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Research Article

Design and Implementation of 4-Axis CNC Machine

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Abstract: In order to achieve the productivity growth in the current trend of the integrative engineering, a series of researches are focused on the development and analysis of the methods for decreasing the time required for the transition from computer modelling of the product. A CNC router is a computer controlled cutting machine related to the hand held router used for cutting various hard materials, such as wood, composites, aluminium, steel, plastics, and foams. The main objective of this research is to design and develop for the 4-axis CNC machine. This research is aim purposely for a small scale product that use CNC machine which is commonly use in the industries specifically for a small product. This paper mainly focus on the methodology design and development of 4-axis machine CNC to fulfil the main objective. This paper is based on the fabrication of a mini CNC router which is compatible to extrude as CNC milling machine and also to make this CNC machine very less expansive and affordable, compact in size and less power consuming and user friendly interface to operate very smoothly. Instead of routing by hand, tool paths are controlled via computer numerical control. This machine is modified as 4-axis CNC by adding extra axis named A-axis. Function of A-axis is rotation parallel with X-axis like a lathe. So Function of this CNC machine is much more than 3-axis CNC that based Cartesian coordinate 3D motion.
Keywords: CNC, 4-Axis, G-Code, M-Code, 3D motion, Manufacturing.

Introduction

Nowadays, more and more machines are being converted in CNC machines due to their high accuracy, high precision, less setting time and greater repeatability. The CNC router is ideal for hobbies, engineering prototyping, product development, art, and production work. A CNC router typically produces consistent and high-quality work and improves factory productivity. Routers are generally for producing larger work and more commonly built with the idea of cutting wood, plastics, composites, aluminium, steel, plastics, and foams. Also, routers are most commonly found in a 3-axis setup (X, Y and Z). This set up will allow cutting of basic profiles and 3-dimensional relief machining. Numerical control is such a useful thing that can control a machine with numeric values and codes. In the world of high precision fast growing technology Retrofit Design concept for developing low cost high accuracy high precision machineries is required.

For several years, rigorous research has been conducted in the area of CNC milling from diverse perspectives. The five-axis milling machines are classified according to the combination and order of the linear (T) and rotational (R) axes. The selection of certain variant is very important because not every machine can perform any task. That numerical control is then advanced into computer programming and CNC machine stepped on to the flow of production Automation and precision are the key benefits of CNC router tables. A CNC router can reduce waste, frequency of errors, and the time the finished product takes to get to market.

The commercial CNCs are bulky and so much expansive and not possible to afford by normal people in home. So the machine with computer ability and in less size mini CNCs came in. CNCs are much complex in its function. It works with the simultaneous interpretation of software and hardware. In modern CNCs production of a product is fully controlled automatically by the help of CAD and CAM. CNC stands for computer numerical control. CNC routers can perform the tasks of many carpentry shop machines such as the panel saw, the spindle moulder, and the boring machine. Mini CNCs are much smaller in size and affordable. With much smaller space CNCs can be used by normal people for domestic issues. Here it is tried to develop CNC technology to make it more portable and up gradable to 4-axis with much less power.

Design Methodology

A mini CNC could be designed various ways. One of them are fixed router with movable bed type and another type of design is with 3axia router movement. Methodology is a guideline for a developer to plan the structure and control development process. Design and development of this CNC 4- axis machine consist of several parts which is the mechanical parts, electrical parts and programming. Each part will be design stage by stage according to its priority. The structure of the machine is the prime priority here because the whole system will depend on its design and stability. The operation is all same like the other CNC machines. First, user will key in the data into user interface that have been made on the computer, and then data will be sent to the controller. The controller then read the data and sent it to the stepper motor. And the result, the motor will move according to the user input data. Controller will sent the data to the motor by using number of bit. Whereby these number of bit will determine the rotation of the motor. The master mind of this project is depending on the program. These are the basic dimensions and parts used for the machine;

Overall Parameter:	**Allowable Distance:**
X: 650mm	X: 305mm
Y: 800mm	Y: 350mm
Z: 500mm	Z: 127mm

For this project you will need to have a set of screwdrivers and a set of hex keys or Allen keys, a drill for some extra holes, metal cutting saw to cut some custom parts, soldering station or soldering gun join the wires so they`ll have a good conductivity , and a multi-meter.

Main Components for Mechanical Design (Shafts, Bearings and Lead Screws)

1) Precision Steel Shafts

Ø16mm precision steel shaft for X axis, cuts from 1 piece of 60 inch=1524mm shaft, (2 pieces)

2) Ball Bearings/Bushings

Ø16mm (Ø26 outer diameter) ball bearings/bushings (8 pieces)

3) Trapezoidal Lead Screws (cut from a 500mm long trapezoidal lead screw)

Ø8mm trapezoidal lead screw with 4mm pitch for X axis (1 piece of 650mm long)
Ø8mm trapezoidal lead screw with 4mm pitch for Y axis (1 piece of 500mm long)

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Ø8mm trapezoidal lead screw with 4mm pitch for Z axis (1 piece of 350mm long)

4) Trapezoidal Cylindrical Nuts (that made on a lathe in a local workshop)
Ø8mm with 4mm pitch nut (3 pieces with Ø24mm outer diameter and 24mm long)

Cast Iron Profiles
Before mounting all the parts well need to make some machining to the iron parts. The modifications that they`ll have to make must be done on a milling machine and not by hand. Make some holes thru which screws and trapezoidal lead screws cross (X Base, Y side parts, Z parts), some 5 mm deep holes in which the precision steel shafts are centered, some 5 mm deep holes in which the trapezoidal lead screws end bearings stand (X Base, Y side parts, Z parts). Need to make 3 holes in the Y cross section, two of them for the linear ball bearings and one in center for the trapezoidal nut. In the two pieces of X Y carriage profiles you will have to make 5 pockets in witch will sit tight the 16mm linear ball bearings and a trapezoidal nut .The machining of these parts was made in a local workshop on an old Conventional 3-axis vertical milling machine.

Trapezoidal Lead Screws and Nuts
The next step will be to machine the ends of the trapezoidal lead screws so you can mount the bearings. This will also need a lathe to make the ends more accurately so that the bearings won't be moving in all directions. The trapezoidal nuts were made from scratch, out of alloy that is *an engineering thermoplastic used in precision parts that require high stiffness, low friction and excellent dimensional stability* There are two types of 8mm trapezoidal nuts, first one has 8 mm outer diameter .

Mechanical Components at Z-axis
For the Z-axis,
120x120x30 iron profile (1 piece)
120x60x30 iron profiles (2 pieces)
Ø16 by 300mm long precision steel shafts (2 pieces)
Ø16mm (Ø26 outer diameter) ball bearings/bushings (4 pieces)
Ø8 by 350mm long trapezoidal lead screw (1 piece)
6000zz ball bearings (2 pieces)
Ø8 by Ø16mm outer diameter and 24mm long trapezoidal nut (1 piece)
M5x40mm screw (4 pieces)

Now will mount the ball bushings in all 4xØ26mm holes of the iron profile them will mount the trapezoidal nut in to the Ø24mm hole. Next mount the trapezoidal lead screw in to the trapezoidal nut and then mount the 2 pieces of 6000zz ball bearings in to the Ø26mm hole of the 120x60x30 iron profile.

Insert the 2 shafts into the ball bushings and then mount the 2 pieces of iron profiles at each end of the shafts and trapezoidal screw. The last operation is to mount the screws in to the shafts hole to fix the whole assembly.

Mechanical Components at Y-axis
For this Y-axis:
400x120x30 iron profiles (2 pieces)
120x120x30 iron profile (1 piece)
Ø16 by 390mm long precision steel shafts (2 pieces)

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Ø16mm (Ø26 outer diameter) ball bearings/bushings (4 pieces)
Ø8 by 500mm long trapezoidal lead screw (1 piece)
6000zz ball bearings (1 piece)
Ø8 by Ø24mm outer diameter and 24mm long trapezoidal nut (1 piece)
M5x40mm screws (4 pieces)

The first thing you`ll have to do is to mount all the Ø16mm ball bushings and the Ø16mm by Ø24mm trapezoidal nut in the 120x120x30 iron profile like in step 6 and then insert the shafts in the mounted ball bushings and the trapezoidal lead screw in the trapezoidal nut.

Mount the 2 pieces of the 6000zz ball bearings in the Ø26 hole of each 400x120x30 iron profiles. Next mount the 400x120x30 iron profiles at each end of the shafts and fix them together with the 4 pieces of M5x40mm screws.

Mechanical Components at X-axis
For this X-axis:
400x120x30 iron profiles (2 pieces)
380x60x30 iron profile (1 piece)
Ø20 by 600mm long precision steel shafts (2 pieces)
Ø16mm (Ø32 outer diameter) ball bearings/bushings (4 pieces)
Ø8 by 650mm long trapezoidal lead screw (1 piece)
6000zz ball bearings (2 pieces)
Ø8 by Ø16mm outer diameter and 32mm long trapezoidal nut (1 piece)
Pieces of ball bushing supports (2 pieces)
M5x40mm screws (4 pieces)
M5x60mm screws, for the ball bushing supports (2 pieces)

For start mount the ball bushings in the 2xØ32 holes of the 380x60x30 iron profile and then the trapezoidal nut in the Ø16 hole from the middle of the iron profile. Mount the 2 pieces of 6000zz ball bearings in the 2xØ26 holes of each 400x120x30 iron profiles and 2 pieces of Ø20mm ball bushings in to each ball bushing supports.

Now insert the shafts in the mounted ball bushings and the trapezoidal screw in the trapezoidal nut and then mount the 2 pieces of 400x120x30 iron profiles at each end of shafts and trapezoidal screw. Fix the shafts on to the 400x120x30 iron profiles with the 4 pieces of M5x40mm screws.

Figure 2. Mechanical Assembly for X axis, Y axis and Z axis

Mechanical Components at A-axis

A-axis is located parallel to the X-axis. At A-axis, the workpiece can be rotated 360 degrees and machined by the spindle tool that is fixed along the Z-axis. The workpiece such as cylindrical and square shaft, can be designed any patterns. The operation of this axis is like as a lathe machine but the rotational speed is not too much.

The direction of rotation and speed can be controlled by stepper motor. This axis is composed of a four jaw chuck, a cast iron shaft, three ball bearings with housing, a stepper motor, a coupling coupler and a tail stock.

Cast Iron Shaft: It is used to connect stepper motor and four jaw chuck, fixed with two 38.1mm ball bearing. It is connected four jaw chuck with four 6mm nuts.

Ball Bearing: Two 38.1mm ball bearing are used to fix cast iron shaft and 19mm ball bearing is used for tail stock. These are used to reduce the torque of rotation of chuck that is driven by stepper motor.

Tail Stock: It is used to be horizontal the workpiece for machining when a workpiece is longer than 80mm. The functions of tail stock are to stable a long workpiece and to get centering point.

Four Jaw Chuck: This chuck is suitable for use or various lathes, millers machines, ordinal internal and external grinding machine etc. for workpiece holding so as to and the machine to accomplish their cutting process.

NEMA 17 Stepper Motors: A stepper motor is a special type of brushless DC motor. Electromagnetic coils are arranged around the outside of the motor. The center of the motor contains an iron or magnetic core attached to a shaft. By sequencing the voltage of the coils precise rotational control can be achieved at relatively low cost. By creating toothed shaped coil assemblies and toothed/gear shaped rotors, very high steps counts per rotation of 200 to 400 can be achieved. Stepper motors have a rated voltage and current.

A typical stepper motor like our **NEMA 17** might have a rated voltage of 2.8 Volts and a maximum current of 1.68 Amps. This basically means if you hook it up to 2.8 Volts it will draw 1.68 Amps. If you try to run it at a higher voltage it will draw more current and get excessively hot. Most people don’t hook motors straight to a voltage source. They use a **stepper motor driver**. Stepper motor drivers regulate the current. The stepper motor driver will not allow that to happen and use high frequency pulses to limit the average current to the desired maximum value. Stepper motors are designed to work this way and it is safe to run the motors at up to 20 times the rated voltage. You will actually get better performance by running at a higher voltage than the rated voltage.

Stepper motors can safely run quite hot even when running under correct parameters. It won’t hurt the motor, but should also be concerned with personal safety from burns or heat damage to the machine. Test the settings in machine and set the current at a reasonable value. Stepper motors draw power even when they are not moving, so they are generally not very power efficient. They would be a poor choice for a battery powered toy car, for example. The motors would always be drawing full power and quickly drain the battery. A standard brushed DC motor does not draw any power when not spinning and would be a better choice.

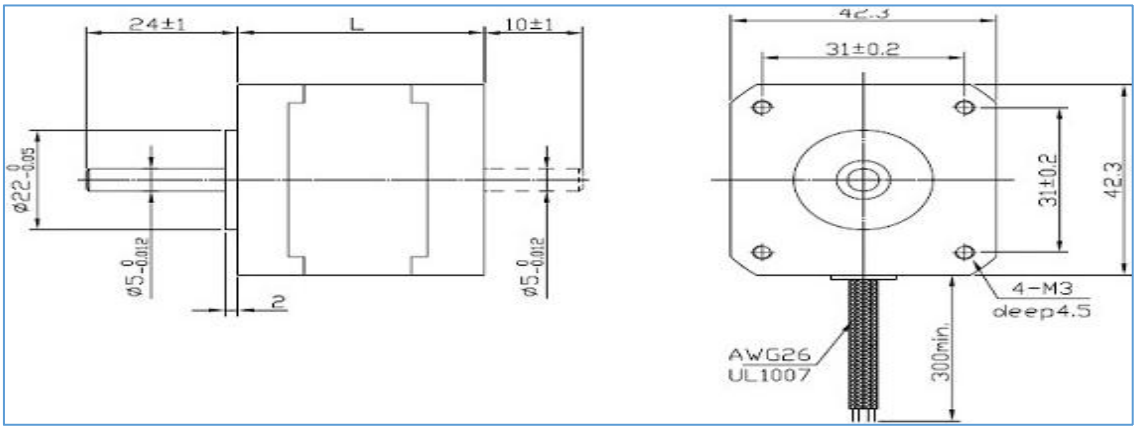

Figure 3. Diagram of Nema 17

Electrical and Electronic Parts

Compatible Shield: Compatible shield (HCARDU0086) is designed to allow you to control a CNC router or milling machine from an Arduino board. It contains 4 driver sockets which allows compatible Pololu A4988 driver modules to be inserted (see HCMODU0068 on our website) providing the ability to drive 3 stepper motor axis (X,Y, & Z) plus an optional 4th auxiliary motor. Additional connectors provide easy connection of end stop sensors and control buttons.

GRBL 0.8c compatible: Open source firmware that runs on an arduino UNO that turns G-code commands into stepper signals) 4-Axis support (X, Y, Z, A-Can duplicate X, Y, Z or do a full 4th axis with custom firmware using pins D12 and D13)2 x End stops for each axis (each axis pair shared by same IO pin) Spindle enable and direction connection. Coolant enable connection.

Motor Drivers (A4988): Most stepper drivers have a means to set the maximum current. It is usually done by setting a voltage at a control pin or from an on board potentiometer. The stepper driver's maximum current assumes you are adequately cooling the driver. It is often hard, even with heat sinks to fully cool the drivers at the maximum current setting. Check your temperatures while using the machine. Most drivers have a thermal protection feature that disables the driver for a brief period of time to allow it to cool. If you are losing steps or hear a ticking or pulsing sound from your motors, it could be due to thermal shutdown. Try lowering the current. If your driver is rated for less current than the motor, that is fine. You just won't get full performance from the motor. If the driver is rated for more than the motor, you must reduce the current to the motors maximum current. It is never a good idea to disconnect a stepper motor wire from a driver with the system powered. Many drivers are not protected from this and will be permanently destroyed.

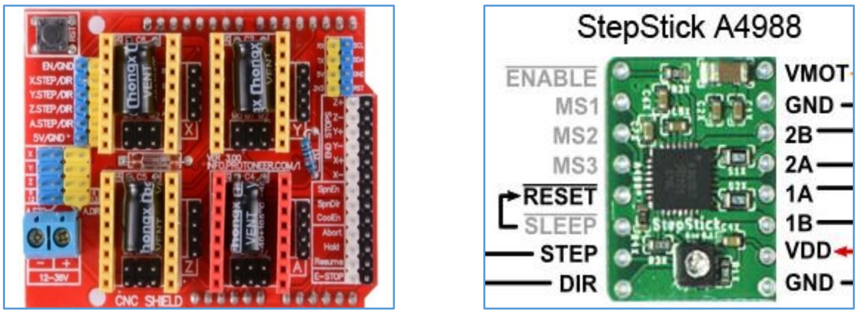

Figure 4. CNC Compatible Red Board & Step Stick A4988

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Software Interface

CNC Controller Card and Mach 3 Software: Mach3 is a software package that runs on a PC and turns it into a very powerful and economical Machine Controller. To run Mach3, need a PC running the Windows 2000, Windows XP, Windows 32-bit Vista or most of latest Microsoft operating system. ArtSoft USA recommends at least a 1GHz processor with a 1024 x 768 pixel resolution screen. Can use this computer for any other functions in the workshop (such as running a CAD/CAM package) when it is not controlling machine.Mach3 and its parallel port driver communicate with the machine hardware through one (or optionally two) parallel (printer) ports.

If computer does not have a parallel port (more and more computers are being built without one), can buy a motion controller board from a third-party vendor that uses a USB port or Ethernet for communication. Mach3 generates step pulses and direction signals to perform the steps defined by a G-Code part program and sends them to the port(s) or motion controller board. The drivers for machine's axis motors must accept March3's step pulses and direction signals. Virtually all stepper motor drivers work like this, as do modern DC and AC servo systems with digital encoders. To set up a CNC system to use Mach3, must install the Mach3 software on computer, and properly connect motor drives to the computer's ports.

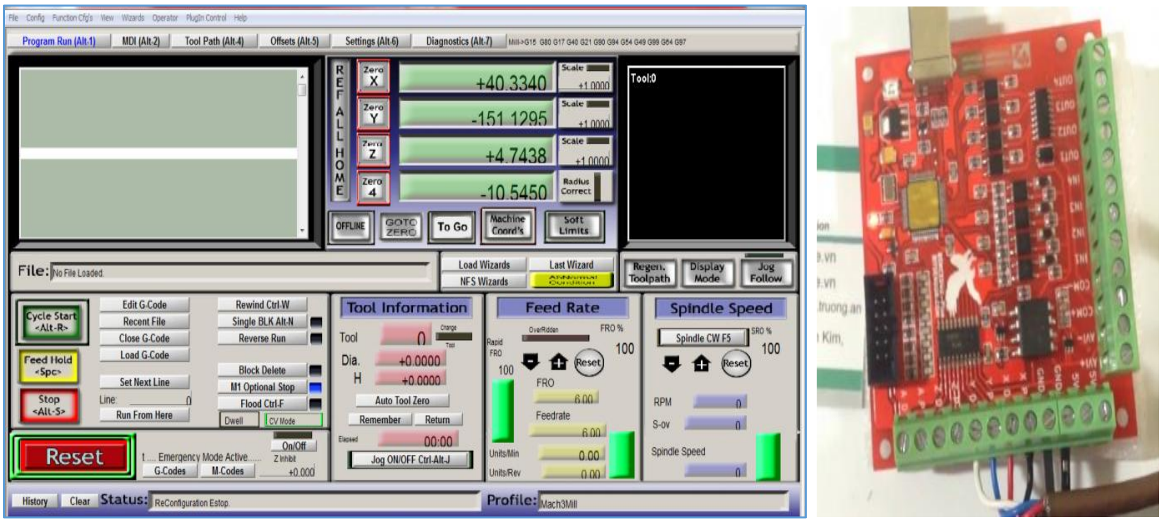

Figure 5. Mach 3 Controller Software and USB Mach 3 Card

Mach3 is a very flexible program designed to control machines such as milling machines, lathes, plasma cutters, and routers. Most connections between machine and the PC running Mach3 are made through the parallel (printer) port(s) of the computer. A simple machine will need only one port; a complex one will need two. Connections for control of special functions like an LCD display, a tool-changer, axis clamps, or a sward conveyor can also be made through a ModBus device. Buttons can be interfaced by a "keyboard emulator" which generates pseudo-key presses in response to input signals. Mach3 will control up to six axes simultaneously, coordinating their movement with linear interpolation or perform circular interpolation on two axes (out of X, Y or Z) while simultaneously linearly interpolating the other four with the angle being swept by the circular interpolation.

The tool can thus move in a tapering helical path if required! The feed rate during these moves is maintained at the value requested by designed part program, subject to limitations of the acceleration and maximum speed of the axes. The axes can be moved by hand with various jogging controls.

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If the mechanism of designed machine is like a robot arm or a hexapod, then Mach3 will not be able to control it because of the kinematic calculations that would be needed to relate the “tool” position in X, Y and Z coordinates to the length and rotation of the machine arms. Mach3 can switch the spindle on, rotating in either direction, and switch it off. It can also control the rate at which it rotates (rpm) and monitor its angular position for operations like cutting threads.Mach3 can turn the two types of coolant on and off.

Mach3 will monitor the EStop switch and can take note of the operation of the reference switches, the guard interlock, and the limit switches. It can store the properties of up to 256 different tools. If, however, machine has an automatic tool changer or magazine, it will have to control this by self. Mach3 provides program macro capability, but must do the programming.

Flexible Shaft, Spindle and AC Motor: Flexible shaft carving systems are not a necessity for woodcarving, but they sure are nice to have for several reasons. Carving with gouges or knives is generally a slow, thoughtful process. To save time I often will use my high speed flexible shaft tool to rough out a carving. With a coarse carbide burr you can chew through wood faster than a school of piranha in a feeding frenzy.

A second advantage is that a flex shaft carver allows me to carve in places that are impossible to reach with either a gouge or knife. Finally, if you want to add textures, such as feathers or hair, no tool is better, in my opinion, for creating these realistic details. A flexible shaft tool derives its name from the flexible cable that connects its motor to a handpiece. These rotary power carving systems consist of just a four primary parts: the electric motor, the speed control, the handpiece and the flexible shaft. As the motor spins, the shaft rotates inside a protective outer sheath, which in turn spins the cutting head affixed to the handpiece. The setup is similar to a dentist’s drill. The torque of a heavy-duty motor, however, is typically much greater, because you are grinding through wood not through tooth enamel.

AC Motors: AC Motors that power a flexible shaft system are available in a variety of sizes from 1/10 horsepower to ½ horsepower. I wanted one with plenty of torque for woodcarving, so I chose a system with a heavy-duty 1/3 horsepower motor, capable of generating a maximum speed of 30,000 rpm. The motor typically has a wire loop on the top which allows you to hang in from a telescoping rod assembly.

The advantage of one of these hanging assemblies is that it you can easily adjust the position of the motor for convenient access to your carving. Motors are generally capable of running in either forward or reverse direction, but you will probably only need the forward setting.

Figure 6. Flexible Shaft, PWM Step down Voltage Regulator & AC Motor

Speed Controller: To control the speed of the motor most people prefer to use a variable speed foot pedal control. This control works like the gas pedal in your car. Just step on the pedal and you will go from 0 to 22000 rpm in a heartbeat. Another option is a bench-top controller. Varying the speed with this controller is simply accomplished by turning a dial.

Handpiece Spindle and Usage: While the handpiece of a flexible shaft cutter is not as lightweight as the one that a dentist uses, it is compact and allows for precision control when you are carving, cutting or texturing the surface of a carving. The system that I have uses two different handpieces. For roughing out a carving, I use the heavier handpiece that can accept burrs with shafts as large as ¼" (6mm).

This thicker and heavier tool can withstand the vibration of heavy grinding. For detail work, a much thinner and lighter weight handpiece is easier to manipulate. In addition to the carving handpieces, other accessories are available, such as a reciprocating carving tool which accepts a variety of carving blades. Grinders and sanding attachments are also available.

As a flexible shaft cutter rips through wood, it can create flying debris and cloud of dust. In addition to protecting your eyes by wearing safety glasses, you should always wear a tight fitting dust mask. Use of a dust collection system can also help filter airborne particles. As you are working with this equipment, always be aware that the cutting burr is spinning at high speed and is capable of cutting you or getting tangled in your clothes.

For this reason, avoid wearing loose clothing and never wear gloves when working with this equipment. To prevent any cuts to your body, wearing a leather apron is advised, because is unlikely that the burr will snag and get caught up in the leather. Whether you are installing trailer graphics or doing a full wrap of a car or van, surface preparation involves a three-step process of detergent washing, solvent cleaning and a final wipe down with IPA.

Features of G-Code & M-Code in Implementation

The G-code interpreter implements a subset of the NIST rs274/ngc standard and is tested with the output of a number of CAM-tools with no issues. Linear, circular and helical motion are all fully supported. Most configuration options can be set at runtime and are saved in EE prom between sessions and even retained between different versions of Mach 3 as you upgrade the firmware.

For descriptions of these G-codes, we follow the NIST G-code guidelines and LinuxCNC.org also provides great documentation for these as well. (G-codes)(M-codes)(Other codes) and the Shapeoko wiki attempts to list all codes supported by Mach 3 with appropriate commentary.

Specification of 4-Axis Cnc Machine

Allowable Distance ➔	X-axis	350mm
Allowable Distance ➔	Y-axis	305mm
Allowable Distance ➔	Z-axis	127mm
Feed Rate		2.72mm/s
Spindle Speed		500 ➔ 20000 rpm
Clamping Range		10-60 mm (Internal Jaws) 30-120 mm (External Jaws)

Supported G-Codes in v0.9i

- **G38.3, G38.4, G38.5:** *Probing*
- **G40:** *Cutter Radius Compensation Modes*
- **G61:** *Path Control Modes*
- **G91.1:** *Arc IJK Distance Modes*

Supported G-Codes in v0.9h

- **G38.2:** *Probing*
- **G43.1, G49:** *Dynamic Tool Length Offsets*

Supported G-Codes in v0.8 (and v0.9)

- **G0, G1:** *Linear Motions*
- **G2, G3:** *Arc and Helical Motions*
- **G4:** *Dwell*
- **G10 L2, G10 L20:** *Set Work Coordinate Offsets*
- **G17, G18, G19:** *Plane Selection*
- **G20, G21:** *Units*
- **G28, G30:** *Go to Pre-Defined Position*
- **G28.1, G30.1:** *Set Pre-Defined Position*
- **G53:** *Move in Absolute Coordinates*
- **G54, G55, G56, G57, G58, G59** *Work Coordinate Systems*
- **G80:** *Motion Mode Cancel*
- **G90, G91:** *Distance Modes*
- **G92:** *Coordinate Offset*
- **G92.1:** *Clear Coordinate System Offsets*
- **G93, G94:** *Feedrate Modes*
- **M0, M2, M30:** *Program Pause and End*
- **M3, M4, M5:** *Spindle Control*
- **M8, M9:** *Coolant Control*

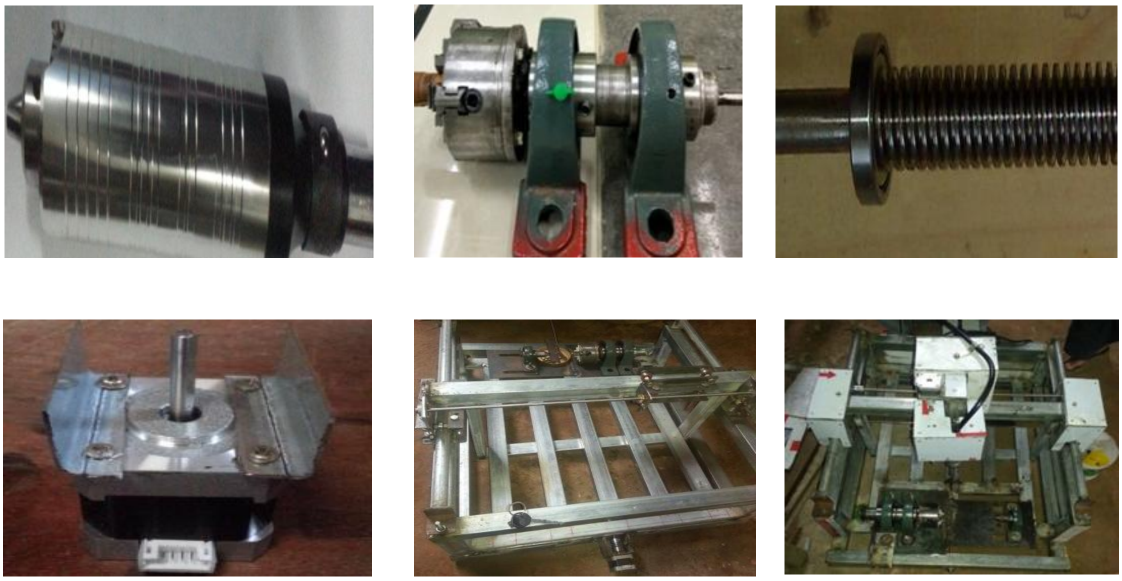
Implementation and Performance Test

In this research, there are three parts, called frame parts, electrical component parts and control software part. In frame parts, we constructed the frame with iron profiles as 3-axis form called Z axis, Y axis, X axis and A axis. Our frame design is designed stable workpiece and moving the machining tool.

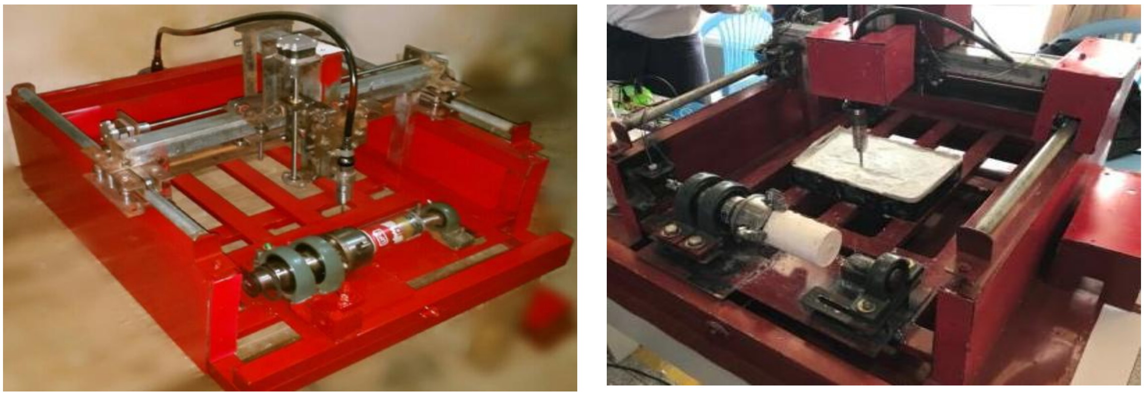
Electronic component are joined together with the colour pin and fixed the motor with Mach 3 USB Card and CNC red borad is supplied by 100W power supply called Universal adapter and 24V DC power supply.

In the controller software, we used the simplest controller called Mach 3 controller that can join with the Cam software like MasterCAM. As the first step, Mach 3 controller is connected with the CNC red board to know them in the computer. After combine the three parts, we comment in the mach3 controller with G-code or MasterCAM. The code is reached Mach 3 that is translated the Redboard.

The Redboard will send to the motor drivers. The motor drivers will drive the stepper motor. The stepper motor will run as your comment. And then, the four axis router will create the various profiles. That is our own design and construction of a CNC Router.



Implementation with Hardware & Software



Performance Test with Workpieces (Acrylics and Plaster)

Figure 7. Implementation & Performance Task of 4-Axis CNC Machine

A job was taken to the machine to test and cut out the defined places by milling operation. The job was quite simple which was programmed by us and then ran by the CNC. A milling cutter was mounted on the CNC and 6mm milling bit was installed to mill the job. Job material was wooden block, fitted in the CNC bed and machined.

Conclusion

After following above research paper, it is concluded that for the design of CNC machine structure, the machine capacity i.e. speed of spindle, workspace of travel of tool post etc. must be considered in design. Also the different forces imparted on machine tool member required to analyse for each member for designing. Here different loads includes cutting force, gravity loads of each member and inertia forces of moving member, which caused stress and deflection in machine tool structure. The most important functional requirements for a machine tool are static, dynamic and thermal performances of the machine tool. Retrofit Design concept plays important role in design and manufacturing of low cost and high precision micro machineries. For CNC machineries there is a need to design and analyze the gantry system which required for improving the design parameters and accuracy of the machines.

To work on Retrofit Design concept, it is a need to study the aspects of Eco-design which helps to learn the environmental impact on the entire product life cycle. With the rising demand of small parts and operations, number of small scale automated machines like CNCs and 3D printers came into the top fabricating work for the industries. The priorities are being given to fabricate those machines in affordable price and size. Here in this paper it has been designed and tried to build a CNC with compatible to 3D printer which is very simple and affordable. It is also taken in account to make it much limited in budget and easily workable. The required power should be minimized somehow.

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