Design & Fabrication of 3-Axis CNC Machine

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ABSTRACT

The introduction of CNC machines has radically changed the manufacturing industry. It is easy to cut Curves or straight lines, complex 3-D structures are relatively easy to produce in manufacturing process, machining work required by human action has dramatically reduced. Making a compact and low cost 3 axis CNC milling machine comes from increase in demand of low cost and portable machine with the increased automation of manufacturing processes with CNC machining can be achieved easily.

CNC automation helps in reducing the frequency of errors and provided CNC operators with time to perform additional tasks without any loss of material. CNC automation also allows for more flexibility in the way parts are held in the manufacturing process and the time required for machine to produce different components can be done easily by only one good experienced operator.

As the increase in rapid growth of technology and software available. It is not difficult so we decided to make a machine which can mill the wood, plastics, thin sheet and alloy using AutoCAD and 3D Printing technology. This allows us not compromise on the load or stress induced in the machine during operations. Improved procedures are employed in this system to reduce the errors in controlling a 3-axis CNC machine, while avoiding any loss in overall efficacy.

We used 3D printed parts to build the overall structure. By using 3D Printed parts, we can reduce the overall budget of any CNC machine and thus, gives an affordable machine for low cost. This allows us to let anyone work on them ease than trying to learn on costly CNC machine. Our aim is to prove that the 3D printed parts are exceptionally good to use in machining works.

Keywords: 3-D Structures, AutoCAD, 3D Printing, 3-Axis CNC machine.

1.INTRODUCTION

CNC machine is a 3-axis machine which has x, y, and z axis which it works on. They come in various shapes and size. But they are also costly which makes them not available for everyone to try on. CNC machine is type of machine which has dc motor or any motor which is used to drill, make holes, cut, engrave or for designing of pcb in electrical. This machine is capable of producing the design with a tolerance of 0.1mm from actual machine. Thus, making this machine usefully in our modern industry. CNC machine is usually of high cost. Hence, not many people or students work on them practically because of price.

Over decades the industry has seen quite a development in the revolution of machinery. This development has lead to lot of changes in the way the parts are machined. Traditional method is good and easy to learn. But just because they are good doesn't mean they are best option available for us to choose from. By using a computerized controlling method, we can get the desired products with high level of accuracy along with lesser lead time. This not only makes us produce lot of products but also helps us achieve high revenue.

Developing the low-cost machine usually comes from the prize they are usually sold. But making a CNC machine, we have to keep in mind the design and they type of machine to work. Working on plastic, wood and acrylic and other soft material should not have any problem to begin with.

Our project main objective is to use 3D Printed parts to produce the frame and structure of the machine. This not only allows us to make the design strong but also eliminate lot of stress induced during machining operation. By keeping a minimal design, we have decided to use basic components for our

project. 3D printing has lot of advantage which can be used a per our needs. It is stronger than wood but not greater than aluminium hence, 3D printed parts are suitable for our project.

For, more precision and accuracy we decided use a NEMA 17 motor with bi-polar design which not only give us accurate steps but high torque of 4.5kg/cm. It is better to use high torque motor. The stepper motors move in precisely repeatable steps; hence they are the motors of choice for the machines requiring precise position control. Stepper Motor provides excellent response to starting, stopping and reversing pulses from stepper motor driver. They are very useful in the various application, especially which demands low speed with high precision. It is a brushless DC motor, so the life of this motor is dependent upon life of the bearings. The position control is achieved by a simple Open Loop control mechanism so doesn't require complex electronic control circuitry. The motor's shaft has been machined for good grip with a pulley, drive gear etc., and especially avoiding stall or slip.

The 3-Axis machine was intended to give a proper section level instrument for testing with 3-hub machining and CAD/CAM systems. The accentuation is on availability and enables us to change the in assembled firmware on the machine. The systems and component that transfer, hold, and guide loads move in linear directions. Also, the duration used to describe computerized and semi-computerized mechanical systems that generate directions of x, y, z axes.

Recent engineering process integrates the use of linear component to allow for rapid low-friction accuracy movement. A lead screw combined with stepper motor, driver, aluminum extrusion, with Belt and Pulley and 3D Printed parts makes filling these necessities easy to change as per our needs. Lead screw motion systems have three basics categorize as

1) The controlling unit,

2). The driving tool,

3).3D Printed support for components.

1.) The Controlling unit: The drive or control devices include a selection of electric motors such as stepper motor, coupler, lead screw of TR8mm with a pitch of 2mm and 4 start.

2) The driving tool: The drive tool, in combining with the drivers, offers the thrust and axial positioning precision of the load as per user given valve. This value ensure that machine move as per the steps/ revolution.

3.) 3D Printed supports for components: This component are usually printed with high settings. We decided to PLA material for 3D print the components. As PLA is cheap and easy to print, it gives accurate component. PLA is also environmentally friendly material. Parts are printed with 0.1mm layer height, with 60mm/sec speed, and a infill of 50% with 4 walls. This setting prove that the parts are strong enough to absorb the load and vibration from the machine.   For the Gantry machine it has 4 types:

•   Gantry type structure it offers a maximum structural performance X axis travel can enlarge according to our request y axis can travel the prepared with as per our required length. Hence. We decided to use 1-meter x 1-meter aluminum extrusion.

•   X axis has Aluminum Alloy Extrusion rail one Stepper Motor and 4 V Wheel synchronized with lead screw of 8mm that controlled driving system to ensure vital dynamic accuracy.

•   As we all know that there is a bit of argument about the name of a particular axis and the direction it moves However, the X and Y axis becomes a problem. The X-Axis should be the longer of these two axes. In other words, the X-Axis is the axis you are facing as you face the machine during operation. Now this may be improper, but it makes it easy to visualize the coordinates as you look at the machine. It simply becomes a Cartesian coordinate system that used to in high school algebra with the Z-Axis moving up and down. The main objective of our project is to design and fabricate CNC machine and to use different software to control the 3-axis machine. And also, to construct the whole system with a limited budget for anyone to build easily.

2.COMPONENTS

Electrical Components:
1.) Stepper Motor
2.) CNC Shield
3.) Stepper Motor Driver
4.) Arduino
5.) Power Supply 12v 10Amps
6.) Dc Connector
7.) Jumpers
8.) 775DC 12v
9.) 775DC Motor Shaft 5mm
10.) Drill Chuck
11.) 12v cooling fan
12.) Limit Switch

Mechanical Parts:
1.) Aluminium Profiles 20x40mm
2.) Lead Screw 8mm
3.) GT2 Belt 200mm and 6mm width
4.) GT2 Pulley 5mm bore, 8mm bore.
5.) V-Wheels
6.) 5mm to 8mm Coupler
7.) Chrome rods
8.) Fl08 Block Insert Bearing
9.) 8mm Linear Bearing.
10.) 608zz Radial Bearing
11.) T Nut M5

12.) Screws M3, M4, M5.

3D Printed Parts:

1.)   Designed some 3d printed parts in Thinker cad.

3.WORKING AND PROCEDURE

Let's first know the basic procedure for calculation of CNC machine operations.

The primary design considerations for building a CNC milling machine are: The maximum work piece size (maximum travel along the axis) is selected as: X = 350, Y = 400 and Z = 220 mm.

CNC machining distance or length divided by speed or rate is the most basic rule. According to different process characteristics, the general formula for the time of multiple processes such as turning, milling and end face is as follows:

$$T=L/f*N, \; N =1000*V/\pi*D$$

Note: T=processing time,
L=cutting length (mm),
N=rpm (operation revolutions per minute)
V=cutting speed,
D=rod diameter (mm),
f=in Give amount mm/rev (mm per revolution)

3.1) WORKING PROCEDURE

For Drawing We Used Inkscape 0.92.5

STEP 1: Inkscape is used to design the plotted diagram or text. In this project by using this software G-code file of a selected image or text is created G-code is a commonly used numerical control programming language which includes X, Y, Z coordinates.
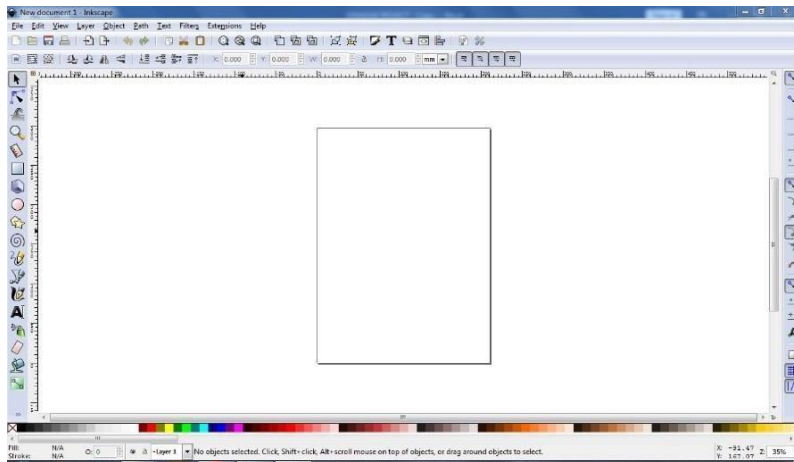

Fig 3.1 Inkscape Layout

STEP 2: The CNC plotter of our project will work within 90cm×90cm area. So, we choose the document properties of the Inkscape 40cmx40cm (Width × Height) which is four times the working area of the plotter because the plotter can draw only in the first quadrant.
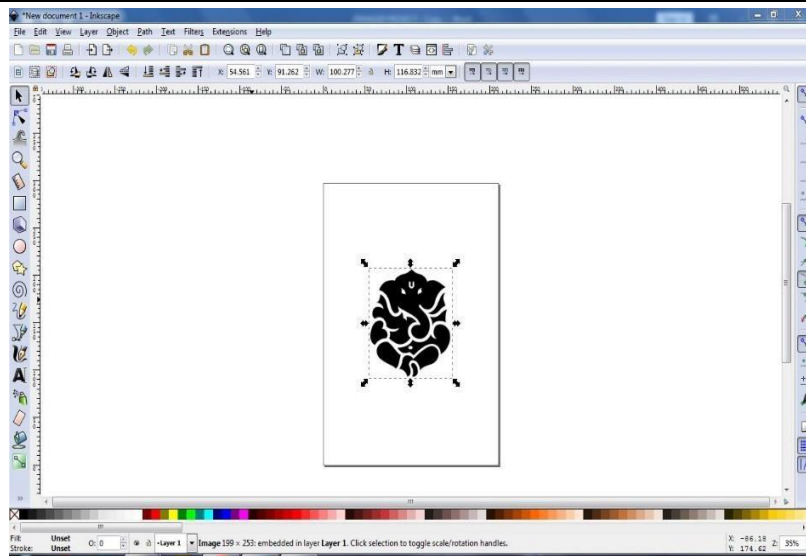
Fig 3.2 Import the Picture

STEP 3: So, we have initially kept the axes at the nearest end of the motors which is considered as origin to easily modify the design. The working area of CNC plotter is shown with the text written in the pre-defined area.

STEP 4: The text is selected using cursor and then select "object to path" from the drop-down window to save the G code form of the selected text.

STEP 5: To create G-code of an image, the file must have a transparent background. The image should be dragged into the selected area then select "trace bitmap" from drop down window to create a transparent image.
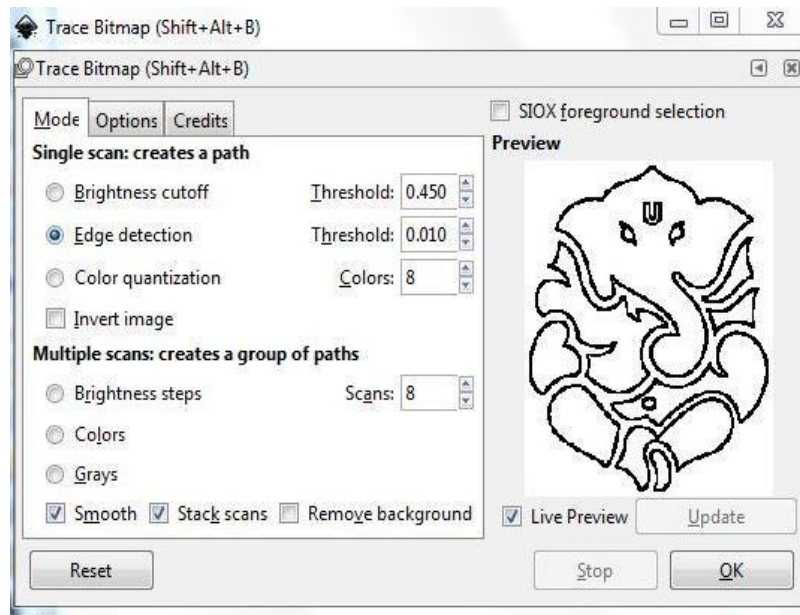

Fig 3.3 Trace Bitmap and Edge Detection Has Been Done

STEP 6: Scans are selected as 8 and "Edge detection" is selected to create black & white image. After adding this transparent image in the predefined area, we`ve used "object to path" command to create the G-code file of the selected image by following the steps described earlier.

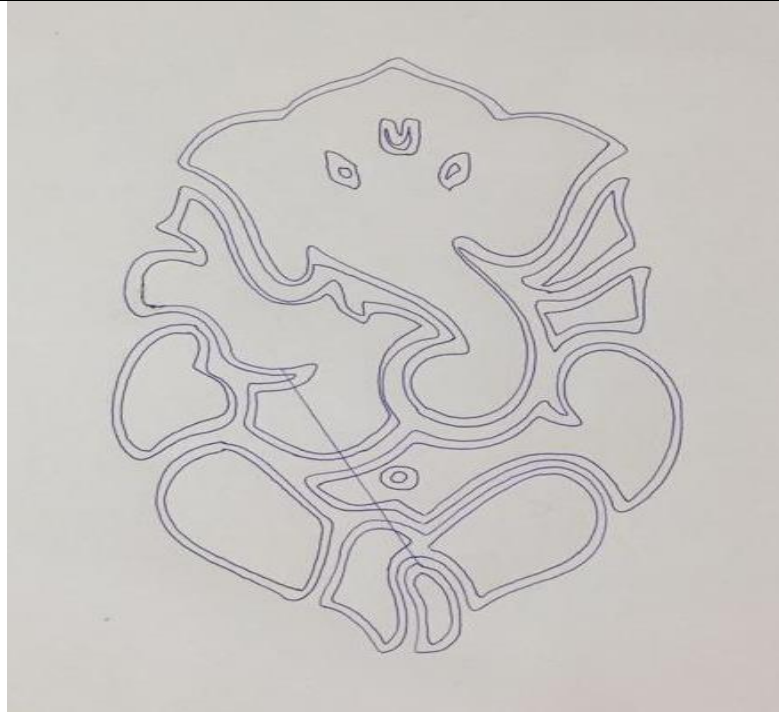**STEP 7**: Result of the following drawing.

Fig 3.4 Final Output Done with Blue Pen

For Cutting Acrylic We Used Easel Software:

STEP 1: Easel software is a paid software. But don't worry it comes with a 30-day free use. So, we decided to use this 30 day to test the software**.** As, this software has a great feature which can automatically calculate the feed, depth of cut and rise of z axis and many more features.

STEP 2: Create the account for easel software as this is online based software.

STEP 3: Connect the CNC machine and let it connect. It takes some time to install the drivers to connect the machine.

STEP 4: You can see the main page of easel software. Where you can choose what material to cut, type of drill bit to use. Size of work piece area, position of the work piece area. It also comes with a live preview so that we can actually know what we are cutting along with depth of cut of the material.
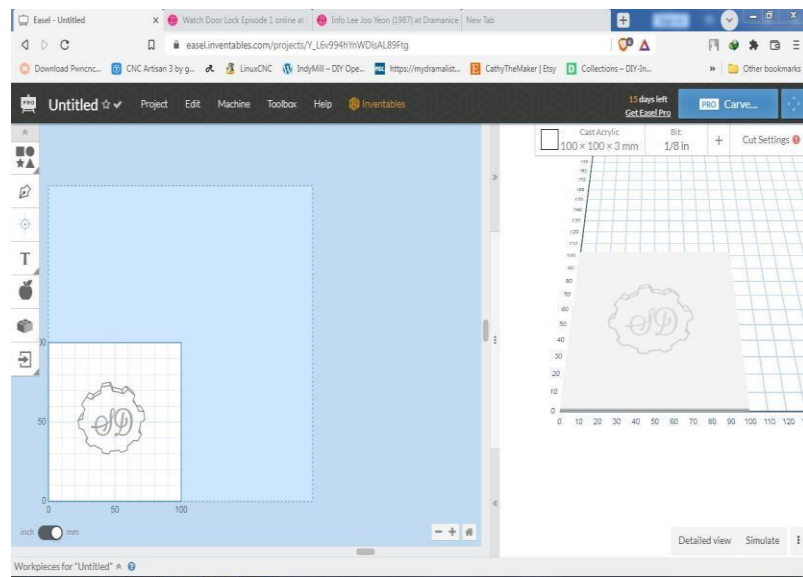

Fig 3.6 Easel Interface

STEP 5: Click on cut settings to set your desired value for cutting different material.

STEP 6: After, settings cut setting. Click on Crave option on the top right corner of the screen.

Which takes us to set of instruction to follow before actually machining to start.

STEP 7: The first step is about measure the material. This makes sure that the material placed is of right thickness.
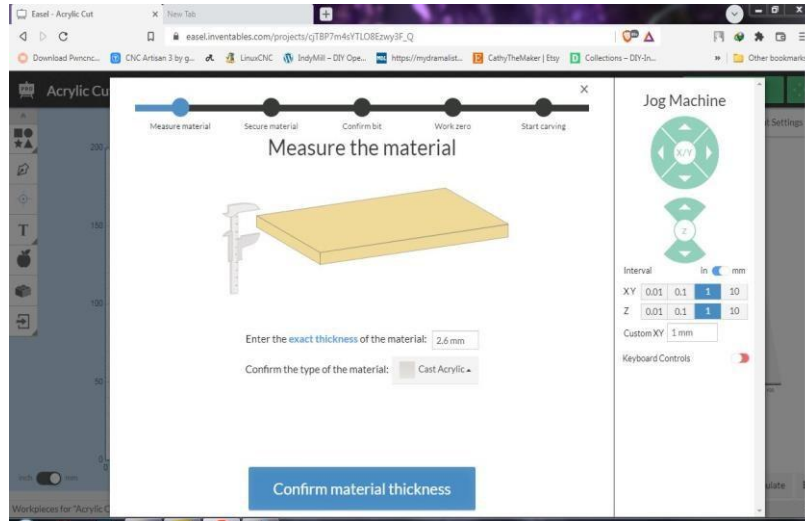

Fig 3.8 Measuring The Material

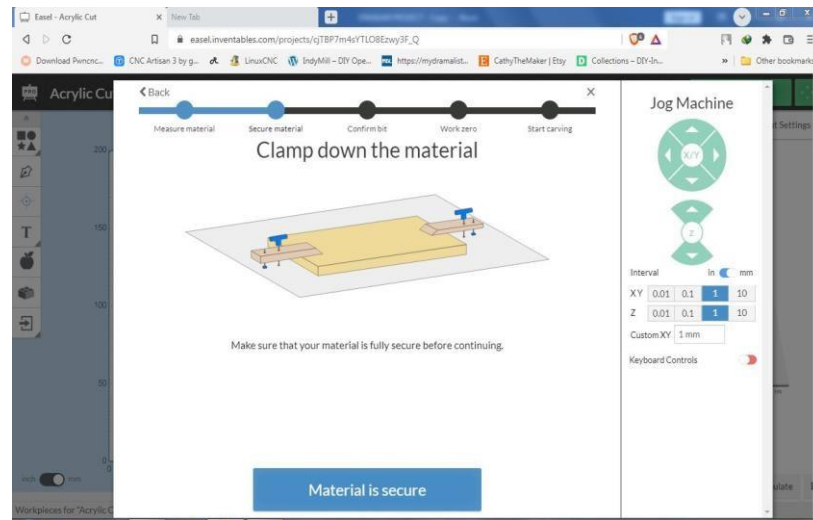**STEP 8**: Makes sure that the material is successfully clamped.

Fig 3.9 Make Sure That the Material Is Clamped

STEP 9: Conform the bit size before starting the operation.

STEP 10: Makes sure that position of the bit is zero to the work piece coordinate. This step is not to be confused with machine coordinates.

STEP 11: Make sure that the bit is raised up a bit to avoid breakage of the bit.

It also makes sure that the spindle is turned on.

STEP 12: After, the process we can move the machine by in built joy stick control on screen and start craving.

STEP 13: Time taken for the job is given on the top right corner.

STEP 14: Result of the job is shown in the below picture.
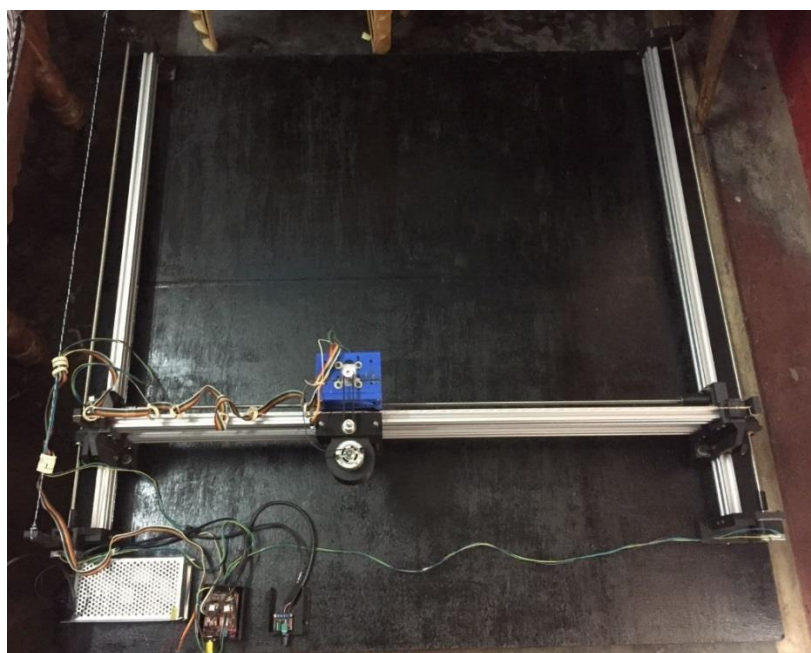
Fig 3.11 The Logo Has Been Engraved Successfully

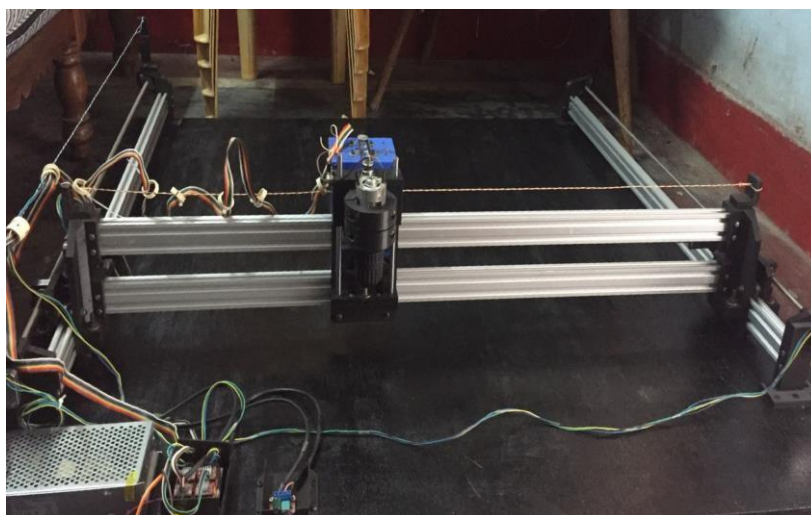**Fig 3.12 Top View Of The Machine**

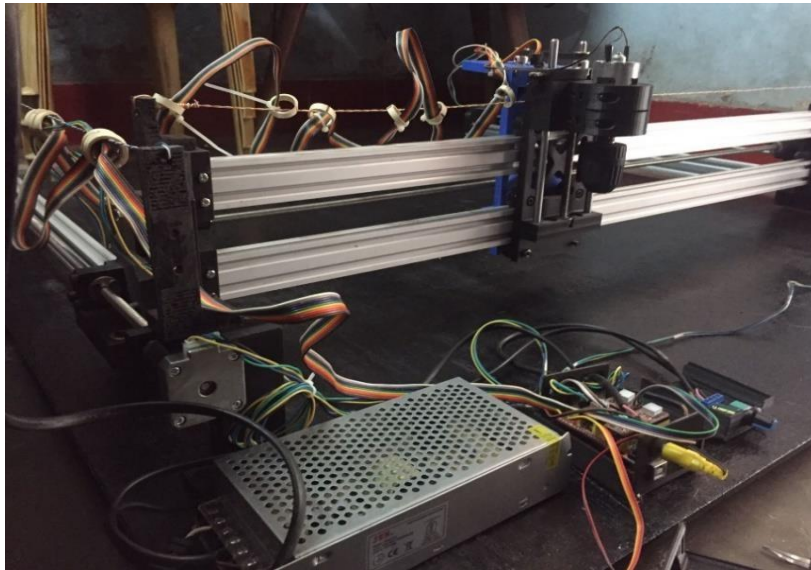**Fig 3.13 Front View Of The Machine**

Fig 3.13 Side View Of The Machine

4.EQUATIONS OR CALCULATIONS

CNC machine mechanically which it required a surface flatness test and perpendicular test as well as the accuracy for every axis movement. It is clearly to understand the accuracy of the geared stepper motor selected in this project is to run the axis is by using a quick calculation in order to obtain the accurate results for moving the stepper motor for desired direction. i.e., 10cm for 10 cm valve without any more high or low value.

Micro stepping

A very common resolution for stepper motors is 200 steps per revolution (aka. 1.8 degrees per step). We will use this resolution as an example in the rest of this post. Often 200 steps per revolution may not be sufficient to achieve the accuracy required by the men upstairs.

1.   To increase the accuracy, you can enable micro stepping. This will increase the number of steps per revolution with a factor of 2n (n is an integer). Micro stepping up to 8x (i.e. 8 times the full step resolution – resulting in 1600 steps per revolution in our example above) is common, but you may even find stepper systems with 256x micro stepping.

2.   One very important drawback with micro stepping you should take into consideration is that the holding torque drastically decreases as the micro stepping factor increases. According to micromo.com a micro stepping factor of 8x will give you only 19.51% holding torque compared to what you get from not enabling micro stepping (256x micro stepping will give you as little as 0.61% of the original holding torque)

$$\frac{360\ Degree\big/_{1\ revolution}}{degree\big/_{step}} = \frac{360°\big/_1}{12°\big/_1} = 30\ \frac{Step}{Revolution}$$

Fig 4.1 Calculation for E-step for Stepper motor

The first thing is to have Step/ cm required for the stepper to move an cm which drives from a stepper motor and the driver which is the A4988driver.

Usually, stepper motors use different steps per revolution as per the stepping angle for each type stepper motor.

That stands for if the stepper motor turns 360° it steps 30 times.

Where the driver is capable increasing the number of steps, now the driver has been set to 1/16 micro stepping which will equal to 30 X 16= 480 Steps.

To get the pitch circumference = distance between teeth X number of teeth= 6mm

Teeth profile	GT2
Teeth number	15
Bore Diameter	Ø6
Belt Width	6mm
Angle per steps	16

Table 1 Belt Specifications

No of Rep	Values
1st repeat	0.45 inch/ 11.43mm
2nd repeats	0.46 inch/11.684mm
3rd repeats	0.45 inch/11.43mm
4th repeats	0.40inch/10.16mm
5th repeats	0.41inch/10.414mm

Table 2 Values For 10mm Movement

4.CONCLUSION

Due to more demand for 3 axis CNC machines with high accurate machining output which can be capable of producing of industrial type of accuracy the retail prize for readymade CNC machine has been high lately. For, Fabrication of small detailed part or portable use the prize range usually higher than one can afford as desktop CNC machine.

In our work, designing a fabricating a CNC machine help us achieve a low prized CNC machine with a overall budget of 20,000 Rs. Excluding the cost of 3D printing. Since, it is DIY project we wanted to try outside box, hence, if you own a 3D printed, anyone can print this machine easily. We, decided to use gantry type because 3D printed parts are better in this type.

We have selected best components to provide accurate and easy products which are readily available for anyone to try building this machine. They are usually decided by software's such as AutoCAD, Fusion360 or Thinker cad. Component such as stepper motors, lead screw of Tr8, Coupling, flange bearing, v-wheels, aluminium extrusion profile of 20x40mm, Arduino, CNC shield, Drivers, 775 DC motor, Motor controller and many other parts are chosen specifically t to bring the output of the machine.

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