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PROTOTYPING OF MINI CNC MILLING MACHINE USING MICROCONTROLLER

Dr. S Ganesh Kumar*[1], Nitish Kumar B V*[2], Ranjith D*[3], Prakash S*[4], Roshan S V*[5]

*[1]Assistant Professor, Department of Mechanical Engineering,
Sri Eshwar College of Engineering, Coimbatore, India.

*[2,3,4,5]Students of Mechanical Engineering, Sri Eshwar College of Engineering, Coimbatore, India.

ABSTRACT

Mini CNC (computer numerical control) miller, may be a machining method that employs computerized controls and rotating multi-point cutting tools to more and more take away material from the piece of work to supply a customize-designed element. This machining process is used for wide selection of materials like metal, plastic, glass and wood to create a spread of difficult and customize-designed elements. Computer numerical management (CNC) is programmed code that represents directions for precise movements within the machines to hold out the operations and this code defines a way automatically to produce a virtual object into a true object. Automated machines are more accurate and more effective than human. CNC machine can be used for making components by different kinds of work actions in the machine's cutting tools.

Keywords: Milling Machine, Arduino UNO, GRBL Software.

I. INTRODUCTION

Mini CNC Milling machine works in a same way as a regular CNC Milling machine. The main differences in them are their size, cost & machining capability. There has been a lot of demand for these small sized machines for multiple purposes. Generally manufacturing is divided into two types - Additive manufacturing & Subtractive manufacturing. In this project, we focus on subtractive manufacturing. A solid block is fed to the machine as a raw material. The desired shape we want finally is fed into the computer of the machine as a coding language. The machine starts to remove the material from the solid block & when it is done, the final geometry can be obtained. This is the core concept of a general machine that does subtractive manufacturing. The two main types of CNC machines are the milling machine and the turning machine, or lathe. In the mill, a cylindrical rotating cutting tool is used for drilling and removing of materials like wood, plastic (e.g., PVC and acrylic), non-ferrous metals (aluminum, copper, etc.), composites and steel. Mills can be vertical or horizontal, and sophisticated machining centers combine both mill and lathe. (In CNC lathe, turning operations like boring, threading, etc. are performed on a cylindrical object). Basic CNC mills have three axes, while basic CNC lathes operate in two axes. Its application is not only limited to manufacturing industry, but also extends to education field. In many higher educational institutions, the students' exposure to hands-on learning of CNC machining is limited to demonstrations by the lab technician or programming for computer animation/simulation. To overcome this issue, usage of simple & cost efficient CNC machine is a great idea.

II. COMPONENTS

1. Mechanical Components :

Stepper Motor: Stepper motor could be a Brushless DC Motor (BLDC) that divides a full rotation into range of equal steps. BLDC Motors convert a train of input pulses into a exactly outlined increment within the shaft's circular position. For Associate in nursing correct positioning of tool & work piece movement, stepper motor is a perfect selection. The movement of 3 axes is target-hunting by a lead screw coupled to the stepper motor.

Figure 1 Nema 17 Stepper Motor

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Lead Screw: Lead screw converts rotational motion into linear motion. They are generally used for low power actuators & where positional accuracy is most needed. Lead screw with square threads is considered to have highest efficiency as they have least friction between their male & female part. The main factor for using square threaded lead screw in this machine is because of its self-locking capability. Even for vertical movement, unless the motor runs, the components would not move down because of gravity.

Figure 2 : Lead Screw

Bearings & Guide Rods: A bearing is a mechanical component that is used to support a long rotating member. They are also used to provide lubrication for a sliding member. Figure c shows how a linear bearing can be used over a rod. Only one degree of Freedom can be achieved using linear bearings. X, Y & Z axes move only in one direction, linear bearings provide smooth & supportive movement. Guide rod acts as a simply supported beam for these three axes. The profile of the guide rod however is round shaped. A guide rod must have a smooth surface so that the movement of an axis over a guide rod will be effortless & easy. Stainless steel rod of appropriate diameter is used for this mini CNC milling machine.

Figure 3 Linear Bearing

Figure 4 shows the assembly of linear bearing, guide roads & lead screw. These three components constitute an axis of the machine. The lead screw is coupled o the motor, as when the motor is powered, the lead screw rotates & coverts rotational motion of motor into linear motion. With the help of linear bearings, the whole setup moves over the guide rods.

Figure 4 Assembly of linear bearing & guide rods

2. Electrical & Electronic Components

Arduino UNO: The Arduino Uno is an open-source micro controller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is supplied with sets of digital and analog input/output (I/O) pins which will be interfaced to various expansion boards (shields) and alternative circuits. The board has fourteen digital I/O pins (six capable of PWM output), half-dozen analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a sort B USB cable. It may be high-powered by the USB cable or by Associate in nursing external 9-volt battery, although it accepts voltages between seven and twenty volts. The UNO is sort of a mini pc with low process capability which will work out knowledge on the given basis. (Refer Table one for Specifications)

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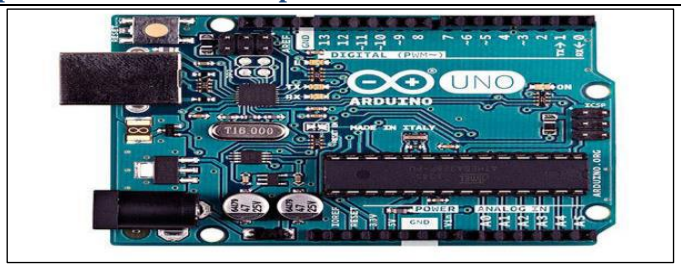

Figure 5

SMPS Device: SMPS stands for Switched Mode Power offer. Its associate degree electronic power offer device that includes a shift regulator to convert wattage with efficiency. It transfers power from DC or AC to a DC load and uses a linear regulator to produce the required output voltage by dissipating excess power in resistance unit losses.

Figure 6: SMPS 24V, 10A

Stepper Motor Driver: It is the driver circuit that enables the stepper motor function the way it does. Stepper motor driver does not a feedback data from the other end. These below mentioned signals control the rotation of the stepper motor.

1. Clock
2. Reset
3. Half/Full
4. Direction

The stepping command is given by the CLOCK signal. RESET command resets the final level signals in a start position. The motor's step is controlled by HALF/FULL signal & the direction f rotation of motor axis is commanded by DIRECTION signal.

Figure 7 Stepper Motor Driver

Spindle motor: The tool for machining is mounted with the spindle motor. The spindle motor is powered directly from the SMPS via an electronic switch so it can be turned ON or OFF, considering safety. These motors usually rotate at high RPMs (12000 RPM). This high speed ensures easy material removal. These motors are designed & constructed in a compact manner. The speed of the spindle motor can be controlled by using an appropriate driver as the speeds differ for different materials. This spindle motor experiences a lot of stress during machining, especially the portion where the tool is held. As the spindle shaft undergoes both the movement, i.e. linear & rotational motion. A Tungsten Carbide end mill tool is used for milling in a plywood material for this project. Tungsten carbide was chosen because of its rigidity & prolonged life.

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Figure 8 24V DC Spindle Motor

Figure 9 3mm Tungsten Carbide End mill

III. CONNECTIONS

Flowchart:

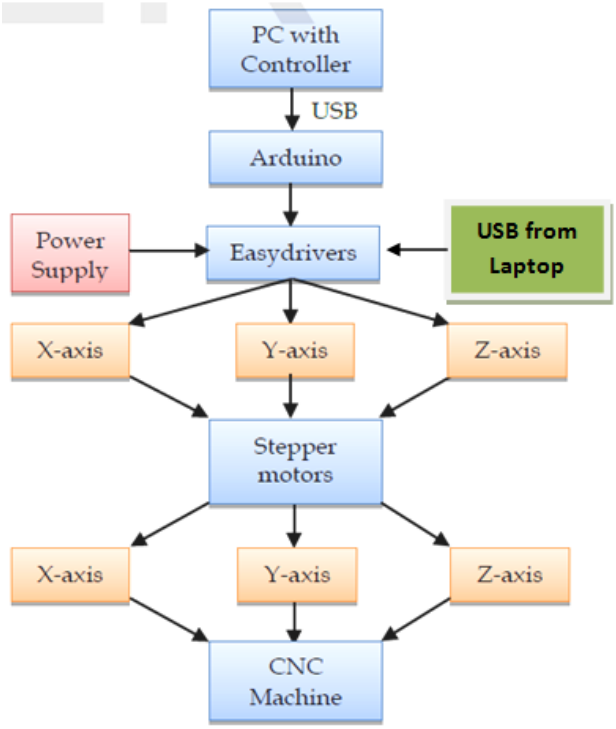

Figure 10

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IV. FABRICATION

Design:

The Design of the individual parts associated with CNC Milling Machine was first studied & analyzed. Then the 3D models of the above specified parts were developed in Solid Works. Fits & Tolerance details were added wherever it was necessary. The same design specification was used to cut the acrylic sheet. The final design of the mini CNC milling machine is attached below, see figure 11 for a clear design shape.

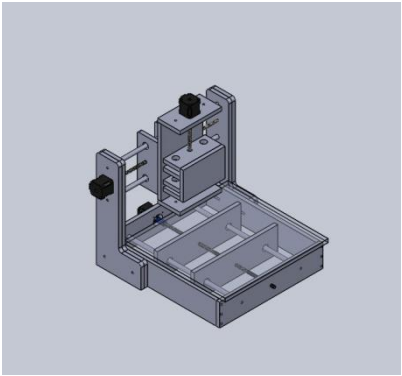

Figure 11 3D assembled view of mini CNC milling machine

Fabrication:

With the raw materials available, using operations like milling, grinding, turning & drilling, all the other parts were fitted in their places according to the design. Fits & tolerances were checked after total assembly. The moving parts were lubricated with machine oil to ensure smooth motion & to prevent rust. The testing was done after both electrical & mechanical assemblies were fully completed. The movement of three axes was monitored separately. The movements were done in 0.1, 1, 10, 100 steps respectively. The step count represents the number of turning/turnings a stepper motor can do in a 360 deg circle. Particularly in Z axis, the speed at which the frame of spindle motor assembly was tested multiple times as it has to carry a heavy vibrating load against gravity.

V. WORKING

Working:

The basic method of CNC-based producing is illustrated in Figure eleven. The half or smart to be machined is meant in laptop assisted style (CAD) code, whose output could be a drawing in one in every of several acceptable formats. This drawing is then fed to the Computer-Aided producing (CAM) code, whose output is that the computer readable code used for numerical management of the machine.

Figure 12 Process of CNC Machines

The code contains alphanumerical directions to the machine within the kind of G and M code. Typically, it's expressed as N (followed by a 3 or additional digit sequence number), G (followed by 2 digits, for preceding functions like motion commands), followed by X (position on X axis to maneuver to), Y, Z. alternative functions embody F (for feed rate, or speed of the cutter within the cutting direction), M (for miscellaneous commands or functions, e.g., fluid on/off, tool modification, etc.), T (tool function), and S (spindle speed function).To feed the CNC codes into Arduino UNO board, we have used open sourced software called GRBL software which converts G, M & other codes into a form that supports in UNO (HEX file). Arduino UNO then sends the converted Hex codes to the individual drivers of the stepper motor. For example, if Z axis is operated, only linear G code is converted & sent to the Z axis driver. Therefore Z axis stepper motor turns clockwise & moves the assembly downwards. In another scenario where X & Y axes both operate simultaneously to make a circle, Arduino UNO

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processes both the axes' data & sends it to the respective driver without any delay. That is why Arduino is called a MINI COMPUTER that can handle simple tasks like these.

CNC Machine Control Software:

GRBL software system implements in optimized C, a set of the RS-274/NGC (Next Generation Controller) customary and has been tested to figure with the G-code of many business CAM tools. It up to thirty kc step rate, and achieves precise temporal arrangement and operation. Accuracies of up to zero.1 metric linear unit are reported by users of the software system.

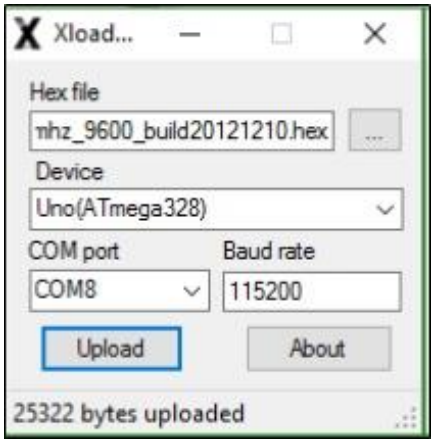

Figure 13 XLoader setup

Compiled Arduino sketch or program files square measure within the sort of .hex files. AN open supply Arduino hex up loader program referred to as XLoader is employed to transfer the GRBL hex file on to the Arduino, while not the requirement for a flash computer programmer. It's offered for Windows solely. The user needs to select the appropriate dropdown menus for Arduino Uno, the GRBL hex file being loaded, and the correct COM port of the computer to which the Uno is connected, with the baud rate for the Uno being set at 9600. The next and final step is to use a program to send the G-code for the particular machining job to the microcontroller loaded with GRBL. For this purpose, we have a tendency to use another open computer program known as GBRL GBRL Controller also has the option to display in real time the current machine position coordinates and the current work position coordinates. Our team has tested the example 3-axis CNC machine with numerous G code files for carving totally different shapes in acrylic and wood work items, e.g., sq. with sickle-shaped edges, circle, and images. Satisfactory results are obtained all told cases. For learning functions, the Command Mode of the G Code Sender program prints out a listing of choices and settings, mistreatment that the specifications for the operation are often used and keep on the Arduino, e.g., steps per millimeter of every axis. Moreover, students are often inspired to extensively attempt the combos of settings for the motor driver. The CNC kit maker additionally provides counseled feed rates and cutting depths for various materials. The screen shot of home page of the controller computer code is illustrated below.

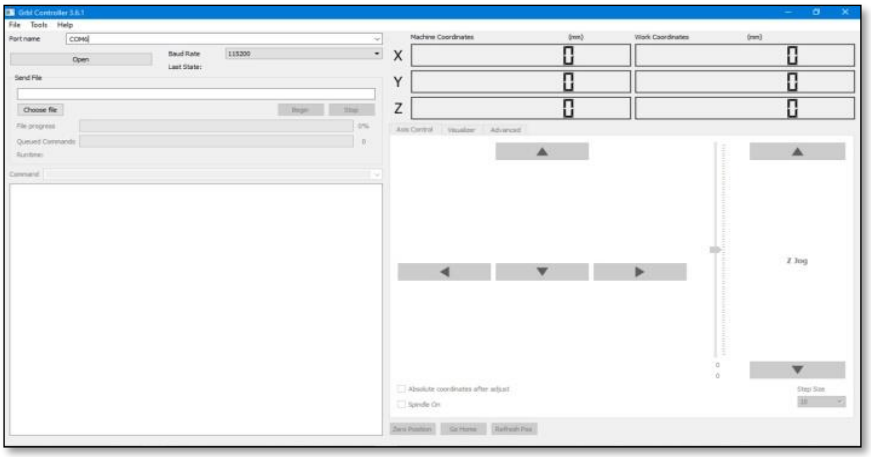

Figure 14 GRBL Controller Homepage

Specifications:

1. Arduino UNO:

Table 1

Microcontroller	UNO: ATmega328 (8-bit)
Operating voltage	5 V
Input voltage	7-12 V
Digital I/O pins	14 (6 provide PWM output)
Analog Input pins	6
DC current per I/O pin	40 mA
Clock speed	16 MHz
PC connection	USB
External power jack	Yes

2. CNC Machine

Table 2

X axis travel	178 mm (7")
Y axis travel	178 mm (7")
Z axis travel	50 mm (2")
Stepper motors	3xNema 17, 1.8º, 200 step/rev, 2-phase, 4 wire, bipolar, 1.3A
Lead screws	Stainless steel, 3xM8x1.25, 20 TPI (Threads/Inch)
Spindle motor	24-36 V DC, 5000-8000 RPM 0.3A no load
Power supply	24 V, 15A, 360 W, switching power supply
Stepper motor drivers	3xsingle axis, rated 3A, peak 3.5A, 24V DC rated, up to 1/16 micro stepping, adjustable step, current, and half-decay
Microcontroller	Arduino Uno, R3 board, with ATmega328P @ 16MHz

3. Stepper Motor:

Table3

General Specifications	
Item	Specifications
Step Accuracy	±5%
Temperature Rise	80° Max
Ambient temperature Range	-20° to 50° C
Insulation Resistance	100MΩ Min.500V
Dielectric Strength	500V AC 1 Minute

VI. CONCLUSION

In this work, the design & development of MINI CNC MILLING MACHINE, and its working were discussed. It has a lot of advantages, the main ones being its simplicity & reliability. This machine can especially be used for educational & research purposes. It provides a way for Engineering aspirants & novices in this field to develop their interests in the CAM (Computer Aided Manufacturing) field. Students & professors can get an insight on product development from the very first stage, IDEA. The hardware components are available in local stores & the machining can be done even using smaller machines. Both the software's used were open sourced; therefore it is easily accessible for students. These two factors make this project economically justifiable. In future work, the frame work is to be made with lightweight Aluminum metal instead of Acrylic plastic sheet. The Z-axis drive is to be coupled with a reduction gear as the stepper motor lacks torque to pull the spindle motor assembly against the gravity. Stress analysis is to be taken for the frame, guide rods & lead screw in both static & dynamic conditions.

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