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Fabrication of portable CNC Milling Machine for Wood

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ABSTRACT

Computer Numeric Control is the automation of machine tools which are operated by Numerical commands. It enables better manufactured product by reducing the number of steps involved and time taken in manufacturing. The current work uses the codes available in CNC technology to control the machining variables on a self-built 2 ½ axis machine. 2 ½ axis implies the controlled motion is along 2 axes (X and Y) and along motion of tool spindle that moves in the Z (depth). The position of the tool is driven by direct-drive stepper motor in order to provide highly accurate movements. Machine is built on a dimensionally stable platform and the parts on which machining is performed are bolted using clamps and bolts. Finally, using the open source Arduino interface and CNC shield this machine is brought to life. The scope of the current work aims to present a working model of the CNC machine which can be used for light drilling, milling operations on pieces of wood.

Keywords: CNC (Computer Numerical Control), Arduino, CNC shield, Stepper Motors, X-base, Y-base, Z-base.

I. INTRODUCTION

A CNC machine performs machining operations in three dimensions from any typical work piece under the supervision of a computer. The introduction of CNC machines changed the manufacturing industry radically. Complex shapes and contours can be easily machined from 3-D structures with minimum human intervention and high precision. The use of CNC machines also reduces the steps in manufacturing process drastically ensuring consistency and quality of end product. CNC automation not only reduces the frequency of errors and also allows flexibility [1]. In the current work, a 2 ½ axis portable CNC milling machine is fabricated that performs operations like drilling and milling on wooden work pieces.

The CNC machine is fabricated using wood, metal and acrylic sheets, which are dimensionally strong and stable ensuring that drilling and milling operations can be performed with quality and precision. All the parts used are fabricated and assembled by means of suitable operations like welding, drilling, cutting etc. Different electronic devices like stepper motors, motor drivers, CNC shield, arduino and a computer make the machine functional to perform different operations based on the codes streamed to the machine.

II. METHODS AND MATERIAL

1.1. STEPS INVOLVED IN THE FABRICATION

The sequential order of steps is as follows [2]:

1. Fabrication of X & Y bases.
2. Fixing of a work holding device.
3. Fabrication of Z base.
4. Installing the electronics.

1.1.1 Fabrication of X & Y bases

Fabrication of X & Y bases was started off by cutting the pieces of acrylic sheet required from a large acrylic sheet. The dimensions were taken by considering the end work piece size ranging between 90x90 mm^2 to 150x150mm^2. X-base was cut to 250x600mm^2 and Y-base was cut to 250x250mm^2 from an acrylic sheet of 8mm thickness.

The X-base rests on a wooden base of the machine. The wooden base of dimensions 1220 x 910 mm^2 and thickness of 12 mm rests on a chromium coated mild steel frame. The frame is welded to a vertical column at the bottom to act as a support and base to the Z-base and spindle. The center lines were marked on the X-base and the indentations required for the fixing of telescopic channels were made on it. Suitable size wooden blocks were selected to act as support to the channels and also to increase the height of channels to match the center of the stepper motor mounted. Later, this assembly was bolted to the wooden base by drilling necessary holes and M4 bolts & nuts were used. A NEMA 17 stepper motor was mounted on the wooden base and a M8 lead screw was coupled to it using a flexible coupling. Two brackets made using bored M8 long nut welded to a MS plate were used to act as support to the lead screw and were heightened using small wooden blocks to match motor's height. Another small bracket with internal threading was used on the lead screw which was attached to the X-base and it advances when the stepper motor's shaft rotates.

Members of the X-base like Stepper motor, Telescopic channels, Brackets which rest on the wooden base are lined with rubber layers to damp the vibrations and reduce noise as depicted in the Figure 1. The maximum limit of motion for X-base is 350 mm.

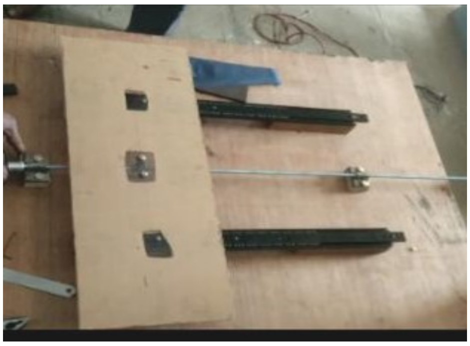


Figure 1 X-Base

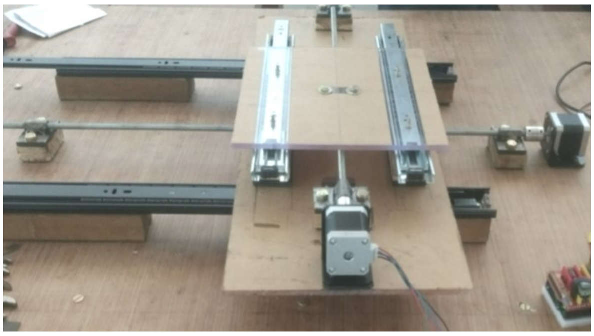


Figure 2 Y-Base

Figure 2 shows the final view of Y base after it is fabricated. The Y base is fabricated on the outlines of X-base. It is fabricated and fitted on the X-base. This setup also has the work holding device.

As mentioned earlier, the dimensions of the bases were calculated estimating the work piece dimension to be 150x150 mm^2 and by considering the motion which is required to be given to each axis for the machining the work piece of given dimensions. The Y-base is made from acrylic sheet of 8mm thickness. The required dimension of Y-base i.e., 250X250mm^2 is cut from a large acrylic sheet by using an acrylic knife. The Y-base is then fitted to the X-base by means of a sliding mechanism to allow easy translation motion and support. For this, firstly the Y-base is marked with centre lines and then proper markings of the holes present on telescopic channel are indented on acrylic. Then the holes of diameter 4mm are drilled on the acrylic sheet using a hand drill. The two telescopic channels and the acrylic sheet are fitted together by using a M4 bolt and nut of 15mm length. To the telescopic channels the X-base is fitted using 4 wooden drilled blocks of dimensions 100x40x20 mm^3. The height of the wooden blocks is maintained to match the centre of the Stepper motor installed on the Y-base. This whole assembly of acrylic base, Telescopic channels, and wooden blocks constitute the sliding mechanism for Y-base and distributes the weight on to it.

On the X-base, a NEMA 17 stepper motor coupled to a lead screw with M8 threading by means of a flexible coupling is fixed using the M4 nuts & bolts. The long length of the lead screw may result in its bending, hence the two brackets provided, impart sufficient support to the lead screw. These brackets are fitted on the wooden heights to match the height of the stepper motor's shaft thereby acting as bearings. One bracket made using the M8 long nut welded to a metal piece and holes drilled is used as a nut on the lead screw for the translation along Y-axis.

1.1.2 Fixing of a work holding device

The work holding device is the most important component in any machine. It is necessary that the work should be properly and securely held on the CNC machine table for effective machining operations. The cutting pressure exhorted by milling cutter is quite high compared to the single point tool of lathe machine. As the current portable CNC machine is intended for machining light objects, it is made up of acrylic base. Therefore a robust mechanical vice is not suitable here.
A work holding device to hold the work piece from all the 4 sides in the XY plane was fabricated using L shaped aluminium plates cut into suitable size and then bolted to the aluminium base. This aluminium base acts as a second Y base so that the real Y base doesn't get damaged when drilling operation is performed to make through holes. The second base is of 3 mm thick. It is internally tapped to screw in the bolts to maintain an

immovable and firm contact between slotted L shaped aluminium plate and the aluminium base.

The reasons for choosing aluminium instead of any other harder material is that the current portable CNC is intended to machine only softer materials like wood and thus does not require robust materials.

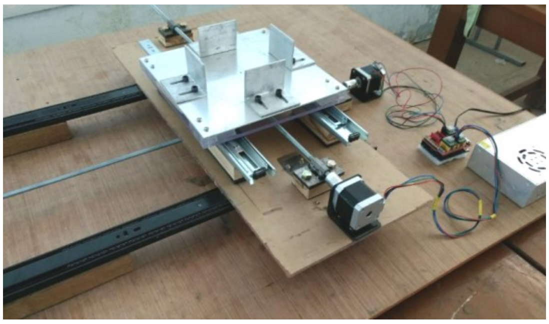


Figure 3 Work holding device

To accommodate the work piece ranging from $150x150mm^2$ to $90x90mm^2$ the four L shaped aluminium bits are slotted. Thus they can slide and hold the work piece firmly. In addition to this, the L shaped bits are internally tapped on the face which holds the work piece to accommodate screws which provides additional support to the work piece. The entire work holding device is replaceable in case of any damage to the work table during operations.

1.1.3 Fabrication of Z base:

As per the general concept of any CNC machine, the Z axis lies parallel to the axis of the tool. Here, the Z base also carries the tool's spindle motor in addition to its vertical advancing.

Figure 4 Z-Base Assembly

The Figure 4 shows the final view of Z-base after it is fabricated. The Z-base which lies parallel to the vertical axis can be coded to move from top to bottom and vice versa. Besides this motion, it must also accommodate the entire setup of Spindle motor and tool holding device. The dimensions of the base were calculated estimating the tool's vertical travel. The Z-base is made from two acrylic sheets of 8mm thickness having dimensions $250x250mm^2$ for the base sheet and $250x150\ mm^2$ for the spindle holding acrylic sheet.

The above acrylic base for spindle motor is then required to be supported by the steel plate present at the end of the vertical frame by means of a sliding mechanism to allow for the easy movement and support to the Z-base. The complete mechanism rests on the base sheet. For this, firstly the spindle motor's acrylic sheet is marked with centre lines and then proper markings of the holes present on telescopic channel are indented on acrylic. Then the holes of diameter 4mm are drilled in acrylic and the two telescopic channels are fitted together by using a M4 bolt and nut of 15mm length. To the telescopic channels 4 wooden blocks of dimensions $40x100x20mm^3$ are fitted by drilling holes in the blocks and the Acrylic attached to MS plate. The height of the blocks is maintained so as to match the Z-base stepper motor's centre. This whole assembly of acrylic base for spindle, sliding channels, and wooden blocks constitute the sliding mechanism for spindle motor and also distributes the weight on to it.

On the Acrylic base, a stepper motor NEMA 17 coupled to a lead screw having M8 threading by means of a flexible coupling is fixed using the M4 nuts & bolts. The long length of the lead screw may result in its bending so 2 brackets are fitted on both ends to provide sufficient support to the lead screw. These brackets are fitted on the wooden heights to match the height of centre of the motor's shaft thereby acting as bearings. One bracket made using the M8 long nut welded to a metal piece and holes drilled is used as a nut on the lead screw for the advancing motion along Z axis. The maximum limit of motion for Z base is 125 mm.

The spindle motor is installed in a hollow wooden piece which is bolted to the acrylic sheet, this setup advances on the lead screw and the motion is controlled by means of coding given to the spindle motor. This spindle motor has a tool holding device which has a chuck and collet arranged to hold he tool bit firmly. The tool can be fixed inside the collet by means of tightening the allen nut present.

1.1.4 Installing Electronics

The electronic components like SMPS, Arduino Uno, CNC Shield, A4988 Stepper motor driver, Micro Limit switches, Relay, Stepper motors, 24v DC motor, AC adapter are suitably installed as per the following diagram [3].

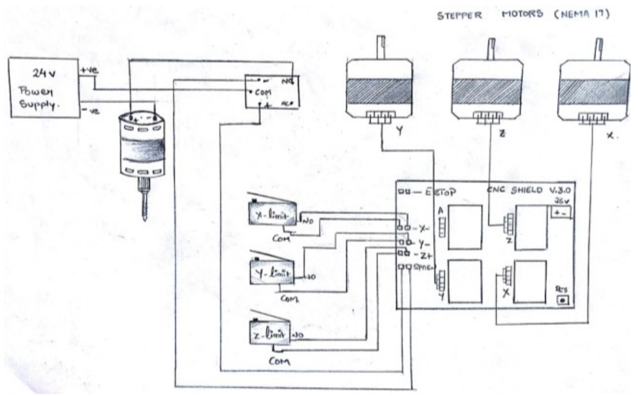


Figure 5 Circuit Diagram

The power source required for the portable CNC machine is 13 Volts DC (for CNC Shield) & 24 Volts DC supply (for Spindle Motor). For this, an SMPS which gives 36 volts DC power output is selected and by means of a potentiometer and gain adjuster it is adjusted to 13V and is connected to CNC shield.

CNC Shield is assembled with Arduino according to its pins and then the A4988 Stepper motor drivers for X Y and Z axes are installed along with the heat sink on the CNC shield.

Then the stepper motors are connected to the CNC shield using stepper motor connecting pins at their respective positions on the CNC shield. Micro limit switches which are activated by mechanical means are firstly positioned in view of extreme position of axes travel lengths and the home position of the machine. The wires from these switches are connected to their respective pins on the CNC shield. Another additional limit switch which acts as an Emergency Stop is pinned to the E-stop pins on CNC Shield and the switch is placed near the operator and can be used in case of Emergency [4].

A DC motor rated 24V is selected for Spindle operations which gives high torque and sufficient RPM required for drilling and milling operations. Since the output from CNC shield is 5V an external power source i.e., a 24V adapter is used in association with relay. A relay is used to switch the power supply from 5V to 24V whenever an electrical impulse is given to on/off the spindle motor. The instruction to turn on/off is taken from the CNC shield and the power supply required, is taken from the Adapter.

A USB from arduino can be connected to a PC. The whole electrical setup is placed in an Acrylic box. After setting up the electronics, certain softwares are used in order to give instructions to the machine using PC, and one of the most familiar and important software is Grbl which is a g-code interpreter and CNC stepper motor controller for the Arduino. It is installed/feed to the Arduino using Xloader software which uploads the '.hex' files to the Arduino board using bootloader. Once the Grbl is uploaded to Arduino, Universal Gcode Sender, which is a java based Grbl compatible cross platform G-code sender is installed on it. It is used to give the machine commands for operations based on the programs written using NC codes and it also stimulates the whole machining process [5].

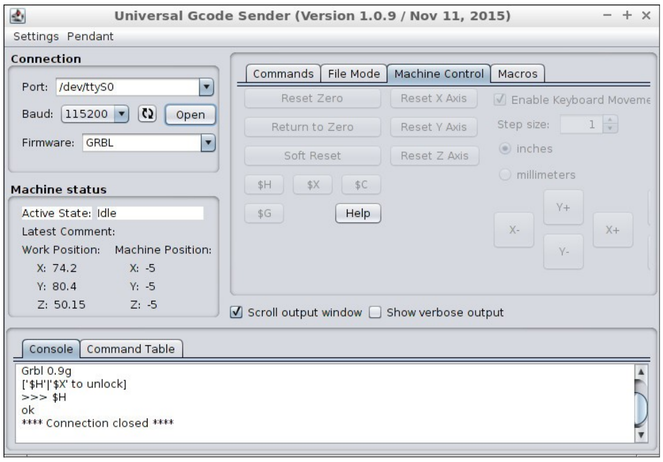


Figure 6 Universal Gcode Sender

In order to test the machine, few simple programs for drilling & milling were performed and the results are shared hereunder.

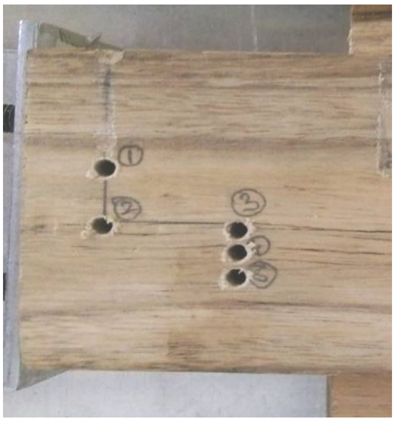
III. RESULTS AND DISCUSSION

2. TEST RESULTS

2.1 Drill Test

This code is executed after the tool is located at work zero.

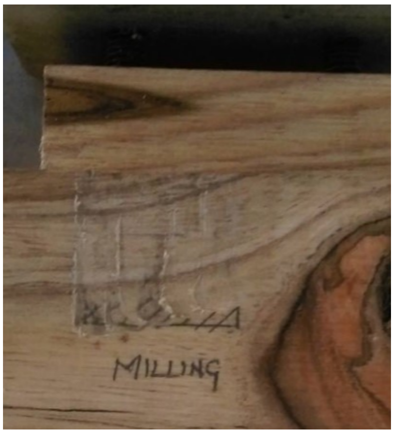
```
M03
G91 G21 G00 Y20
G01 Z-26
G01 Z26
G00 Y10
G01 Z-26
G01 Z26
G00 X20
G01 Z-26
G01 Z26
G01 Y4
G01 Z-26
G01 Z26
G01 Y4
G01 Z-26
G01 Z26
G00 Z10
M05
$H
```



2.2 Milling test

This code is executed after the tool is located at work zero.

```
M03
G91 G21 GOO Y-1
G00 X42
G01 Z-1 F200
G01 Y20
G01 X2
G01 Y-21
G01 X2
G01 Y20
G01 X2
G01 Y-21
G01 X2
G01 Y20
G01 X2
G01 Y-21
G01 X2
G01 Y20
G01 X2
G01 Y-21
G01 X2
G01 Y20
G01 X2
G01 Y-21
G01 X2
G01 Y20
G00 Z25
M05
```



IV. CONCLUSION

The fabricated portable CNC is used to perform drilling and milling operations on Wooden pieces successfully. The results obtained were satisfying.The current CNC machine can be altered to perform operations on other materials by changing the end tool and work holding device. Also, addition of a Bluetooth module to Arduino can help operating the portable machine using an android application in any smartphone.

Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions. Authors are strongly encouraged not to call out multiple figures or tables in the conclusion these should be referenced in the body of the paper.

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