

Design and Fabrication of 3-Axis Computer Numerical Control (CNC) Milling Machine

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Abstract—The idea of making a compact and low cost 3 axis CNC MILLING MACHINE comes from increase in demand of low cost and Portable machine..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..Design and Fabrication is done using a Precision Stepper Motor that combined with Belt and Pulley arrangement on the gantry type aluminum structure on which the x and y axis is smoothly slide on rail bearing and for z axis we use Threaded rod and arrangement for up and down motion that increases and more precisely result obtained..It is an Microcontroller (Arduino uno) based embedded system with a standard pc user interface software for easy drawing..The System also features an offline G code parser and then interpreted on the microcontroller from a USB. Improved procedures are employed in the system to reduce the computational overheads in controlling a 3-axis CNC machine, while avoiding any loss in overall system performance.

Keywords—Mini CNC milling, 3axis, Arduino

I. INTRODUCTION

Computer numerical-controlled (CNC) milling machine is an industrial technology that uses a High rpm Spindle to cut materials. Mini CNC machine is the machine that is similar to usual CNC machine but it's limited by the area of machining. This machine is designed for small and precise measurement. CNC can be grouped into two types, which are rotary machine and milling machine. A rotary machine is basically a device that spins a material piece at a very high speed and the spinner moved back and forth and in and out until the preferred shape is complete. A milling machine is a machine that has spindle which consider as similar as the router, with a spindle that spines and cuts in various direction and moves in three directions along the X, Y, and Z axis. Recently, the industrial world has become faster smaller and in highly advanced technology to make things smaller, thinner and portable. As well as now the things in engineering and technology world have microcontroller in NANO and micro size. This also goes to 3-axis CNC machine; these machines nowadays have range size in the open market. Every type of machine has its own function, even still the size are big or small. Depends of the machine specification CNC can machine a big work-piece or small work-piece which is to be considered as a mini CNC machine according to the specification of the design. This paper work is to overcome the problem of machining the small part. Where the mini CNC machine is going to give the small area of setup the work-piece and it will be easier to get the accurate result of the work-piece.

Over decades, industrial technology has transformed many aspects of daily life. Several studies has been carried out for the development of such a (CNC) machine on smaller thinner, lighter weighted and budget cost. From the related journal and research, the main idea in carrying out this work of CNC development. As the technology of CNC machine characterized by accessible price and technology so rip that even individuals can design and construct CNC controlled machine[1]. Advanced facility and precision of control of CNC tools, if it's compare with usual machine, has had a significant influence on the development of function components, frame body, stepper motors, and control circuits. Construction and evaluation of Low-cost table CNC milling machine by using low-price milling cutter for the main spindle due to a low voltage supply of the main cutting forces it is possible to use the tools of smaller dimension to machine materials like wood, aluminium and plastic materials. Design and Implementation of Three Dimensional CNC Machine [2] where it discusses the design of low cost three dimensional CNC. The main function is a microcontroller based CNC machine and it's communication between personal computer (PC) and CNC machine by Software sub system that gets a set of commands and fetch it to the mechanical sub system in order to be control the 3-axis. Software sub system that is a PC that provides easy to use interface for user to program commands in such a language that microcontroller accepts. The author conclude that using C++ as language on NET platform as an alternative of using any ROTS which is expensive and not user friendly and not possible to execute in general PC which user has to get a separate operating system. The design of this system is user friendly which give accurate results and flexibility to us

For more Precision and Accuracy of CNC machine we are particular to pick segments Bipolar Stepper engines are utilized .It can be viewed as brushless DC motor, whose rotor pivots in for high torque discrete rakish augmentations when it . Stepper engine drive for PC numeric The stator conveys the attractive field which makes the rotor adjust itself to the attractive field The attractive field can be modified by consecutively invigorating or "venturing" the stator curls which creates turning movement control machine is genera reason stepper engines are evaluated with determination as. 1 low as 0.9° . Exactness, top of the line stepper engines are capable to[3] accomplish up to 0.05° . It is significance to take note of that stepper engines weight and power proportion is high, from where happens a most extreme achievable power too. PC based controller peruses G-code instructions,the code is produced by EASEL and Milling Software which straight forwardly create the G code for that Design it spares our chance make all procedure Easier.Large CNC frameworks, due to the overheads forced by an extensive G-code increment the equipment cost of the framework which making it excessively expensive for use by little enterprises. At the prior created microcontroller based CNC framework had numerous disadvantages. The GRBL G-Code interpreter[4] for instance, actualized just a portion of the numerous g-codes .Numerous wanders like ROTS based Embedded CNC structure and An Open Architecture Numerical control System Based on Windows have executed Operating structure on the embedded system[5] which lessen the taking care of and memory breaking point of the structure. Along these lines, these structures required top notch and exorbitant chip. It require for a G-code parser using an Arduino based microcontroller which is facilitated bit of the structure, is separated, a tremendous diminishment in the cost is refined, as needs be making the system unobtrusive for little scale organizations and individuals.

Program charges are made up by words . CNC controls utilize a word address design for programming. By word address arrange, we imply that the CNC program is comprised of sentence-like orders. Each charge is comprised of CNC words, every one of which has a note address and a numerical esteem. The note address (X, Y, Z, and so forth.) tells the control the sort of word and the numerical esteem tells the control the estimation of the word. Utilized like words and sentences in the English dialect, words in a CNC charge tell the CNC machine what it is we wish to do at the present time[6] The CNC developer must have a capacity to imagine the activity of the machine and he says, in comparative way, a manual CNC software engineer must have the capacity to picture the machining tasks that are to be performed amid the execution of the program[7] Then, in well ordered request, the software engineer will give an arrangement of orders that influences the machine to carry on likewise.

As perceived, "programs are set up of requests and charges are contained words". Each word has a letter address and a numerical regard. The letter address tells the control the word compose. CNC control makers do contrast concerning how they choose word names (letter addresses) and their suggestions. The beginning CNC programming engineer must reference the control maker's redoing manual to choose the word names and suggestions.

A pivot is a way of movement controlled by the CNC machine control. It can be direct (movement adjacent to a straight line) or round (a turning movement). The aggregate of tomahawks a machine has finishes up its machining capacities. For machining focuses, a three pivot CNC machine will have three straight tomahawks. A four or five pivot machine will have three straight tomahawks and additionally maybe a couple turning tomahawks.

The 3-Axis machine was intended to give a proper section level instrument for testing with 3-hub machining and CAD/CAM systems[8]. It has not been wanted to supplant present, higher end machines, for example, those made by Manufacturing Corporation. The accentuation is on availability and enables the client to totally change the in assembled firmware on the machine . With a specific end goal to build a three hub machine[8] there is a prerequisite to choose which the parts need to utilize so it can accomplish easily and productivity comes about.

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 liner system combined with stepper motor, driver,Aluminium Extrusion,with Belt and Pulley makes filling these necessities conceivable.Stepper Motor used as the driving and controlling instruments provide response, control, Linear motion systems have three basic categorize as 1) The control, 2). The drive tool, 3).The support of components.

The drive or control devices include a selection of electric motors such as linear, stepper. The drive tool, in combining with the drive, offers the thrust and axial positioning precision of the load. The guidance machines of the systems control travel direction and linear accuracy as well as support the load

Machines are presented with the traditional floor plate and mobile gantry,as well as special gantry mills with integral table providing heavy duty turning capabilities .the milling head rides over two rails(often steel tubes) which lie at each side of work surface.

For The Gantry machine it have 5 types:

- Gantry type structure offers maximum structural height dynamic performance X axis travel can enlarge according to client request y axis can travel the prepared with untested as crossbeam adjustment mechanism which can reach it off span at 7 m
- X axis has Aluminium Alloy Extrusion rail one Stepper Motor and 4 V Wheel synchronised with Belt and Pulley that controlled driving system to ensure vital dynamic accuracyAdditional extraordinary rigidity roller style linear guide ways for Y-axis cartel the benefits of both box way and linear guide ways which make the unit can do a heavy duty cutting, fast movement and low abrasion capabilities.
- Z-axis have an extra-large size linear guide ways which along with larger saddle and high rigidity box structure headstock which provides best cutting rigidity
 - As we all know that there is a bit of argument about the name of a particular axis and the direction it moves. Both sides of the argument have their merits [9]. The arguments begin when assigning axis to the device itself. Most people will call the axis holding the spindle the Z-Axis. However, the X and Y axis becomes a debate.The X-Axis should be the longer of these two axis [10]. 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 this paper is to design and fabricate a Compact CNC MILLING Machine and to use software to control the 3-axis machine. This project describes the design, fabrication and assembly requirement of the machine and the criteria required to build the machine sufficiently. And also to construct the whole system with a limited budget

II-METHODOLOGY

The structural design of the machine including to wiring connection and the software adopted to generate codes and C+ language. Finally but not last is Development the base of the design that has been achieved.

A. Structure Design

The machine structure is the vital part of the machining tool. It merges all machine components into a single complete system. The machine structure is vital to the efficiency of the machine since it's directly affecting the total dynamic stiffness and also affecting the damping response. Perfectly designed structure can afford high stiffness, which leads to precise operation. Mini scaled machine tool required more precise stiffness than the regular large scale machine tool as shown in Fig. 1.

The initial design will be drafting or sketching then when the design satisfied. The next level will be deciding the criteria required which is firstly the length travel. The length travel is the length of the X, Y and Z axis that travels from one point to another. The X axis move left & right, Y axis move front & back, Z axis moves Up and Down. Travel length that is to be designed is X axis 10cm and Y axis 10cm and Z axis. This structure comes with less materials hence it's very less expensive to build which it's designed to cut papers, engrave leather, wood & plastic cards.

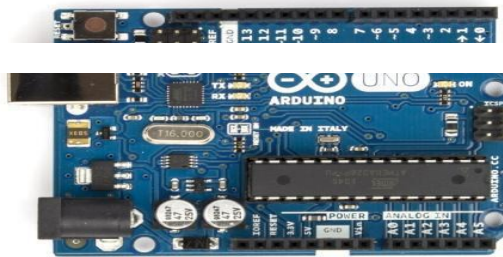


Fig.1 Arduino UNO

Stepper Motor Driver Board: RMCS-1102 is micro-stepping drive designed for smooth and quiet operation is chosen to drive the NEMA 17 stepper motor. Stepper motor Driver Board receives the control signal form the micrcontroller board

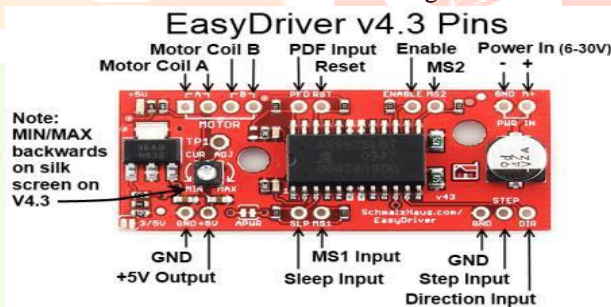


Fig.2 Easy Driver v4.3 pins

C.MECHANICAL SYSTEM:

The mechanical system which is assembled in such a way that the 3-axis movement is achieved by using the linear rails assembled with linear bearings. Stepper motors are mounted to the each axis which is source of motion acted according to the control signal generated from the electronics circuit. Each stepper motor is coupled through the shaft couplers to each of the Lead/Ball screw of each axis which is responsible for converting the rotational motion of the stepper motor to linear motion. The linear motion of each axis is carried away smoothly by the linear rail assembly connected to the each axis which is capable of load carriers and allow linear motion in each axis. The controlled motion in each axis is achieved directly by by controlling the rotation of the stepper motor. The speed of the motion in each axis can also be controlled by direct control of the speed of the stepper motor by giving required control signals. Thus the tool path of the spindle fixed to the end effector is controlled in each axis for smooth carving or cutting action of work piece.

D. Design and Fabrication-

- [1] Start from the Base install 4 to 6 rubber feet.
- [2] Make a working area bed 500*500mm
- [3] Install four gantry on each side.
- [4] Make X and Y frame by fixing sliding rod to gantry.
- [5] Make the Z axis frame.
- [6] Assemble it with Threaded rod and nut assembly.
- [7] Fix the timing belt and Sliding roller on each axis
- [8] Assemble belt and pulley with Stepper motor.

[9]Fix the spindle on z axis and power supply.

[10]Connect power supply to extension board and give the command by easel software.

D. Programming and Coding System :

The apparatus chain of CNC-based assembling is spoken to in the fig11. The part to be machined is outlined in a PC supported plan (CAD) programming, whose yield is an attracting one of numerous worthy organizations most best configuration is .stl arrange. This attracting is then nourished to the PC helped producing (CAM) programming, whose yield is the machine intelligible code utilized for numerical control of the machine. Since execution of the G code is machine subordinate, it is important to try out various decisions for an open source G code mediator for the Arduino, so the right movements are acquired for the machine tomahawks through the stepper engine driver. We have utilized GRBL, an open source G-code mediator or processing controller for the Arduino advancement board.

E-Computer aided design SOFTWARE: Computer-helped plan (CAD) is the utilization of PC frameworks to aid the creation, alteration, examination, or advancement of an outline 3D sections for CNC cutting.CAD devices in the most genuine sense are intended to enable you to effortlessly change and control parts in view of parameters. The most broadly utilized tradable work document organize is .STL records are essential since, they are utilized by CAM instruments to create Gcode OpenSCAD, FreeCAD, HeeksCAD PTC Creo (once in the past PTC Pro/Engineer), Dassault Solidworks, Autodesk Inventor, Auto CAD are a few cases of CAD bundles

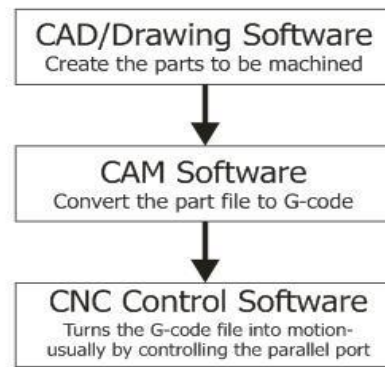


Fig.3Sequence of Programming

CAM SOFTWARE:Computer Aided Manufacturing, or CAM, devices handle the middle of the road venture of making an interpretation of CAD records into a machine-accommodating configuration utilized by the Microcontroller board. CAM programming needs a .STL record design from CAD programming to create machine agreeable GCODE. Some case bundles resemble CAD/CAM, G-Simple, FreeMill, Dolphin CAD/CAM, CamBam, Vizion (ArtCam), OneCNC, VirtualGibbs, MasterCAM , BOBCAD-CAM, MeshCAM, VisualMill, TurboCADCAM, DeskCNC, SheetCAM, OneCNC, SprutCam, EdgeCAM, ArtCAM and so on.

CNC CONTROL SOFTWARE (GCODE Sender): Gcode Sender is utilized to send the G-code records to a coordinated equipment interpreter(Atmega 328).Gcode Sender will take a G-code program in document and send it line by-line to the Atmega 328 microcontroller. The Gcodes will send over the serial ports through USB correspondence between the PC and microcontroller .GRBL Controller is programming that is intended to send GCode to CNC machines is ,, for example, 3D processing machines. It isn't super brilliant, it simply needs to give the client a decent method to get summons down to whatever controller they are utilizing



Fig. 4 Milling text by Easel Software

III.Result and Discussion

Software results

The machine process is using a graphical user interface (GUI) e.g., “EASEL” which is graphical software that runs into a PC for creating and designing an image to be convert it into G-Code .nc file which used to run the design into GRBL Controller.

Mechanical results

CNC machine mechanically which it required a surface flatness test and perpendicularity test as well as the repetition accuracy of the axis movement. It is clearly to understand the accuracy of the geared stepper motor selected in this project to run the axis is by using a quick calculation in order to obtain the accurate results.

$$\frac{360 \text{ Degree} / 1 \text{ revolution}}{\text{degree} / \text{step}} = \frac{360^\circ / 1}{12^\circ / 1} = 30 \frac{\text{Step}}{\text{Revolution}}$$

The first thing is to have Step/ inch required for the stepper to move an inch which drives from a stepper motor and the driver which is the Easydriver. Typically stepper motors uses different steps per revolution as per the stepping angle.

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 microstepping which will equal to $30 \times 16 = 480 \text{ steps}$

To get the pitch circumference =

$$\text{distance between teeth} \times \text{number of teeth} = 3 \text{ mm}$$

Axis Accuracy and repeatability

Using a stepper as an accurate movement for CNC is its role of machining success. A machining measuring tool is used to measure how accurate is the stepper motor precision to get it to run. An experiment is held with controlling a stepper using an arduino connected with an easy driver which it has a built in parameters for de-acceleration and acceleration.

Utilizing a G-code to move the pivot's is the way what measures the repeatability and this code are implemented through GRBL application which been gathered with arduino. With a specific end goal to get into the analysis the necessities are : DTI dial test pointer as appeared in Fig. 5, Stepper engine, Arduino, Easydriver, GRBL application.

The results are in each repeated measurement been held is not only testing the stepper motor accuracy but it is the whole system is perfectly accurate $\frac{480}{\pi} = 160 \text{ mm}$ which will get the theoretically number in the real world numbers.

Table 1 shows the pulley specification used in this project which the number of teeth is the core of calculation.

In this Fig.6 will show how was the axis's are accurate in each repeat the X axis readings are given in Table 2 and the accuracy of the y-axis has been promising the precision values that in each repeat the value was fixed every time testing the values of Y-axis shown In this Fig. will show how was the axis's are accurate in each repeat the y axis readings are given in Table 3.

that mean in one revolution we will able to travel 3 mm so to find out how many steps it takes to travel one inch which will get the theoretically number in the real word numbers

Teeth profile	GT2
Teeth number	15
Bore Diameter	Ø3
Belt Width	3mm
Angle per Step	12°

Table-1 Pulley Specification

No of Rep	Values
1 st repeat	0.45 inch
2 nd repeat	0.46 inch
3 rd repeat	0.45 inch
4 th repeat	0.48inch
5 th repeat	0.46inch

Table.2X axis Repeated Data

No of Rep	Values
1 st repeat	0.4912 inch
2 nd repeat	0.4914 inch
3 rd repeat	0.4913 inch
4 th repeat	0.4912 inch
5 th repeat	0.4912 inch

Table-3 Y axis Repeated Data

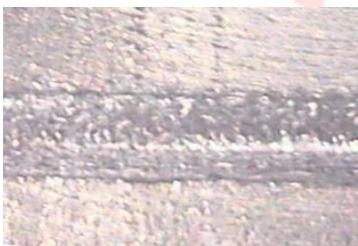


Fig 20 ., Surface Of cutting



Fig 21 . Surface Of cutting



Fig.22 Surface of cutting

G CODE -

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(ADITYA)
(A)
N10 G0 Z2
N20 G0 X0 Y0
N30 G1 Z-1
N40 G1 X10 Y30
N50 G1 X20 Y0
N60 G0 Z2
N70 G0 X17.222 Y8.333
N80 G1 Z-1
N90 G1 X2.778 Y8.333
(D)
N100 G0 Z2
```

N110 G0 X30 Y0
 N120 G1 Z-1
 N130 G1 X30 Y30
 N140 G1 X38.333 Y30
 N150 G2 X46.667 Y21.667 I0 J-8.333
 N160 G1 X46.667 Y8.333
 N170 G2 X38.333 Y0 I-8.333 J0
 N180 G1 X30 Y0
 (I)
 N190 G0 Z2
 N200 G0 X58.333 Y0
 N210 G1 Z-1
 N220 G1 X58.333 Y30
 (T)
 N230 G0 Z2
 N240 G0 X70 Y30
 N250 G1 Z-1
 N260 G1 X86.667 Y30
 N270 G0 Z2
 N280 G0 X78.333 Y30
 N290 G1 Z-1
 N300 G1 X78.333 Y0
 (Y)
 N310 G0 Z2
 N320 G0 X96.667 Y30
 N330 G1 Z-1
 N340 G1 X106.667 Y16.667
 N350 G1 X106.667 Y0
 N360 G0 Z2
 N370 G0 X106.667 Y16.667
 N380 G1 Z-1
 N390 G1 X116.667 Y30
 (A)
 N400 G0 Z2
 N410 G0 X126.667 Y0
 N420 G1 Z-1
 N430 G1 X136.667 Y30
 N440 G1 X146.667 Y0
 N450 G0 Z2
 N460 G0 X143.888 Y8.333
 N470 G1 Z-1
 N480G1X129.445Y8.333

IV. CONCLUSION

Due to more demanded for mini scaled 3-axis CNC machine with highly accuracy parts in different industry, the retail for 3-axis mini CNC machine has noticeably been increased. For fabrication small parts need to be provided both flexibility and efficiently in the manufacture assembling, the CNC machine has achieved the desired precision and accuracy.

In this work, a mini 3 axis cnc machine designed and fabricated with a low-priced of 18000 Rs. Throughout the structural design stage there was many common CNC approaches and reduce total cost which is affordable for individuals and small business. Due to a success selection of a body parts and precision calibration, testing and structures been found and tested. The most appropriate structure is the gantry type structure was chosen and designed through a Autocad software. Precarious components such as liner guides, stepper motors, and microcontrollers and modules is precisely choosen among a huge different choices in order to fit the requirements.

The best cost components are selected to provide accuracy and simplicity and as well as budget limitation. The assembling of a mechanical parts and emerging it into an electronic components are perfectly been considered. A model of a CNC machine is assembled in house using and in the lab to perform a testing criteria of the machine components before assembling it. The steps of building a wooden structure are followed in detail from a CNC structures company has been followed to meet the accuracy while merging it into an electronic as well as mechanical parts together. The configuration and calibration steps are clearly given with all details. The complete machine functionality verified using a various of tests which flows from softwares test into a mechanically tests, the errors has been initially clarified and determined to ensure reliability of the machine. As well as finding a best possible solution in human monitor interface (HMI) rather than using a PC to be mobilized is using a touch screen from Raspberry Pi as computer. Since Raspberry Pi equipped with it's own embedded Operating system Linux, while the user can practically copy a machine code G-Code file hooked on the system using a simple USB driver which will help to stream the machine code to arduino Uno

In conclusion the exactness of the smaller than expected 3-hub CNC machine body parts amassing has prevailing to accomplish the targets of this task in conservativeness precisionly and repeatability goal. It give and meet all necessity at little scale in moderate cost

V. FUTURE WORK:

It is wanted to scale up the model CNC machine as far as size, utilize all the more capable motors, fortify the edge and worktable with materials like aluminum or cast iron, and expand the CNC control programming with programming for reenactment in front of genuine run. For instructional purposes and for more exact task, it is desirable over form CNC machines with DC or AC servomotors and encoder input utilizing PC-based movement controllers. It is intended to actualize the multi pivot around 4 to 6 hub CNC switch. The execution of 3D printing (Rapid prototyping) innovation to a similar equipment conceptual is progressing plan for printing 3D models. we can likewise change over it into laser CNC machine.

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