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DESIGN AND DEVELOPMENT OF 3 –Axis CNC ROUTERAT LOW COST

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Abstract

This paper discusses the design and development of low cost 3-axis CNC router with Arduino UNO microcontroller.This is combined with the spindle drill and milling bit. This CNCrouter can be used for cutting, engraving on wood, foam,plywood object.Firstly we make the design on computer software like online software CNC apps.com where we write the alphabet name or design then itgenerated the G-code file in .txt extension which can open in notepad.We also can edit the dimension of Design picture in txt file. Further, we open the universal g code sender open source software connected Arduino UNO with computer. Upload the file on software which sent the data to motor driver of stepper motors. Spindle motor which attach to z axis will create pattern on objects automatically according design drawing file upload through software.After testing on CNC machine can be used for cutting, engraving on wood, plywood, acrylic, foam to 2D or 3D objects with high carving accuracy and high depth accuracy. This CNC router works on a object with maximum size of 300x300mm.

Keyword: *CNC, Microcontroller, Cutting, Engraving, Arduino UNO*

1.INTRODUCTION:

Working with automatic mechanical equipment demands precise, accuracy, speed, consistency and flexibility. In this case it takes the help of embedded computer applications to do the job. One of the mechanical equipment combined with microcomputer that has been widely used is a CNC machine (Computer Numerically Controlled). CNC machines are used for mechanical work such as cutting, engraving, drilling and others. In modern CNC systems, end-to-end component design is 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 via a post processor, and then loaded into the CNC machines for production. In either case, the series of steps needed to produce any part is highly automated and produces a part that closely matches the original CAD design. With the on-going development of technology and economy, new industrial requirements such as high precision, good quality, high production rates and low production costs are increasingly demanded. Most of such requirements, including dimensional accuracy, conformance to tolerances of finished products and production rate can be met with better machine tools. CNC machines are popular and widely used in the industry is a CNC that can form objects on acrylic, glass, wood and plate, mostly using laser, knife, or drill as cutting media. Research on the manufacture of CNC machines and fundamentals of embedded algorithms with the aim of producing high performance CNC machines with low cost has been widely practiced. Research about realization of low cost CNC machine by Jayachandraiah [3], discusses the development of a low cost 3-Axis CNC router. This research [3] is main literature review on hardware mechanic design. Research by Paulo [1], realizes a 3 axis CNC machine as well as a LabVIEW-based application program as an instruction giver. The paper does not specifically specify the use of the CNC machine. Other realization of CNC machine by Ali [4], present a controlling system for CNC machines to mill and drill PCB board also performed by [5-7]. Object of PCB result of milling and drill and detail of test result not shown in paper. Research on the development of algorithms for CNC machine control by Desai [8], in his paper discussed the development of algorithms for interpreters and interpolators and then tested on CNC machines for linear as well as circular interpolation.

Other fundamental research by Awari [9], conducted a study for the Selecting parts for low cost CNC milling machines that can be used in Small Scale Industry. The realization of CNC machines by Pawar [10] to draw objects. The main purpose of this work is to make efficient, reduce

errors, and also increase the accuracy of the production. However in that paper has not been discussed in detail these parameters.
From the review of the studies described above can be concluded that research on CNC both hardware manufacture and algorithm development is active in order to produce a good performance CNC machine but still at a low cost. Therefore in this paper is discussed a design of cheap 3-axis router CNC machine based on microcomputer as its main control. In this CNC machine mounted spindle drill that can move automatically by stepper motor. This CNC router machine can be used as a tool to form 3-dimensional objects such as cutting, engraving, marking on wooden, acrylic and PCB objects. This paper also discussed in detail the results of testing the CNC performance parameters.

2.Methodology:

The first step in the operation of CNC machine was calibrating the tool, it was aimed to know whether the stepper motor and any other system were working according to the program that has been configured. Followed by setting the

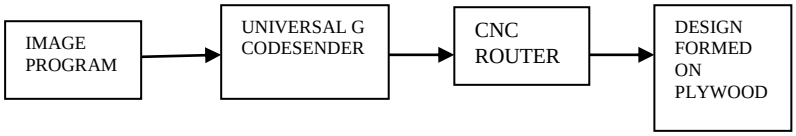
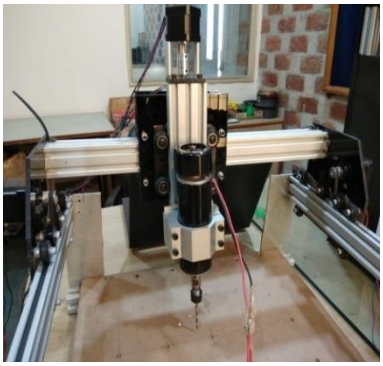


Figure 1BLOCK DIAGRAM OF PROCESS

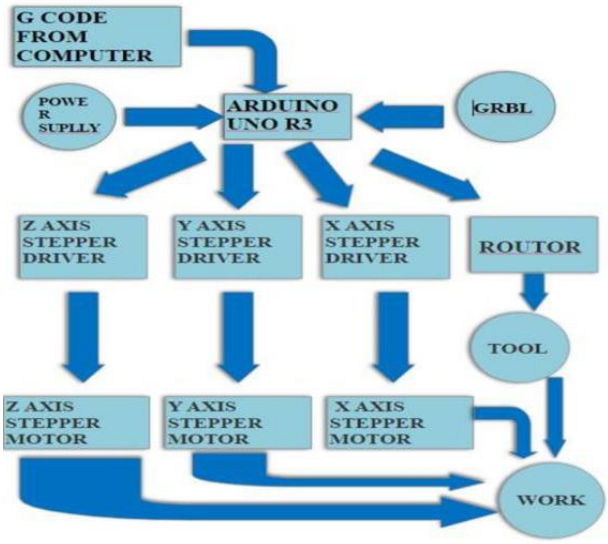
starting position of the spindle drill on the CNC machine using Universal G code Sender software both automatically and manually by hand spinning. Spindle drill speed can be set up to a maximum speed of 15000 rpm (rotation per minute). After the CNC machine is calibrated, the design with the .gcodeextension format was uploaded using Universal GcodeSendertoArduino Unowith serial communication. The microcontroller will read the data as a command and provide logic to the *A4988* motor driver. The data received by the motor driver was used to drive 4 Nema 17X, Y and Z axis stepper motors, so that a pattern will be formed on the object according to the design. The whole system block diagram that has been designed is shown in Figure 1.

3.Mechanicaldesign:

The main tools in mechanical design consist of mdfboard, stepper motor, aluminium extrusion, solid v wheel,acme screw and nut, coupling beam, power supply and spindle. In figures

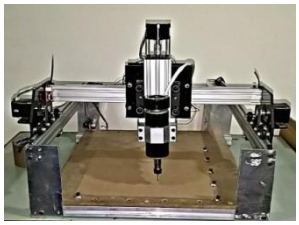


which controlled by Arduino Unomicrocontroller,



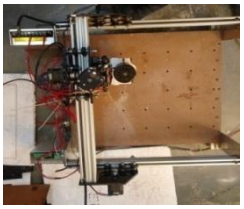
4. Electronic design:

The electronic system used on microcontroller based CNC machine was the power supply which used as a voltage source on personal computers and CNC machine. Personal computer was used as a device to run some software such as Xloader, Universal GcodeSender, and Arduino *IDE*, also to send design file to Arduino Unomicrocontroller using serial communication. 12V 10A power supply was used as a voltage source for *A4988* driver motor to run the 4 Nema*17* stepper motors and 12V voltage source was used as a driver motor and Arduino Unocooler to avoid overheating that could damage the component. 110V power supply was used as a voltage source for spindle , the voltage that goes into the spindle drill was set using a motor controller. The 4Nema *17* stepper motors will move the spindle drill inthedirection of the X, Y and Z axes, so that the object can be formed in the wood board according to the design. Display of microcontroller based CNC machine that has been built can be seen in Figure.



(a)Front view

(b)Corner view



(c)Topview

Specification of spindle motor of 500watt:
Operating voltage: 100VDC
Power: 500W
Speed: Up to idle up to 15,000 rev / min
Torque: 5000G/CM
Insulation resistance:> 2 megohms
Dielectric strength: 400V
Diameter: 52mm
Chuck portion length: 45MM
Chuck portion diameter: 16mm
Motor Length: 200MM
High precision spindle runout 0.01-0.03

5. RESULT AND ANALYSIS

To check the step size, accuracy resolution test the CNC router to engraving first we make design form. Clip the workboard size of working area on to platform so it can not move when operation going on. Upload the design file to universal g code sender software into the ardiunouno using CNC shield v3.

5.1 Step size :

The next thing to consider is positioning resolution you require. The number of steps per revolution ranges from 4 to 400. Commonly available step counts are 24,48 and 200. Resolution is often expressed as degrees per step. A 1.8^0 motor is the same as a 200 step/revolution.The trade-off for high resolution is speed and torque. High step count motors top out at lower RPMs than smiliar size. And the higher step rates needed to turn these motors results in lower torque than a similar size low step count motor at similar speeds. In this paper Nema 17 stepper is used which have degrees per step is 1.8 and step per revolution is 200.

5.2 Precision:

- 23 teeth : =>69.57 steps/unit(error:0.00618mm)
- 24 teeth : =>66.67 steps/ unit (error:0.00495mm)
- 25 teeth:=>64 steps/unit(error:0)

The overall results are

- **16 teeth : 10 microns**
- 17 teeth : 10.62microns
- 18 teeth : 11.25 microns
- 19 teeth: 11.88 microns
- **20 teeth : 12.5 microns**
- 21 teeth: 13.13 microns
- 22teeth : 13.75 microns
- 23 teeth : 14.37 microns
- 24 teeth : 14.999microns
- **25 teeth : 15.625 microns**

More the teeth more the resolution decreases.

At the time of configuring firmware it will need somehow to give a setting that will tell your firmware how many teeth as your axis pulley.
In the grbl software we provide the amount of steps per unit(mm) that your stepper motor to move 1 mechanical unit.
Steps per mm= (motor steps per rev*driver microstep)/belt pitch*pulley number of teeth)
A 1.8^0 stepper motor will need 360/1.8 = 200steps/turn
The driver microstep parameter is here 16(16 micro steps)
Some results for 16 microstep, GT2 belt and 1.8^0/step(200 steps) motor:

- **16teeth: =>100 steps/unit(error:0)**
- 17teeth: =>94.12 steps/unit(error:+0.00124mm)
- 19 teeth: =>84.21 steps/unit(-0.00249mm)
- **20 teeth: =>80 steps/unit (error:0)**
- 21 teeth: =>76.19 steps/unit(error:0.00249mm)
- 22 teeth: =>72.73 steps/unit(error:.00371mm)

This is why we use CNC belt pulle of 16, 20or 25 teeth pulleys to avoid possible errors on firmware side due to possible rounding.

5.3 Resolution

The resolution is given by following formula:
Resolution in mm = 1mm/Number of steps per mm
Resolution in micron= 1000/ number of steps per

5.4 Speed

In the opposite of the resolution where the lower the amount of teeth the higher the resolution,the lower the amount of teeth the slower the speed will be. To put it simple:
16teeth=> 100steps/mm
20 teeth => 80 steps/mm.
(20% faster) 25 teeth=>64steps/mm,
(36% faster) ass each step is taking tha same amount of time in microsecond, you will need 20% less time to move 1mm with a 20 teeth pulley compared with a 16 teeth pulley and 36% less time for a 25 teeth pulley to perform 1mm.

Line No	Design	Measurement Result	Accuracy (%)
1	51mm	51.5 mm	99%
2	51mm	52 mm	98%
3	51 mm	51.5 mm	99%
4	51mm	51.5 mm	99%
5	51 mm	52 mm	98%
6	51 mm	52 mm	98%

5.7 Accuracy Test

The accuracy test was done to check the level of precision of CNC machine in making the design which send to controller. The test input was simple line of 50mm length on plywood and 2.5mm depth using the3.1mm milling bit with spindle of 14000rpm speed and measure the length of line and found that 99% accuracy.

Table1 : Accuracy Test

5.8 Depth test

The depth test is done to determine the precision level of depth on the plywood by CNC router when working. We create line by different depth 3mm of 3mm milling bit and spindle speed of 15000rpm.the depth cut by cnc router is measure by help scale and this show that 100% precision accuracy.

Table 2: Depth measurement

Line No	Depth in design	Measurement Result
1	3mm	3mm
2	3mm	3mm
3	3mm	3mm
4	3mm	3mm
5	3mm	3mm
6	3mm	3mm
7	3mm	3mm

6.CONCLUSION:

The CNC router machine was built usingATmega328pmicrocontrollers combined of 4 stepper motors, with 300x300m working area and using the 500watt spindle air cooled.The CNC machine used for cutting and engraving on plywood to form 2D or 3D objects with 98.5% carving accuracy and 100% depth accuracy. The four stepper motors was controlled using GRBL library and universal g code sender software. The cost of 3 axis CNC router is reduced.

REFERENCES

[1] Paulo, Rogério, and Maria., 2010, "Prototype CNC Machine Design," International Conference on Industry Applications.

[2] Widarto., 2008, "*TeknikPemesinan*. jakarta: DirektoratPembinaanSekolahMenengahKejuruan,".

[3] B. Jayachandraiah, O. V. Krishna, P. A. Khan, and R. A. Reddy., 2014, "Fabrication of Low Cost 3-*Axis* Cnc Router," *Int. J. Eng. Sci. Invent.*, vol. 3, no. 6, pp. 1–10.

[4] M.A.A. Ali, A.M.A. ELShaikh, and S.F. Babiker., 2016, "Controlling the CNC Machine using Microcontroller to Manufacture PCB," Conference of Basic Sciences and Engineering Studies (SGCAC), pp. 116-120.

[5] K.J.Madekar, K.R.Nanaware, P.R. Phadtare, V.S. Mane., 2016,"Automatic mini CNC machine for PCB drawing and drilling," International Research Journal of Engineering and Technology (IRJET), vol. 3, issue: 2, pp. 1106-1110.

[6] R. Basniak and M.F. Catapan., 2012,"Design of A Pcb Milling Machine," ABCM Symposium Series in Mechatronics, Vol. 5, pp. 1339-1348.

[7] C.F. Wise., 2007, "Fabrication of Printed Circuit Boards Using a Table Top CNC Mill," *the Technology Interface/Fall 2007 Wise*

[8] D.P. Desai and D.M. Patel., 2015,"Design of Control Unit for CNC Machine Tool using Arduino based Embedded System," International Conference on Smart Technologies and Management for Computing, Communication, Controls, Energy and Materials (ICSTM), pp. 443-448.

[9] D. Awari, M. Bhamare, A. Ghanwat, K. Jadhav, and J. Chahande., 2017,"Methodology for Selecting Components for Fabricating CNC Milling Machine for Small Scale

Industry," International Journal for Scientific Research & Development, Vol. 4, Issue: 11, pp. 168-171.

[10] A.S. Pawar, M.J. Halunde, S.M. Nayakawadi, and Ms. P. P. Mirajkar., 2017, "3 AXIS DRAWING MACHINE," International Research Journal of Engineering and Technology (IRJET), vol. 04 Issue: 03, pp. 693-697.