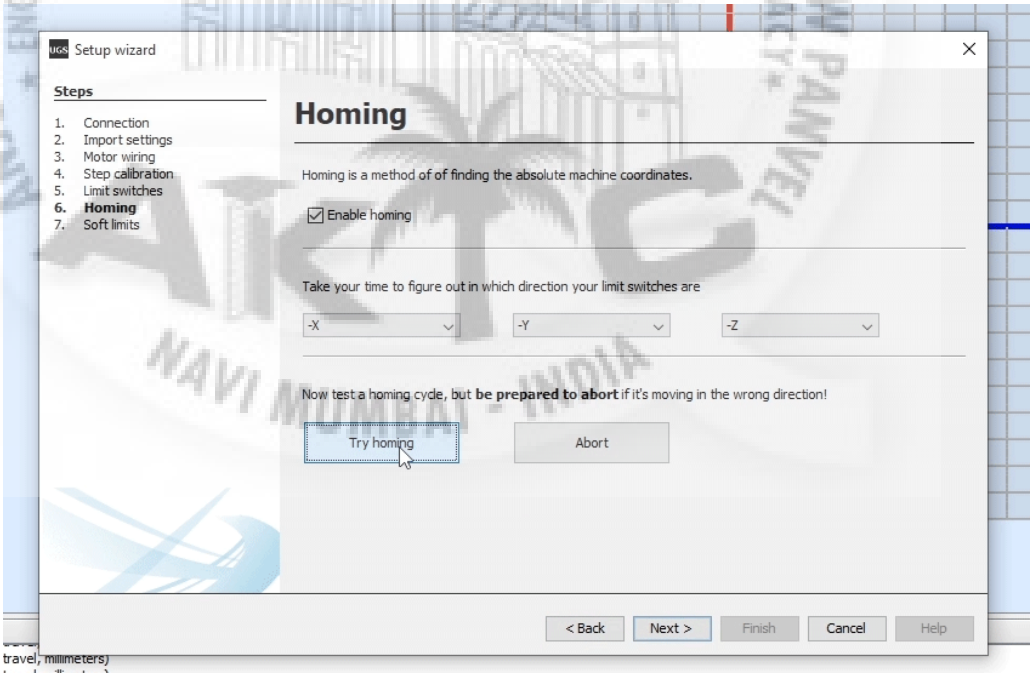
Here it's worth noting that sometimes we need to disable Z axis limit switch. That was the case with my DIY CNC Foam Cutting machine where I didn't need the Z axis limit switch and I had to disable it in order to be able to properly home the machine. So, to do that, we need to edit the config.h file which is located in the Arduino library folder (or Documents\Arduino\libraries).



Here we need to find the homing cycle lines and comment the default set for 3 axis CNC machine and uncomment the setup for 2 axis machines. In order the changes to take effect we need to save the file and reupload the grblUpload sketch to our Arduino board.

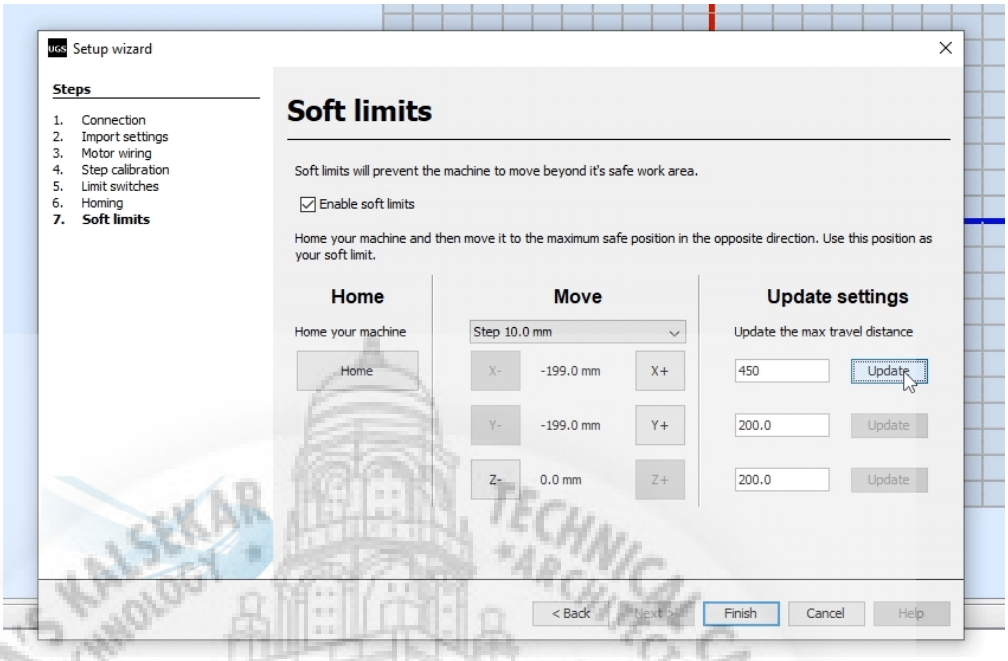
Nevertheless, in the next step we can either enable or disable the homing of the CNC macing.

Using the "Try homing" button the machine will start moving towards the limit end switches. In case it goes the opposite way we can easily invert the direction.



Finally, in the last step of the Setup wizard we can enable soft limits for our CNC machine.

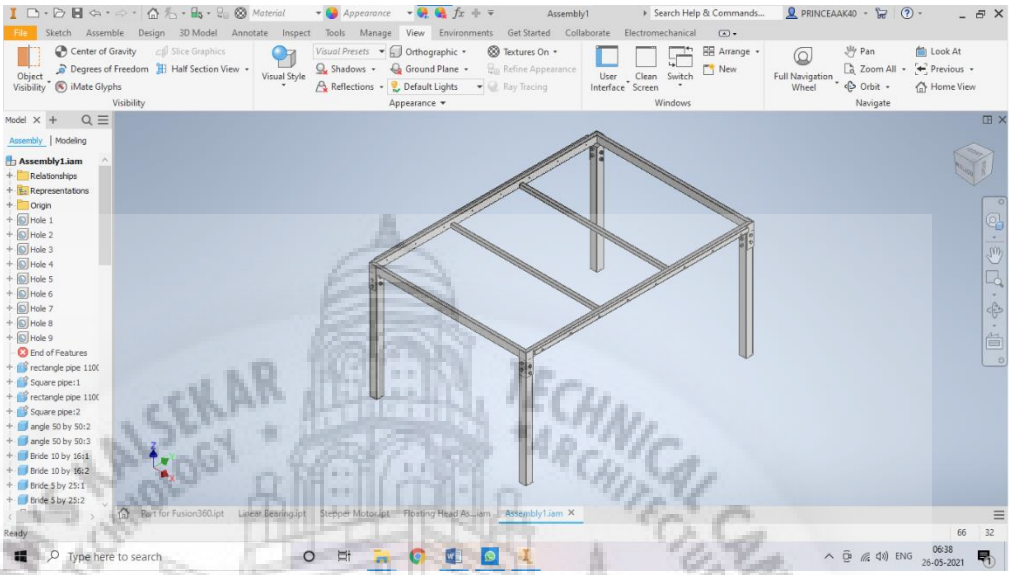
The soft limits prevent the machine from moving beyond the set working area.



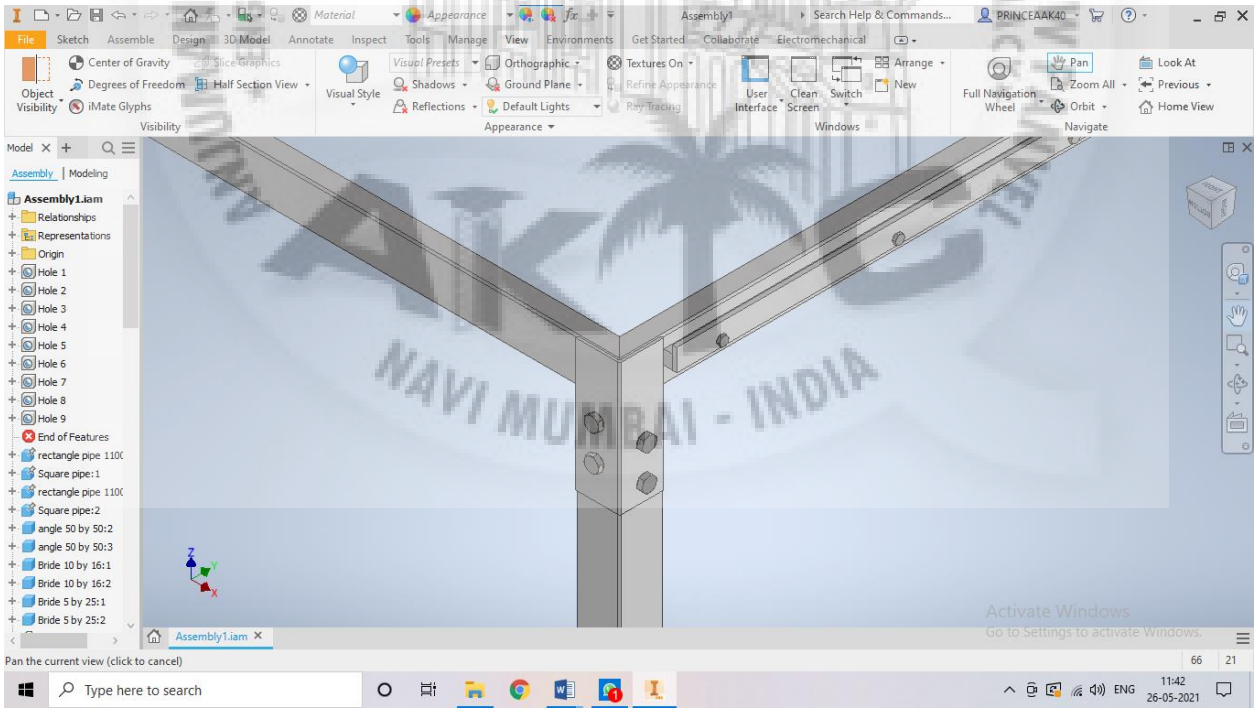
DESIGNING

Designing

Gantry:



We made our gantry using MS rectangular and square pipes, the gantry dimension is 1500mm x 1100mm x 750mm considering the job size and the use of machine. The gantry was designed by considering the work load and the application of machine. The upper part of gantry is made using 50mm x 25mm x 2mm rectangular pipe and welded,4 rectangular pipe is used i.e. 1500mm x 2 units and 1100mm x 2 units. The bottom part of gantry is made



using 50mm x 50mm x 3mm square pipe, they are tightly bolted by 4 unit of 75mm angle of length 100mm each. To perfectly level the gantry with floor each legs are equipped with M10 bolt leveller.

Axis (X-axis, Y-axis):

To precisely control the movement of plasma torch and cutting path we designed 3-Axis i.e. X-axis, Y-axis, Z-axis respectively. The Y-axis is made in consideration to control the motion of torch in 1500mm (larger side), this axis travels on rack and pinion mechanism and the mechanism is assisted with bearing for low friction and smooth travelling. The X-axis is made in consideration to control the motion of torch in 1100mm (perpendicular to larger side), this axis travels on rack and pinion mechanism and the mechanism is coupled with shaft and bearing setup for minimum friction and smooth travelling.

Transmission

For channelizing the power of our motor in x-axis and y -axis according to the requirement and to give required movement to our torch we decided to use rack and pinion system for mentioned reasons.

1. The rack and pinion system was more durable than the lead screw or belt drive.

2. The torque carrying capacity is high.

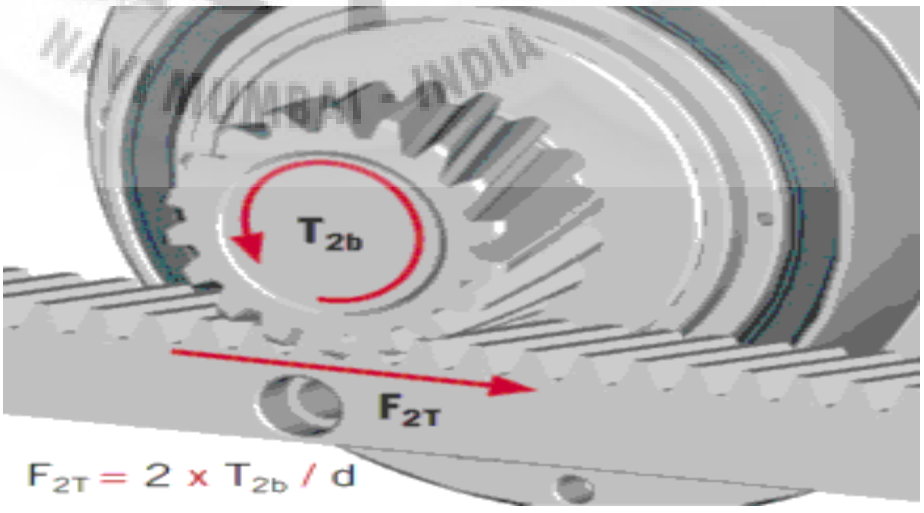
3. It can be used for a longer length as compared to lead screw.

4. It provides more workspace.

5. It can be easily coupled with the motor.

RACK AND PINIION:

The material we selected for rack and pinion is mild steel because of its high strength and durability. As for the dimensions we have used following calculations.



CALCULATE RACK AND PINION: IMPORTANT DEFINITIONS

To make it clear we give you some important definitions:

Tangential force or feed force: This is the force [in N] needed to deliver the linear movement profile.

Torque: This is what the pinion sees and is simply tangential force * arm (radius pinion) [in Nm].

In this case,

$$F2T = 2 * T2B / d$$

Safety factor: Apex recommends a safety factor of at least 2 for horizontal and 3 for vertical drives.

Friction coefficient: How heavy – or light – does the system run? A widely used value is 0.1 or 0.15.

External forces: For example: is the system used to push products? Then this force should be added to the tangential force.

$$\propto = V / t\propto \qquad (m/s2)$$

Tangential force, $FN = M * g * \mu + M * a + F$ (N)

Torque, $TN = (FN * d) / 2000$ (Nm)

Design torque, $TNV = TN * SB$ (Nm)

Max. Speed pinion, $NV = (V * 19100) / d$ (rpm)

As for the above calculations we have selected rack and pinions of module 4.5 mm, and the diameter of the pinion selected is 42mm which consists of 25 teeth's and the length of the rack is 4m in total.

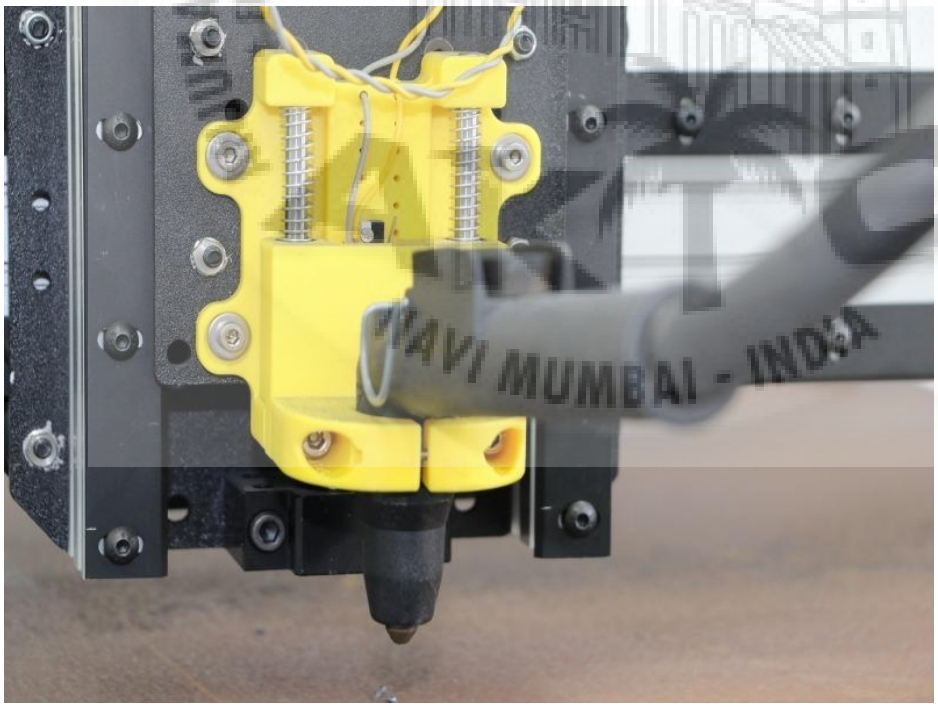
Z-axis:

While the Z-axis is made to control the height of torch, the axis length or the length of movement is kept to 200mm, the axis travelled on lead screw for very precise travelling and with minimum backlash, for better cutting.

LEAD SCREW:

As for the movement of the torch in the z-axis or also known as torch height controller (THC), we have used lead screw coupled with a stepper motor for the following reasons,

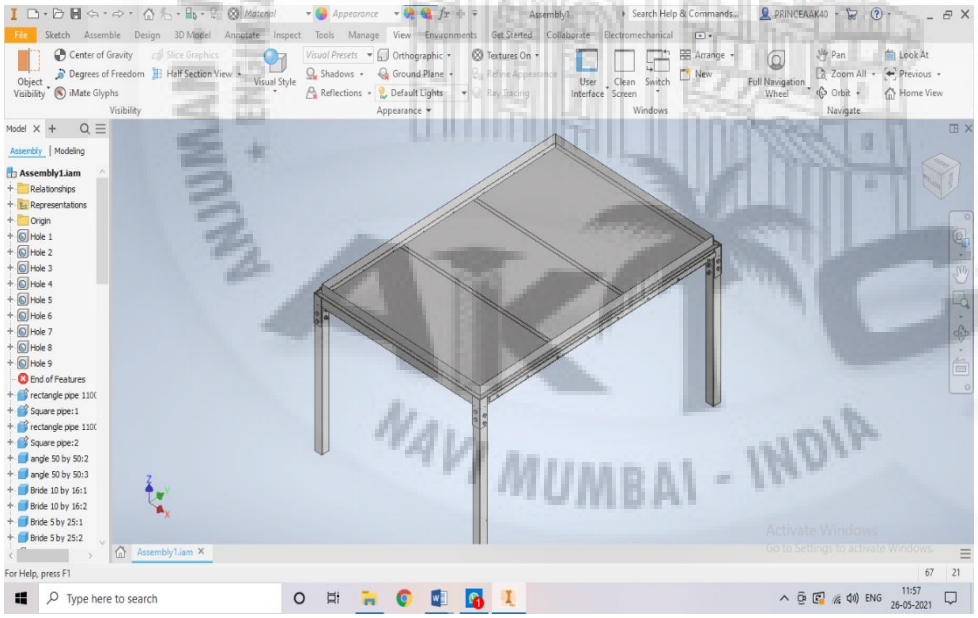
1. The range of motion is less.
2. The axis of motion is vertical.
3. The torque required is less.
4. Fine adjustment can be achieved.



As considering the range of motion and the power and torque required we have chosen a trapezoidal lead screw or also known as acme lead screw having a pitch of 2mm and diameter of 8mm.

Water table:

When CNC plasma cutting, there are a lot of good reasons for using a water table instead of a dry, or down draft table. A water table is less expensive to purchase, does not require a dust collector (in most areas), reduces noise, eliminates dangerous arc flash, reduces heat distortion and keeps parts cool, just to name a few. And even though it is an older technology, a significant number of large gantry CNC plasma and oxy-fuel cutting machines are still sold with water tables. Some water tables are simply a tank, filled with water, and burning bars on top. But that won't get you the full advantages of underwater plasma cutting. Construction of the table is quite simple; a large chamber is built into the table, below the burning bars. The water table is made by bending the 24gauge GI sheet into desired dimension of 1450mm x 1050mm x 75mm (height) to perfectly fit between gantries. The water table is placed between the upper parts of gantry with support of two 25mm x 25mm square pipe. The burning bars to be placed in water table is made up of SS material, the dimensions are 1440mm (length) x 6mm (height) x 2mm (thickness). The water table is also designed for under water operation.



Designed by	Checked by	Approved by	Date		Date	
Faiyaz	prof.yusuf khan				28-05-2021	

CNC PLASMA CUTTING MACHINE	GROUP NO. 07		
	CNC plasma cutting machine	Edition	Sheet 2 / 2

BILL OF MATERIALS

Bill of Materials

Sr. no.	Components	Description	Nos.	Cost (Rs.)
1	Square Pipe	Material: M.S 50*50*3[1200mm] 50*50*3[750mm] 19*19*1[1200mm]	***1*** ***4*** ***2***	400
2	Rectangle Pipe	Material: M.S 50*25*2[1550mm] 50*25*2[1250mm]	***2*** ***2***	600
3	Stepper Motor Nema 23	Ratings:- 12V 3A	***4***	2500
4	Motor Driver	tb6600	***4***	3000
5	Arduino Mega	2560	***1***	1000
6	Shaft Supports	Shaft:1100mm Bush type Bearing:50*45	***1*** ***1***	2000
7	Bearings	O.D :30mm I.D :9mm	***4***	200
8	Rack & Pinion	Rack:-20×20mm (4m length) Pinion:- 42mm(dia) Material : MS	**1** **3**	7000 1000
9	Bright Strip	10KG (length 6m approx.)	**1**	1000
10	Pulley	Dia:- 46mm Material:- MS	**8**	800
11	Power Supply	Smps{switching mode power supply} Ratings:- 12V 20A	**1**	1200
12	Limit Switch	Ratings: 5V	**10**	100

Sr. no.	Components	Description	Nos.	Cost (Rs.)
13	Lead Screw	M10 [200mm] Module: 2mm	**1**	500
14	Galvanized Sheet	24 gauge 1800*1400 mm	**1**	2000
15	Plasma Cutter	Rilox CUT 40 MOS Cut Thickness<8	**1**	20000
16	Cutting Torch/Notch	P80 Pilot arc Non-Touch	**1**	5000
17	Nut And Bolt	Material: M.S {M10}	**16**	200
18	Allen Key Bolt	Hardened Steel M8,M5,M6	**40**	*400*

CONCLUSIONS

Conclusions:

In modern CNC systems, end-to-end component design are highly automated using computer aided design (CAD) and computer-aided manufacturing (CAM) programs. The programs produce a computer file that is interpreted to extract the commands needed to operate a particular machine by use of a post processor, and then loaded into the CNC machines for production. Since any particular component might require the use of a number of different tools i.e. plasma torch, laser cutter, gas cutter, water jet cutter, etc.

With the increasing demand for small scale high precision parts in various industries, the market for small scale machine tools has grown substantially. Using small machine tools to fabricate small scale parts can provide both flexibility and efficiency in manufacturing approaches and reduce capital cost, which is beneficial for small business owners. In this project, a small scale three axis "CNC PLASMA CUTTING MACHINE" is designed and analyzed under limited budget as compared to industrial machines.

FUTURE SCOPE

Future Scope:

1. Upgrading the transmission hardware of machine, i.e. using hardened steel rack and pinion instead of MS. This will allow the machine to do heavy duty work and increase the working life of machine.
2. Hardened steel made rack and pinion is much more resistant to corrosion, can bear more load or torque, it can achieve better speed in transmission and will be less prone to wear and tear.
3. By upgrading the electronic parts of machine, we can increase its applications. Not only we can use plasma torch, but also we can use gas cutting, laser cutting and water jet cutting.
4. Components like, using stepper motor or servo motor with proper gear box and with proper spring mechanism can actually make the machine to run with Zero backlash, this machine is already equipped with spring mechanism and can run with minimum backlash. Upgrading these will components will assist in better speed, load carrying capacity and better torque.
5. One can also upgrade the heart of this CNC machine i.e. ARDUINO, for extra control and for high end precision. By using we can run other software's like Mach3, which will have more controls and different modes of cuttings.
6. We have intentionally designed this machine to use two cutting heads i.e. we can use two tools simultaneously. The X-axis is intentionally extended by 100mm from each side so that we can add extra tool and both tool can reach to maximum ends. This will definitely increase the work efficiency.

List of Suppliers:

1. VISHA World:
Phone: 022 23862650 Mobile: + (91)-22-23862622
Address: 17. Shree Ganesh Bhavan, 1" floor. 349. Lamington Road. Opposite Police Station, Grant Road East, Mumbai - 400007

2. MACNE Technology:
Phone: 022 23823553 Mobile: +91 9821460547
Address: 18. Shree Ganesh Bhavan, 1" floor, 357, Lamington Road, Opposite Police Station, Grant Road East, Mumbai - 400007

3. New Silicon Electronics:
Address: Shop Number. 4, Ganesh Bhavan Building, 351, Opp, Lamington Rd, police station, Grant Road East, Grant Rd, Mumbai – 400007

4. JK Machines & Tools:
Mobile: 098206 29601
Address: Shop No. 6, Mount Galaxy Building, Kishan Nagar Number 4, Rd Number 28, Shanti Nagar, Wagle Industrial Estate, Thane West, Mobile: 098206 29601
Thane – 400604

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https://youtu.be/FggSRQqB_a4
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