CNC Plotter Developed for Plethora Machining Purposes

Mithil Badam¹, PVS Subhashini²

¹, ²Department of Mechanical Engineering, Vasavi College of Engineering, Telangana, India
badam.mithil05@gmail.com¹, siva726@yahoo.co.in²

Abstract - In the manufacturing of any mechanical component, it requires various operations like facing, drilling, boring etc. Earlier were used to machine by conventional lathes and milling machines. However, the present scenario is different, machining capabilities and the numbers of operations which are needed are automatically produced by using CNC machines. CNC (computer numerical control) is an automation of gadget equipment the usage of computers executing pre-programmed sequences of device manage instructions CNC is different from manually controlled machine and machines automated by computer aided manufacturing (CAM) alone. CNC machine moves in three (x, y, z) or more axes. CNC’s are incredibly versatile and allows one to cut a variety of different types of products and materials. Most of the CNC’s routers can cut soft and hard wood, plastics and other composites and nonferrous metals. This paper aims at fabricating a CNC machine which can draw images or text on the surface like paper, softwood, metal sheet etc. The fabricated CNC mini plotter has two axes, namely X and Y axis. It uses two stepper motors and a servo motor for z-axis. The machine is operated by accesses of G-codes directly using software called “INKSCAPE” microcontroller board, based on the ATmega328p microcontroller, which was developed by Arduino.cc. Along with this, there are other electronic components like motor shield, stepper motor drive, GRBL controller are programmed for successful functions of the machine. The intensification of the present work is to model a low cost and effectively working mini CNC plotter machine which can be used for plethora machining purposes.

Keywords: CNC plotter; INKSCAPE; Fabrication; GRBL controller

1. INTRODUCTION

Computer Numerical Control (CNC) is the automation of gadget gear by using computers executing pre-programmed sequences of gadget manipulate commands. It is different from a manually controlled machine and machines automated by computer-aided manufacturing (CAM) alone. CNC machine moves in 3 (X, Y, and Z) or more axes. Nowadays in CNC systems, the design of any mechanical component is highly automated. And even its manufacturing is also highly automated [1].

The object’s dimensions are defined by means of computer-aided design (CAD) software after which translated into production directives by computer-aided manufacturing software for manufacturing purpose. Since any mechanical part might require different tools like cutting tools, drills, saws, etc. – modern machines often combine multiple tools into one. CNC machines are incredibly accomplished and allow one to machine a different products and materials. The exact abilities of a machine are depending on its size, rigidity, and power [2]. Usually, most CNC’s routers can cut soft and hardwood, plastic, other composites, and non-ferrous metals.

2. LITERATURE REVIEW

In this paper, we are designing a low-cost three axis Mini CNC Plotter using stepper motor, Arduino microcontroller, and motor manipulate software program. In 1775 for operations like slicing, shaping and many others., a Canon the boring machine or Lathe became invented but it may do best one paintings at a time and additionally other dangers just like the requirement of ordinary tracking, professional labors and much less accuracy. In 1947, John parsons attempted to govern device tool movement the usage of 3-axis curvature data which changed into further developed for the discovery of CNC system [3]. But this one is of high value and its production is very tough. In our venture, we are looking to create a low-value CNC plotter of small or medium length and an open structure.

Based on CNC principle, 2D Robotic Plotter will work. The software program used for programming the Arduino board are namely Inkscape (0.48.5), Processing (3.0.2), CAMOTICS, Arduino IDE. The accurate and efficient association and proper use of the programs along with the circuit make up an efficient 2D Robotic Plotter (CNC).

The fabrication of low-value CNC gadget is used to lessen price and complexity of the machine. This paper is address the layout of a low-price automated CNC gadget for PCD drawing and drilling [4]. The objective of this project is to design and drill PCB based on a low-cost CNC machine, it will be achieved by incorporating features of PC with ATMEGA328 controller in an Arduino. G-code is used for the operation of whole system G code nothing but a language for making computerized machine tool to
understand ‘How to make something’ and to define instructions like where to move & how fast to move.

Designed and implemented a CNC plotter using spare parts on a solid surface to draw a PCB layout or an image [5]. Inkscape software is used to feed G-code to the gadget the usage of processing software program. Arduino UNO with an ATmega328P microcontroller is used because the manage device. The microcontroller converts G-code into a fixed of system language practice to be sent to the motor driving force of the CNC plotter.

The machine basically works with three stepper motors (two for X-axis & one for Y-axis) and micro-servo controller (for Z-axis). Where in Arduino Circuit plots the input given from the pc through ‘INKSCAPE Software’ on the sheet that’s positioned on the drawing board using micro-controller. The plotter has 4 axis manage (2 X-axis and 1 Y & Z axis resp.) and a micro-servo controller for movement of the pen. This system reduces human effort and also reduces the chances of error. The efficient and correct mounting of all the parts and proper use of software and correct alignment of the circuit makes the system more efficient.

3. MATERIALS REQUIREMENTS AND SOFTWARES

Frame - A clamp is a mechanical tool used to preserve an object in a fixed role. The metallic rod of period 410mm, diameter 5mm are supported and used as guide methods to the X and Y axes tables [6]. The timing belt is a non-slipping mechanical power belt and it can seek advice from both toothed belt, a bendy belt with enamel long-established onto its internal floor. Timing pulleys are purposeful pulleys that have either enamel or pockets across the out of doors diameter of the pulley frame. Timing enamel interact holes within the metal belt, while timing wallet engage pressure lugs on a belt's inner circumference. These teeth or wallet are used only for timing, no longer for energy transmission.

3.1 Electrical and Electronic Components

A stepper motor is a brushless DC electric powered motor that bisects a full rotation right into a same quantity of steps. Brushed DC motors rotate constantly when DC voltage is applied to their terminals. The stepper motor is known through its quantity of steps. Brushed DC motors rotate, scaling, skewing and transferring.

CNC defend v3.0 can be utilized as force growth board for inscribing device, 3D-printers, and other devices. There are 4 slots within the board for stepper motor drive modules, can pressure 4 stepper vehicles, and every stepper motor most effective need IO port, that’s is to mention, 6 IO ports can pretty nicely to manipulate three stepper motors, it’s very handy to apply. After inserting Arduino CNC defend v3.0 into Arduino UNO and hooked up GRBL firmware then you can quick DIY a CNC engraving gadget.

A stepper motor motive force (A4988) is a micro-stepping driver for controlling bipolar stepper motors it has a integrated translator for clean operation. From our controller, the stepper motor is managed by means of 2 pins. One might also help for controlling the rotation route and the second one for controlling the stairs [8].

3.2 Electrical and Electronic Components

Inkscape is an unfastened and open-source vector images editor. We can create or edit vector photographs which include illustrations, diagrams, line arts, charts, trademarks, and complicated paintings. It can supply primitive vector shapes (eg. Rectangles, ellipses, polygons, arcs, spirals, stars, and 3D boxes) and text. These patterns may be stuffed by way of solid colours, radial or linear coloration gradients and their borders may be stroked, both with adjustable transparency [9]. Embedding and non-compulsory perceiving of raster pics are also supported, permitting the editor to create vector pix from images and different raster sources. And it may generate as G-code record layout. Generated shapes can be further employed with adjustments, along with rotating, scaling, skewing and transferring.

GRBL controller is software program that is designed to send G-Code to CNC machines, which includes 3D milling machines.

4. METHODOLOGY

The 2D vector graphic created by Inkscape is saved into G-code file by using MakerBot Unicorn extension. This G-code file is imported into GRBL application by which the plotter machine is controlled. GRBL send G-code to ATMEGA328P (Arduino Uno) by means of Bluetooth or USB cable, Arduino sends this code to motor shield, motor shield receives this code and sends to stepper module which is attached to it. Each stepper module controls a single stepper motor of X, Y and Z axes. Hence the ATMEGA328P, Motor defend, and Stepper module act like interfacing module among PC to the controller. This code is further exceeded to stepper motor by way of smooth drivers which convert the code and as in keeping with commands the stepper motor actions. We want three axes X, Y and Z which operates as follows X stepper motor pass left and right Y stepper motor moves back and front and Z stepper motor up and down as according to given dimensions those axes will pass on.
5. MATHEMATICAL CALCULATIONS

From specifications of stepper motor

Rated current: 0.43 amp
Rated resistance: 8 Ohm

Then, Power = \( I^2 \times R \) \( \text{(1)} \)

\[ P = 0.43^2 \times 8 = 1.48 \text{ watts} \]

Theoretical power of stepper motor = 1.48 J/s

\[ P = \frac{2\pi NT}{60} \] \( \text{(2)} \)

where \( P = \) power of the motor, \( N = \) speed of the motor (rpm), \( T = \) torque on the shaft

\[ 1.48 = \frac{2\pi NT}{60} \]

\[ NT = \frac{(1.48 \times 60)}{2\pi} = 14.13 \]

If, \( N = 200 \text{ rpm} \)
\[ T = 70.65 \text{ N-m} \]
\[ T = r \times F \sin \theta \] \( \text{(3)} \)

where \( F = \) linear force applied on pulley; \( r = \) distance measured from the axis of rotation to where the linear force is applied; \( \theta = \) the angle between \( F \) and \( r \)

\[ r = 5 \text{ mm}, \ T = 70.65 \text{ N-m} \]
\[ F = 14.13 \text{ N} \]

Therefore, load on the pulley must be less than 14.13N when pulley running at 200rpm.

\[ T_2 = T_1 + f \] \( \text{(4)} \)

where, \( f = \) friction, \( T_1 = \) belt tension on loose side, \( T_2 = \) tension on tight side

\[ T2T1 = e^{0.06} \] \( \text{(5)} \)

In this problem load is equal to sum of frictional force and inertial force. But table is moving with uniform velocity, so inertial force is zero.

Load on motor = frictional force
\[ = \mu \ m_1 g \text{ or } \mu m_2 g \]

\[ \mu = 0.2, \ m_1 = 0.8, \ g = 9.81 \text{ m/s}^2 \]

Load on y - axis motor = \( f_1 = \mu \ m_1 g \)
\[ = 1.57 \text{ N} \]

Load on x - axis motor = \( f_2 = \mu \times m_2 \)
\[ = 0.5886 \text{ N} \]

From above calculation, we observe that \( f_1 \) and \( f_2 \) are less than 14.13 N.

\[ F_1 = (T_1 + T_2) = 1.57 \text{ N} \]
\[ T2T1 = e^{2 \times 170180 \pi} \]

\[ \therefore \ T2T1 = 7.98 \]

\[ T_3 = 7.98T_4 \]
\[ f_2 = T_3 + T_4 = 8.98T_4 = 0.5886 \text{ N} \]
\[ T_4 = 0.066N; \ T_3 = 0.52N \]

Voltage of stepper motor = 0.28 Volts

Volts resistance of stepper motor = 8 \( \Omega \)

\[ V = I \times R \] \( \text{(6)} \)

\[ I=0.28/0.035 = 8 \text{ A} \]

Power = \( (I^2) \ R = (0.035)^2 \times 8 \)
\[ P = 9.8 \times 10^2 \text{ W} \]

\[ P = T \times \omega \] \( \text{(7)} \)

where \( T = \) torque, \( \omega = \) angular velocity
\[ T = r \times F \] \( \text{(8)} \)

\[ r = \text{Arm radius, } F = \text{load} \]

Feed Rate (f) = 200 mm/min = 200/60 = 3.33 mm/sec
\[ f = r \ \omega \] \( \text{(9)} \)

\[ \omega = 0.66 \text{ rad/sec} \]

\[ P = r \times F \times \omega \] \( \text{(10)} \)

\[ F = 2.96 \text{ N} \]

So, load must be less than 2.96 N
\[ M1a1 \leq 2.96 \text{ N}; M2a2 \leq 2.96 \text{ N} \]
\[ T1+T2 \leq 2.96 \text{ N}; T1+T2 = 2.96 \text{ N} \]
\[ T2/T1 = e^{0.06} \]
\[ T2/T1 = e^{0.7 \times 170 \times 18} = e^{2.076} \]
\[ T2 = 7.98T1 \]
\[ T1 \leq 0.329N; T2 \leq 2.63N \]

T1 and T2 are tensions in the belt

Load = frictional force + inertia.

Inertia is zero because acceleration is zero.

Friction = \( \mu mg \)
\[ F1 = 0.2 \times 0.6 \times 9.81 = 1.17 \text{ N} \]
F2 = 0.2 * 0.2 * 9.81 = 0.39 N
F1 and F2 are less than 2.96 N.

6. RESULTS AND DISCUSSION

This section deals with the fabrication procedure and calculation of the Mini CNC plotter machine. Fabrication part includes marking, cutting, grinding, welding, drilling, modeling for 3D printing, Assembly. For every fabrication process, marking is the first step followed by every individual. Indicating is a process to mark the required dimension on the workpiece to carry out further mechanical processes like cutting, drilling, welding etc.

Table 1 Calculated time values for the specified feed rate

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Feed rate (Mm/min)</th>
<th>Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>200</td>
<td>120</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
<td>99</td>
</tr>
<tr>
<td>3</td>
<td>300</td>
<td>85</td>
</tr>
<tr>
<td>4</td>
<td>400</td>
<td>67</td>
</tr>
<tr>
<td>5</td>
<td>500</td>
<td>58</td>
</tr>
<tr>
<td>6</td>
<td>800</td>
<td>44</td>
</tr>
<tr>
<td>7</td>
<td>1000</td>
<td>40</td>
</tr>
</tbody>
</table>

From Table 1, it has observed that irrespective of surface as the federate increases time is decreasing. On a base (wooden plank) the clamps of respected axes(x and y), i.e, C-clamps to hold y-axis and T-clamps to hold x-axis for drilling holes and firm the rods into it, plotting base for drilling holes and for fixing it on rods with the help of 3D printing holders, holes are made on the base plate on which VCD drive and a pen is to be placed to arrange this whole setup to x-axis rods by means of 3D printing clips.

Hacksaw blades are made of high-speed steel which are used for cutting metal. This blade is locked in the frame. Typical hacksaw blade lengths are 10 to 12 in (250 to 300 mm). Blades can be as small as 6 in (150 mm). The pitch of the teeth can be from 14 to 32 teeth per inch (TPI) for a hand blade.

A grinding machine is a type of tool that is advanced for grinding workpiece. It firstly uses an abrasive wheel as the cutting tool. The rough surface of the abrasive wheel fragments off minute portions of the workpiece as needed. It is named as a grinder. A grinder is largely performed to get absolute shape and complete the given materials with least surface roughness and high surface quality. It is primarily a finishing operation that removes relatively small quantities of metal, to deliver highly detailed products. However, some of the grinding processes also take swiftly removing high volumes of metal.

Then welding process is carried out by joining two or more metal pieces together by heating the surfaces to the point of melting with an electric arc, or by other means.

The Drilling operation that uses a drill bit to make a hole in solid materials. The drill bit is a multi point rotary cutting tool. The bit is rotated at rates from hundreds to thousands of revolutions per minute. This penetrates the cutting edge against the work-piece, shearing off chips from the hole.

7. CONCLUSION

A CNC machine which can draw images or text on the surface like paper, softwood, metal sheet etc. is constructed which has two axes, namely X and Y axis. It uses two stepper motors and a servo motor for z-axis. The machine is operated by accesses of G-codes directly using software called “INKSCAPE” microcontroller board, based on the ATMega328p microcontroller, which was developed by Aurdino.cc. Along with this, there are other electronic components like motor shield, stepper motor drive, GRBL controller reprogrammed for successful functions of the machine. Finally time is calculated for the specified feed rate is presented. It is observed that irrespective of surface as the federate increases time is decreasing.

REFERENCES

