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Design & Development of Mini CNC Milling Machine

Nagaraja T.K.[1], Punith Kumar T.M.[2]
[1]*Assistant Professor, Department of Mechanical Engineering, JSSATE, Bangalore,*
[2]*Student, Department of Mechanical Engineering, JSSATE, Bangalore,*
VTU Belgaum, Karnataka, India

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ABSTRACT

In the area of CAD/CAM/Manufacturing Technology lab courses, the high cost of commercial CNC machines like mills and lathes limits the quantity of machines accessible to the students. Increase in the rapid growth of Technology significantly increased the usage and utilization of CNC systems in industries but at considerable expensive. The idea on fabrication of low cost CNC machine came forward to reduce the cost and complexity in CNC systems. This paper discusses the development of low cost CNC machine which is capable of 3-axis simultaneous interpolated operation. The lower cost is achieved by incorporating the features of a standard PC interface with micro-controller based CNC system in an Arduino based embedded system. This machine has 3- axis namely the x, y and z axis Mini CNC machine is a small CNC machine that can operate like a normal CNC machine with a limited area of the machining. This mini CNC machine has been operated successfully on wood, polymer and aluminum for various operations like end milling and drilling.

Keywords: Design, Development, Mini CNC, Milling, Machine, Axis, systems.

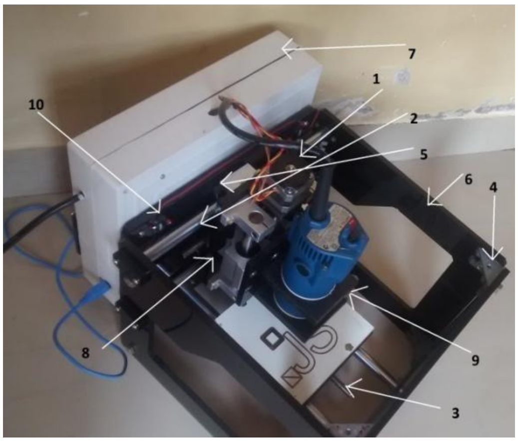

Fig. 1 Assembled mini CNC milling machine

I. INTRODUCTION

The idea behind development of mini CNC machine is to full fill the demand of CNC machine from small scale to large scale industries with optimized low cost. A major new development in computer technology is the availability of low-cost open source hardware, such as the Arduino microcontroller. An advantage of open source hardware is that a wide variety of ready-to-use software is available for them on the web therefore the prototyping and development times are drastically reduced. In this paper, the development of mini 3-axis CNC milling machine using Arduino-based control system is presented with following specifications: Low cost, easily operable, Easy interface, Flexible, Low power consumption. This project describes the development of the machine and the criteria needed to build the machine. The Mini CNC Machine is initially designed by referring to the criteria that was decided. The criteria are the travel path length, type of linear motion, type of linear drive, motor and controller, and type of material that used. This machine's travel on the X axis is 150 mm and Y axis is 150 mm & Z axis 70 mm.

Sl No	Description	Qty
1	Stepper motor	03
2	Guide rod	06
3	Lead screw and nut	03
4	L-piece joint	09
5	Linear bearings	06
6	Acrylic sheet	07
7	Ardunio microcontroller	01
8	Coupling bush	03
9	Bore plate	02
10	Limit switches	06

Table:1 Components of mini CNC milling machine

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II. LITERATURE REVIEW

The limitations of commercial CNC machines for large scale deployment in educational environments, several authors have studied the development of such machines on a smaller, low-cost scale. For example, Pabolu and Srinivas [4] have designed and implemented a three axis CNC machine using an 8-bit microcontroller. The development is in Net platform using C# programming language on a Windows XP computer, but the motors have limited power. Andrei and Nae [5], [6] have developed a simpler commercial size CNC router (worktable dimensions: 624x824 mm) running with Mach3 software on a desktop PC, but requiring a parallel port. A low-cost, desktop design and evaluation of a CNC machine for modeling and educational purposes is proposed by Pahole, et al. [7]. The working dimensions are 180x140x250 mm. The static rigidity and positional accuracy of the machine are experimentally measured, and the commercial Mach3 machine control software is used with a parallel port-equipped personal computer. Sherring da Rocha, et al. [8] have presented a prototype CNC machine under development running on a PC with Lab VIEW which has advantage of ease of visual programming tools. The PC is interfaced with low-cost embedded microcontrollers through the serial port. The CNC machine designs above rely on the use of stepper motors of limited power in open loop mode. [9] discuss results of research on an open CNC system using Windows PC with a four-axis motion controller.

III. COMPONENTS OF MINI CNC MILLING MACHINE

3.1 Linear Bearing

A ball bearing is a type of rolling-element bearing that uses balls to maintain the separation between the bearing races. The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads.

3.2 Lead Screw

A ball screw is a mechanical linear actuator that translates rotational motion to linear motion with little friction. A threaded shaft provides a helical raceway for ball bearings which act as a precision screw. As well as being able to apply or withstand high thrust loads, they can do so with minimum internal friction.

3.3 Guide Rods

Linear rods are rigid strong C-45 shafts which are used to carry the load without affecting the motion and supports linear movement .Linear rods with linear bearing assembly are used to carry the loads and supports the structures in linear motions the total load of the structure is taken away by the linear rod bearing assembly and therefore the load on screw rod is reduced and causes precise smooth linear motion.

3.4 Limit Switches

A Limit Switch is the simplest type of end stop a simple mechanical switch positioned to trigger when an axis reaches the end of its motion. Limit switches are used to protect the stepper motor and circuit by shutting the motors by triggering the switch when the axis reaches its end .The signal pin from limit switches are connected to the microcontroller board to sense the axes ends.

3.5 Stepper Motor Nema 17

A stepper motor is a brushless, synchronous electric motor that converts digital pulses into mechanical shaft rotation in a number of equal steps.

IV. DESIGN REQUIREMENTS

4.1 Lead Screw Selection

4.1.1 X axis lead screw

The movement required is = 150mm

Size = M10

Pitch, $p = 1.5$ mm (1)

Major diameter, $d_o = 10$ mm (2)

Mean diameter, $d = d_o - p/2 = 9.25$ mm (3)

4.1.2 Y axis lead screw

The movement required is = 150mm

Size = M10

Pitch, $p = 1.5$ mm

Major diameter, $d_o = 10$ mm

Mean diameter, $d = d_o - p/2 = 9.25$ mm

4.1.3 Z axis lead screw

The movement required is = 70 mm

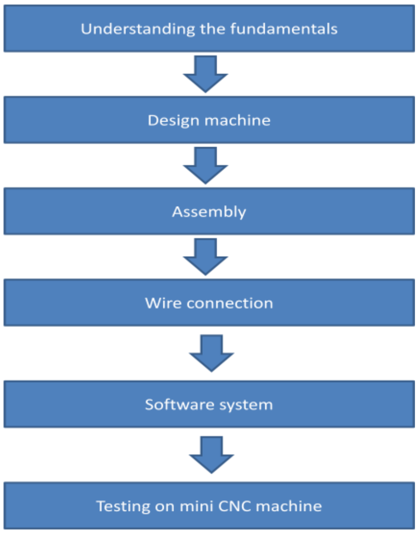
Size = M10

Pitch, $p = 1.5$ mm

Major diameter, $d_o = 10$ mm

Mean diameter, $d = d_o - p/2 = 9.25$ mm

V. FLOW CHART



X- axis travel	150 mm
Y –axis travel	150 mm
Z –axis travel	70 mm
Stepper motor	Nema17,1.8°,200steps/rev,2-phase,4wire,bipolar,1.3A
Lead screw	Stainless steel M10x1.5
Spindle motor	30000rpm
Power supply	Input – 220V AC Output -12VDc, 10A
Microcontroller	Ardunio uno with ATmega328 16MHZ

Table No: 2 Machine specifications

Fig 5.1 Flow chart

VI. METHODOLOGY

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 allows linear motion in each axis. The controlled motion in each axis is achieved directly 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 effectors is controlled in each axis for smooth carving or cutting action of work piece.

6.2 Electronic Control System

Electronics system is responsible for generating control signal to the stepper motors which guides the motion of tool path in each direction or axis. Electronics system is comprises of Power supply, Microcontroller board and Stepper motor driver board.

6.2.1 Power Supply

Power supply is heart of the CNC system which converts the AC voltage to DC voltage and supplies required voltages to the corresponding devices. Microcontroller board receives 12v supply where as the stepper motor board receives 48v.

6.2.2 Microcontroller Board

Atmega 328p Arduino based microcontroller development board is chosen here to control the motion of the system. It acts as brain of the CNC system which receives the commands from the software system from computer connected through the USB serial port. Arduino development board is flashed with the GCODE interpreter code which was written in the C language, which is responsible to generate the control signal for corresponding command signal from the computer system to the stepper motors which directly controls the motion of the tool path. The command from computer or software system is received and converts them to the actual electronic signals to the Stepper Motor Driver Board.

6.2.3 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 microcontroller board to the terminals PULSE and DIR which generates the corresponding digital pulse signals for 3 Lead stepper motor to control the rotation of the motor.

6.2.4 Electronics Circuit Wiring

The wiring of the various components of electronics system is represented in the Fig., shown below. The microcontroller board is connected to the computer system through the USB serial port. The Stepper Motor Driver board terminals PULSE and DIR of each Board is connected to the microcontroller terminals from 2 to 7 pins (2 terminals for each axis stepper motor driver) respectively. Terminals A+, A-, B+ and B- of Stepper Motor Driver Board are connected to the 3 lead stepper motor directly. Power supply is provided for all the components of electronics system. To avoid the axis motors going out of safe operating range, six limit switches have been installed two for each axis. An emergency stop button manual operation has also been used for the machine.

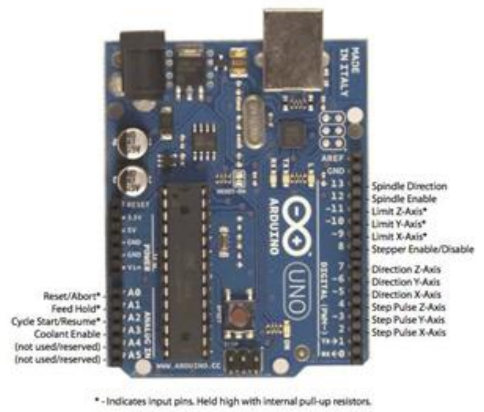


Fig 6.2.4 Arduino microcontroller pin configuration

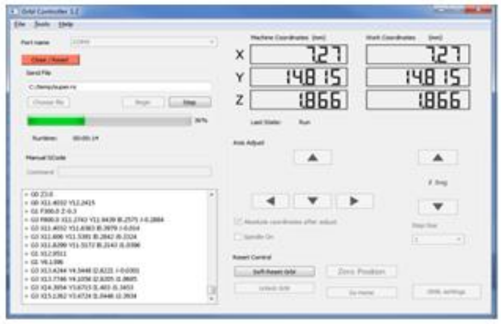


Fig 6.3 CNC control software window

6.3 CNC Control Software

G code Sender is used to send the G-code files to an integrated hardware interpreter (Atmega 328). G code Sender will take a G-code program in file and send it line-by-line to the Atmega 328 microcontroller. The G-codes will send over the serial ports through USB communication between the computer and microcontroller. GRBL Controller is software that is designed to send G-Code to CNC machines is, such as 3D milling machines. It isn't super smart; it just needs to give the user a nice way to get commands down to whatever controller they are using.

6.4 G Code Firmware for Microcontroller

G-code firmware is the Brain of the machine which is responsible for tool path control .G-code firmware is a program code written in optimized C language which interprets/compile the G-codes. G-code Firmware reads each line of the G-code file received and generates the actual electronic signals to the motors and thus motion is controlled over the three axes. We have used an open source G-code interpreter or milling controller for the Arduino development board. GRBL is a no-compromise, high performance, low cost alternative to parallel-port-based motion control for CNC milling. It will run on a vanilla Arduino as long as it sports an Atmega 328. The controller is written in highly optimized C utilizing every clever feature of the AVR-chips to achieve precise timing and asynchronous operation. It is able to maintain up to 30 kHz of stable, jitter free control pulses .It accepts standards-compliant G-code and has been tested with the output of several CAM tools with no problems. Arcs, circles and helical motion are fully supported, as well as, other basic functional g-code commands. Functions and variables are not currently supported, but may be included in future releases in a form of a pre-processor.

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VII.ASSEMBLY DIAGRAM



Fig 7.1 Z-axis assembly

Fig 7.2 Y-axis assembly

Fig 7.3 Final assembly of mini CNC machine

VIII. RESULT

The design and development of mini CNC milling machine was designed and assembled with all parts. The model was tested and we were able to do operation like drilling and milling. The model was successfully tested on wood.

8.1 Milling Operation: This operation is carried out by using 6mm shank diameter end mill. Milling is done at several speeds on various materials without any difficulty.

IX. CONCLUSION

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 thesis, a small scale three axis CNC milling machine is designed and analyzed under very limited budget.

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