iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** III **Month of publication:** March 2020

DOI:

www.ijraset.com

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue III Mar 2020- Available at www.ijraset.com

Design and Fabrication of 3-Axis CNC PCB Milling and Drilling Machine - Calculation

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Abstract: ***Computer numerical control milling and drilling, are the machining process which utilizes automated controls and turning multi-point cutting devices to remove material from the work piece and produce a designed custom part or product. These processes are suitable for machining a wide range of materials and are used for producing a variety of custom-designed parts and products. Drilling and Milling are the most common cutting technique which are targeted for the production of holes and milling operation. High precision and quality are always required. In this paper, we have focused on design and manufacturing of milling and drilling machine for milling and drilling operations on composite material like PCB.***
Keywords: Milling, Drilling, PCB, Design, Composite material

I. INTRODUCTION

Manufacturing a PCB Milling and Drilling machine requires a great deal of accuracy because sudden variation in speed may cause rough operation and while manual drilling if feed rate is to fast it may cause vibration of sheet and if RPM is to high it can cause melting of metal sheet .While manufacturing we must be aware of that spindle must not vibrate at high speed and motor, spindle and column must adjusted rigidly to avoid vibration. Assembly of PCB drilling and milling machine is easy as most of parts are available and we do not need to manufacture it. Feed component must not be as unbending as in metal cutting. To guarantee this we have to give spring power as feed power since when we feed physically it might cause over the top power so spring power may weaken the inordinate measure of power.

II. CONSTRUCTION

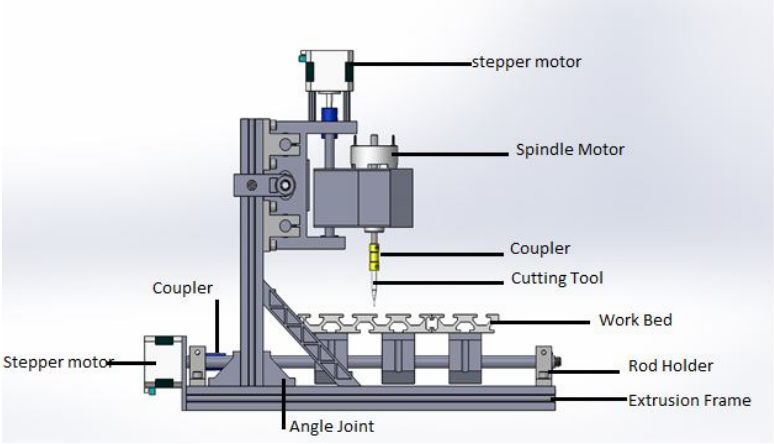

Fig 1: Construction of Project

The principle tools used in the mechanical design consist of work board which is of aluminium extrusion, smooth rods, lead screw, angle joints, stepper motor, ball bearing, support stands, anti-backlash nuts. The PCB is placed in the system then it is drilled automatically through path planning. By the PCB design software, it generates the coordinate in x, y, z direction. To control the drill the system is consist of 3 stepper motor. The automatic PCB drilling machine uses a path planning algorithm, which locate the exact travelling path for the tool to move. In this project, the position of the drill hole and milling operation is taken by the developed software. Then it calculates the previous and current co-ordinate and sends the coordinate information Micro-controller unit over USB cable. Stepper motors move on the basis of co-ordinate information to accomplish the drilling and milling of the PCB.

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III. WORKING PRINCIPLE

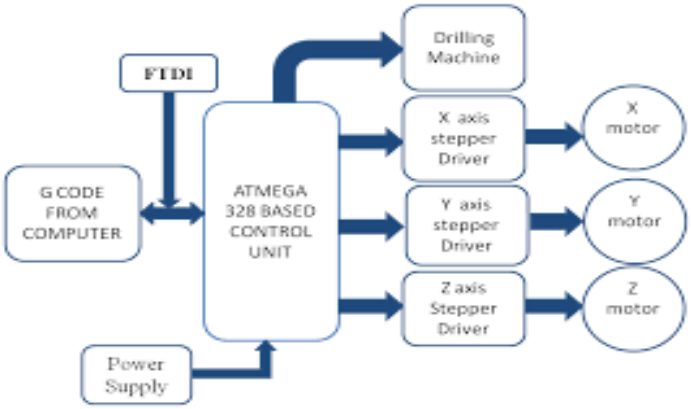

Fig 2: Block diagram of 3-Axis PCB Milling and Drilling Machine

The machine designed based on co-ordinate measurement machine, therefore the machines have designed with three coordinate, X, Y and Z. The PCB is moved along the X and Y axis and Z co-ordinate are used to move the tool up and down. We are using EAGLE software which is an open source software to provide design to PCB. Then the file is transferred to the candle software which is basically G-code converter. It converts design of PCB in G codes. Pc is connected to Arduino uno with usb cable. It is connected to the GRBL controller which control the motion of machines. Which gives the motion to stepper motor which are connected in 3 different axes. As per the command received from the software 3 motors work in 3 axes individually or with each other. According to the motor our whole assembly works as workbench moves along Y-axis, spindle motor moves along Z-axis, and the motor assembly moves along X-axis

IV. DESIGN PARAMETERS

Fig 3: Aluminium Extrusion Frame

We used Aluminium Extrusions Aluminium Profiles Frame for milling and drilling Machine. Which reduces the cost and have good durability.

Fig 4: Lead Screw

Leadscrews are commonly used in linear actuators, machine slides (such as in machine tools). Leadscrews are a key component in electric linear actuators. A lead screw turns rotary motion into linear motion combining a screw and a nut where the screw thread is in direct contact with the nut thread.

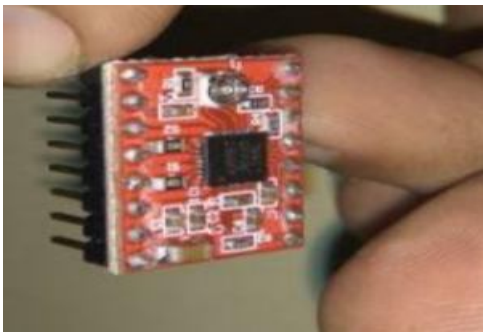

Fig 5: Motor Driver

The motor driver is a module for motors that allows you to control the working speed and direction of two motors simultaneously. This motor driver is designed and developed based on L293D IC. L293D is a 16-pin motor driver IC. This is designed to provide bidirectional drive currents at voltages from 5v to 36v.

Fig 6: Stepper Motor

NEMA 23 is a stepper motor with a 2.3×2.3-inch (58.4×58.5 mm) faceplate and 1.8° step angle (200 steps/revolution). Each phase draws 2.8 A at 3.2 V, allowing for a holding torque of 19 kg-cm. NEMA 23 Stepper motor is generally used in Printers, CNC machine, Linear actuators and hard drives.

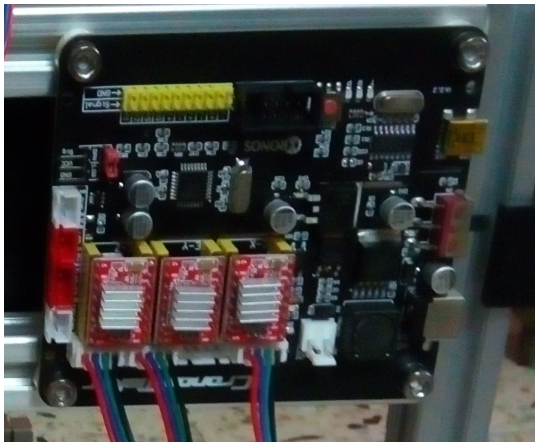

Fig 7: Arduino

Arduino Uno is a microcontroller board dependent on ATmega328. Its working voltage is +5V. it comprises of 14 advanced I/o pins. It can withstand input voltage from 7-20 V. The DC Current per pin 40ma. It has 32kb of glimmer memory. It working default clock recurrence is 16MHz.

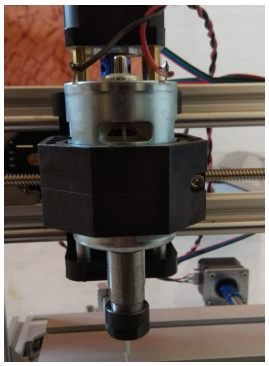

Fig 8: Spindle Motor

The CNC spindle is the heart of any mill. It consists of a rotating assembly with a taper where tool holders may be installed. A spindle motor with optional transmission of some kind rotates the CNC spindle. The transmission matches the highest power rpm range of the CNC spindle motor to the spindle rpms that are ideal for the particular speeds and feeds of the material being cut.

V. DESIGN OF SPINDLE SPEED AND POWER REQUIREMENT

Design of PCB drilling and machine require to calculate cutting force and power required for it. To calculate this, we need to fix the range of diameter we can drill / mill on machine. In this paper we have calculate all the value for the diameter of 0.1 mm, but it can be calculated upto as per the required diameter for that we are going to produce machine.

1) Spindle speed (N)= (Vc * 1000)/3.14*d
where d = drill bit / mill bit diameter (mm), Vc is cutting speed.
2) Cutting Speed (Vc)=(3.14*d*N)/1000
3) Degree of Freedom=4
Cutting Speed (Vc)=(3.14*d*N)/1000
4) Feed=Feed/Revolution*N
5) Feed/Tooth=Feed/N*no. of teeth
6) Cutting Feed=F/T*no. of teeth
7) Metal Removal Rate
$= (3.14*d^2*Fr*L*n)/4L*1000$
$= (3.14*d^2*Fr*n)/4*1000$
Where d is Drill Diameter, Fr is drill feed, N is and L is length of hole.
8) Drilling Time (T)= (Hd*No. of holes)/Speed *Fr
Where Hd = Hole Depth, and Fr = feed

A. Calculations for 0.1mm

Spindle Speed @5000rpm …. Considering maximum speed of spindle motor
Cutting Speed (Vc) = (3.14*0.1*5000)/1000
=1.57 mm/min
Feed of Spindle
Feed/rev = 0.1 @5000rpm
Feed = 0.1*5000
=500 mm/rev

Feed/Tooth= (500)/5000*4
=0.025 mm/rev
Cutting Feed=0.025*4
=0.1 mm/rev
Metal Removal Rate= (3.14*0.1*0.1*500)/4*1000
$= 3.92*10^{-3}$ mm^3/min

1) Accuracy: While features as small as 0.1mm are possible, the average CNC user can expect a trace width of 0.3mm with a clearance of 0.3mm. Stepper motor provides 1.8-degree step angle, stepper drivers provide 1/16 micro stepping. 1.8*(1/16) = 0.112 thus 0.112-degree accurate movement is obtained.
2) *Effectiveness:* As comparing with chemical etching process CNC machine gives more efficiency than the etching process.
3) *Durability:* The durability of the drill before the set up and motion is 48/100. The drill bit durability, therefore, 48 is divided by 100, minus the change in length of the drill bit; for example, if the change in length is 1 inch, the final durability is 48 divided by 99, which is 2.0625
4) *Sustainability:* Sustainability means that a process or state can be maintained at a certain level for as long as is wanted. While performing experiment we seen that the engraving tool can be used for 5-6 PCBs.
5) *Accessibility:* Accessibility is the degree to which a product, device, service, or environment is available to as many people as possible. Accessibility often describes hardware and software designed to help those who experience disabilities. This machine can be operated by any person.

VI. CONCLUSIONS

The Design of PCB milling and drilling machine is very important aspect as we require drilling and milling on very delicate material like acrylic which is used for PCB. Designing with various speed range will give wide application of milling and drilling machine with various diameter hole can be drilled in single machine and it will reduce cost of manufacturing

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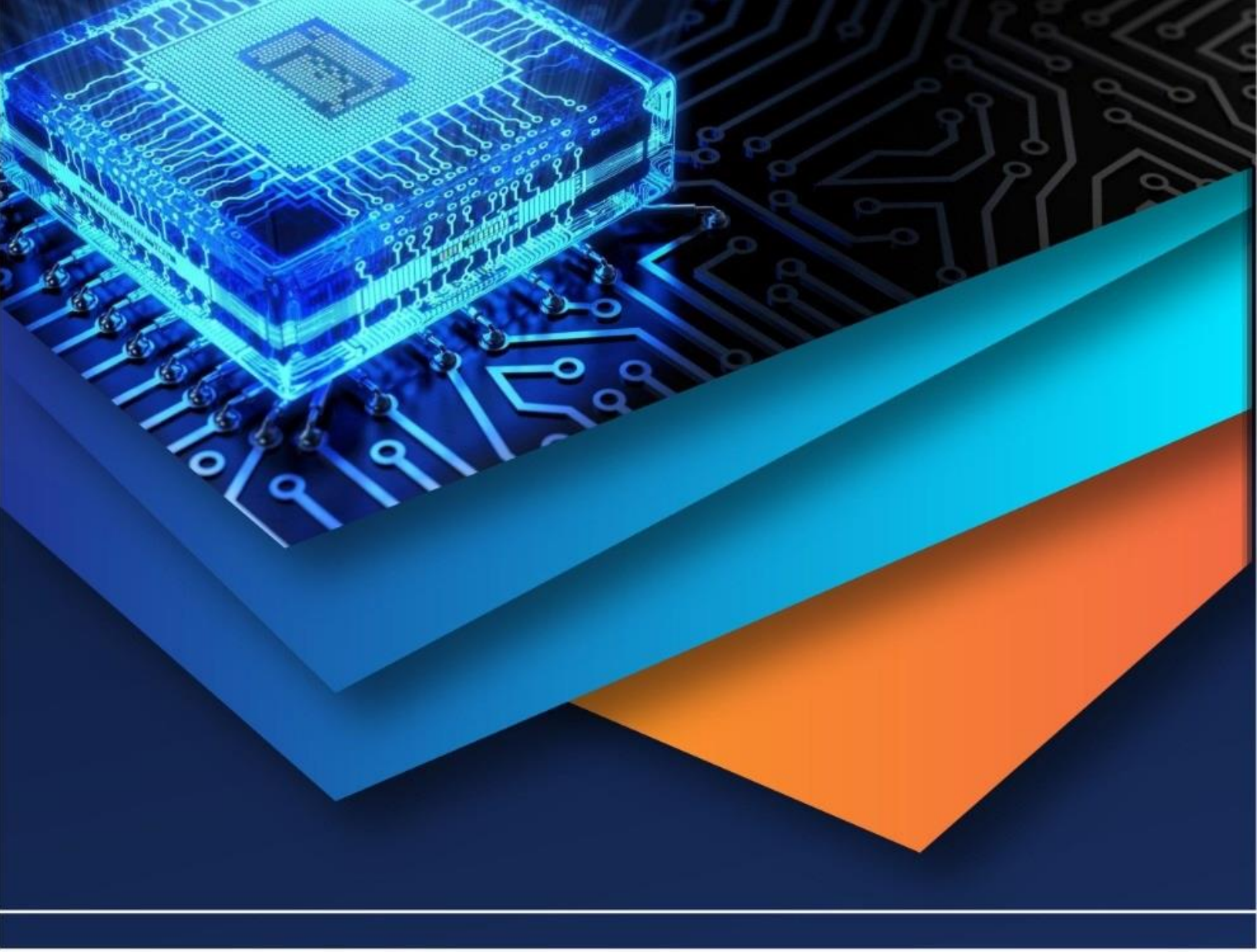

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