

A UNIQUE DESIGN FOR A PORTABLE CNC SKETCHING MACHINE

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Abstract

Computer Numerical Control (CNC) machines have become more popular nowadays because of its capability to produce complicated products. It has become mandatory for the researchers to know, learn and utilize these machines effectively. In general CNC machines are of high precision, reduced cycle time and are of high cost. In some cases, high accuracy and cycle time are not very important. The aim of this work is to build a low cost and portable 3-axis CNC sketching machine which can be used in certain circumstances, like poster making where high accuracy and cycle time are not a major concern. In this research work, Arduino microcontroller has been used along with a CNC shield which can provide the necessary accuracy level for controlling the stepper motors. G-codes will be generated using the CAM software and will be fed into the microcontroller with the help of a processing software (Universal G-code Sender). The microcontroller converts the G-codes into electrical pulses and sends it to the CNC shield which will control the motor movement in the X, Y, Z axes. This machine can be used for sketching simple images. The main objective of this research work is to build a CNC Sketching machine with a reduction in cost and in power consumption, but with a decent amount of accuracy and cycle time.

Keywords—Sketching, CNC, Universal G-code sender, Arduino, CNC shield, motor driver.

I. INTRODUCTION

Conventional machines have certain limitations, while performing the machining operations with regard to the accuracy they can produce. Around 1940's NC (Numerical Control) machines had started to emerge, which had helped

to automate the machining process. The NC machines helped to do machining processes with a better accuracy when compared to conventional machines. These machines work on a set of instructions which consists of numbers, letters and symbols. The instructions were fed into punch cards or were perforated. The Machine Control Unit (MCU) can read the instructions and can send the signals to the drives. When the program has to be edited, all the instructions must be fed once again into the punch cards, which is time consuming and not economical.

During the 1980's CNC machines had started to appear in industries. The rapid growth in the electronics industries was one of the main reasons, for the development of Computer Numerical Controller. CNC machines have a lot more advantages than NC machines. In CNC machines, the program can be stored in the computer and can be edited easily. CNC machines can do machining with a higher accuracy much higher than NC machines. Complicated parts can be machined by CNC machines at ease due to high degrees of freedom.

Today CNC machines play a major in machine tool industries. Using CAD software, the required design can be sketched. Once the sketching is done, the file will be imported into a CAM software which will generate G-codes. These G-codes will be fed into the CNC, which will then send electrical signals to the servo drives to control the movement of the stepper motors. By using the precise movement of the stepper motor, the required design can be achieved. With the help of a stimulation software, we are able to understand the movement of the tool path and this reduces the risk of accidents occurring during the machining process. The cycle time of a machine, plays a major role in determining the cost of a machined product. Since this work focusses more on reducing the cost of the machine, the cycle time is not considered as a major factor.

II. LITERATURE REVIEW

The Design and the Development of a CNC Plotter Machine [1], mainly focusses on the design and selection of components. In this work, for each axis, only one motor has been employed. The x-axis Stepper motor has been placed at the centre, so that another motor can be avoided. But the problem faced with that is, the motor needs to carry the load of the worktable. So, a large worktable cannot be used, which considerably reduces the work area of the machine. For a large work area to be employed, the motor must have a high torque, which increases the cost and the power consumption.

3-axis CNC Milling machine [2] can be controlled by using an open-source software, Universal G-code Sender. Although this project focusses on the reduction of the cost, the x-axis uses two stepper motors, which could have been reduced by making constructional changes. The excess use of the motor requires another motor driver which adds on to the cost and it increases the power consumption.

Microcontroller based low-cost CNC Plotter [3] has a low power consumption and is reasonable in cost, but the machine

is so small, which makes the work area also small which is approximately 10cm x 10cm. The smaller work area makes this machine unsuitable for applications such as poster making.

Considering the literature from [1],[2],[3], it is clear that the cost and the power consumption must be reduced without compromising the work area (approx. 35cm x 35 cm). Design of the machine has to be changed, so a unique design in which the x-axis is elevated above the work area is developed.

III. TECHNICAL DESIGN

Modeling has been done by using the Fusion 360 software. Fig 1 shows the Isometric view of the 3D design of the machine. The design is simple and ergonomic, so in case of the failure of any component, the component could be replaced easily since most of the components have temporary joints. The outer structure and the bearings are joined for better robustness.

Fig 2 shows the 2D sketch of the model. 2D sketches are generated from the 3D model using Fusion 360 software.

Fig. 1 Isometric view

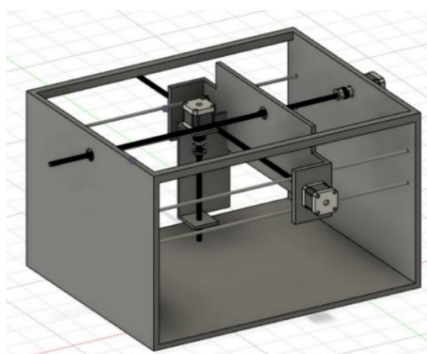
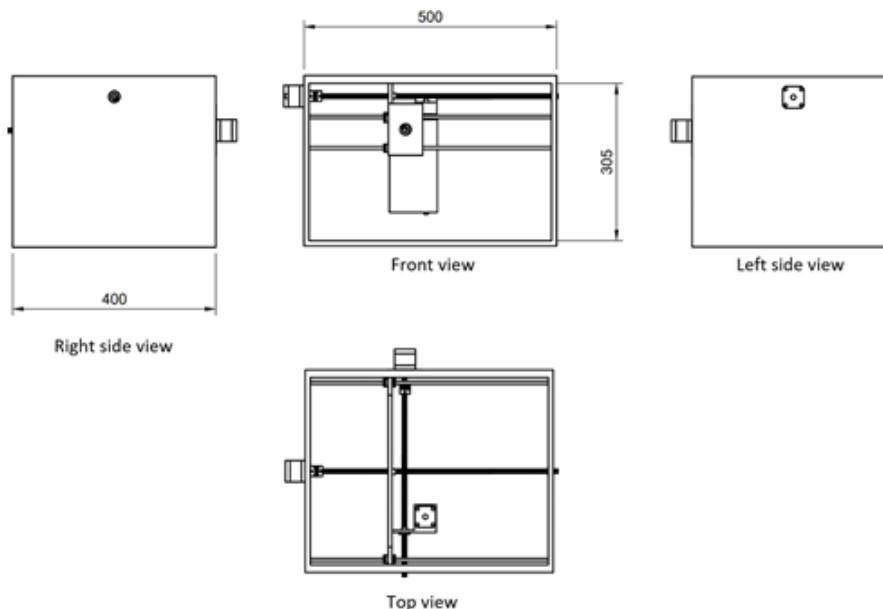


Fig. 2 2D Sketch

IV. TECHNICAL SPECIFICATIONS

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Table 1 and 2 consists of the mechanical and electronic components used in the project along with the specifications of each component

Table 1 Mechanical Elements

| S.NO | COMPONENTS | SPECIFICATIONS |
|------|---------------------------|--|
| 1. | Lead screw | Diameter: 8mm Pitch: 2mm No. of starts: 1 Length: <ul style="list-style-type: none"> 500mm(X-axis) 400mm(Y-axis) 60mm (Z-axis) |
| 2. | Stainless steel rod | Diameter: 6mm Length: 500mm |
| 3. | Aluminum flexible coupler | Inner diameter(d) d1: 5mm (for motor shaft) d2: 8mm (for lead screw) |

Table 2 Electronic Components

| S.NO | COMPONENTS | SPECIFICATIONS |
|------|----------------------------------|--|
| 1. | NEMA 17 stepper motor | Rated voltage: 12V DC Rated Current: 0.4A per phase Step angle: 1.8 degrees Torque: 2.6 kg-cm No. of Phases: 2 4-wire, 200 steps per revolution Operating Temperature: -10 to 40 °C |
| 2. | Switch Mode Powers Supply (SMPS) | Input voltage: 170-270V Output voltage: 0-12V DC Maximum output current: 5A |
| 3. | Stepper motor driver(A4988) | Maximum operating voltage: 35V Minimum operating voltage: 8V Maximum current per phase: 2A Micro-step resolution: <ul style="list-style-type: none"> full step, 1/2 step, 1/4 step, 1/8 step, 1/16 step. |
| 4. | Arduino CNC shield | Operating voltage: 12-36V DC |
| 5. | Arduino | Model: UNO |

V. IMPLEMENTATION

The assembly is done as per the design.

1) *Selecting base material:*

Mild Steel is chosen because of its high tensile strength and impact strength. It also has very good ductility and weldability.

2) *Adding the vertical supporting frames:*

The frames are welded onto the base plate.

3) *Drilling holes for ball bearings:*

Holes are drilled using a boring machine and bearings are carefully joined.

4) *Drilling holes for motors:*

Holes of different diameter are bored onto the supporting plates to insert and screw the motor.

5) *Adding horizontal supporting element:*

The horizontal supporting element is added to prevent the vertical supports from shaking.

6) *Assembling the axis feed drive system:*

Finally, the supporting rods and lead screws are inserted in the holes. The X, Y and Z axis feed drive systems are made as per the 3D design. Fig 3 shows the final setup of the machine.



Fig. 3 Final setup

VI. PROCESS FLOW

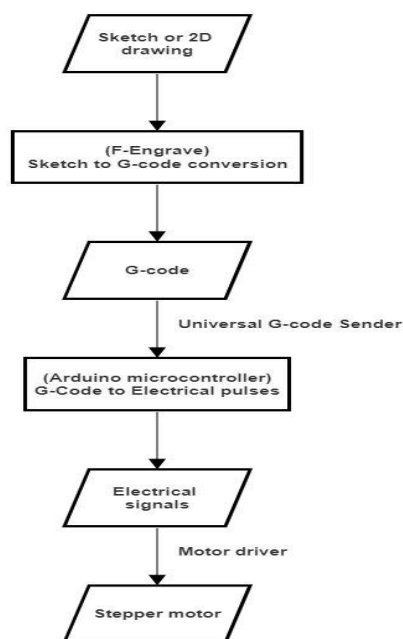


Fig. 4 Process flowchart

Fig 4 shows the flowchart of the entire process. First the sketch will be converted to G-codes using CAM software. Once the G-codes are ready, the codes will be transmitted to the Microcontroller using an interfacing software. The Microcontroller will convert the G-codes to electrical pulses using the GRBL firmware. The Motor driver will provide the required pulses to the motor for it to rotate. The synchronous movement of the motors produces a 2D sketch on the paper.

A. *CAM Software*

F-engage CAM software is used which converts text and images into G-codes. Images in the form of DFX format can be imported into the software for the conversion. Parameters such as height, width, thickness, z-safe, plunge rate, feed rate can be given using the software. Once the parameters are given, the image can be converted to G-codes.

B. Micro-Controller Interfacing Software

The Universal G-code Sender (UGS) is an interfacing software which interfaces G-codes with the micro-controller. The G-code generated from the F-Engrave software needs to be imported into the UGS software. Certain parameters of the lead screw like linear movement per 125 pulses needs to be entered into the software. The software can auto calibrate according to the entered value. Even soft limits can be set using the software. Once all these steps are done, using Jog mode all the axes of the machine will be set to a proper position. Then the program can be started.

C. Firmware

GRBL is a Firmware which is uploaded into the Arduino Micro-controller. UGS sends the G-code to the Arduino. GRBL will help to convert each line of G-code into electrical pulses and sends those pulses to the CNC shield which then controls the Stepper motors and the desired motion can be achieved.

D. Input

Fig 5 shows the F-Engrave Window after the Letter 'H' has been entered in the Input text. The required text can be entered in the Input text box. Text Font properties and G-code Properties can be changed as per the requirement. Once everything is done, click on File and Save as G-code.

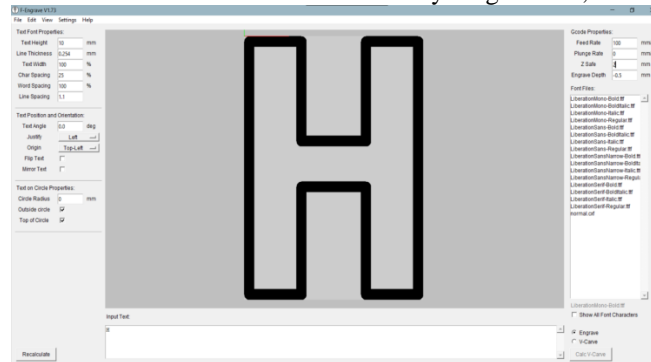


Fig. 5 F-Engrave – Text

Fig 6 shows the F-Engrave Window after the House image has been imported. For images to be imported into F-Engrave the format must be in (.dxf). So, the images must be converted

into .dxf format before importing it into F-Engrave. Image properties and G-code properties can be given as per the requirement and G-code can be saved.

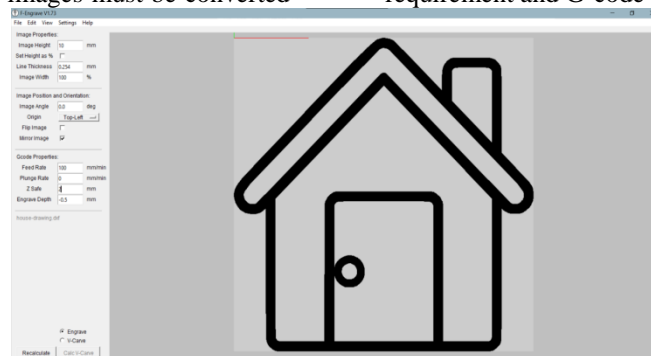


Fig. 6 F-Engrave – Image import

E. G-code conversion

There are seven steps to be followed for setting up the UGS

- 1) *Connection*: Connection must be established between the controller and the computer

- 2) *Import settings*: Any setting saved previously can be imported

- 3) *Motor wiring*: In case if the motor is connected in the reverse direction, the direction could be changed using the software

- 4) *Step calibration*: This is a very important step. Since the pitch of the lead screw varies, step calibration must be done to achieve the desired linear displacement

- 5) *Limit switches*: Hard limit switches can be enabled if required.

- 6) *Homing*: Homing is a method of finding absolute machine coordinates. But hard limit switches are mandatory for homing.

- 7) *Soft limits*: Soft limits switches can also be set if required. But Homing needs to be enabled before enabling soft limits.

Fig 7 shows the Window of various states like Units, Distance Mode, Work Offset, Active Plane which should be checked before starting the machine.

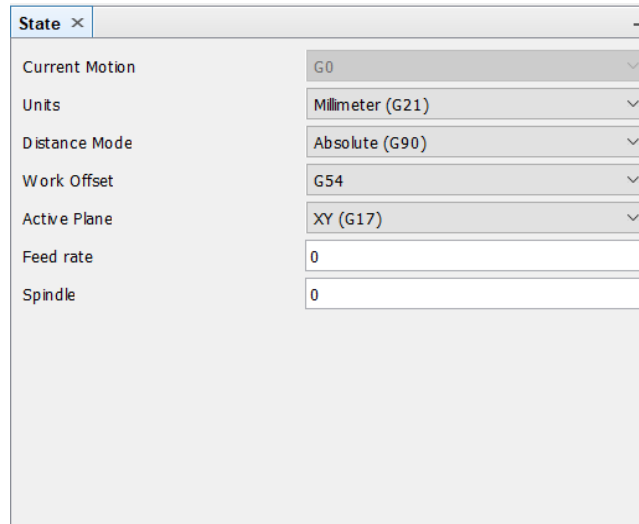


Fig. 7 State of units, mode, plane

Once these steps are completed the G-code can be imported into the UGS. To import G-code click on File and Open.

Once the G-code has been imported, the initial position can be set using jog mode. After setting the initial position, the

play button can be pressed to start the sketching. Fig 8 shows the UGS Window after all the initials has been done.

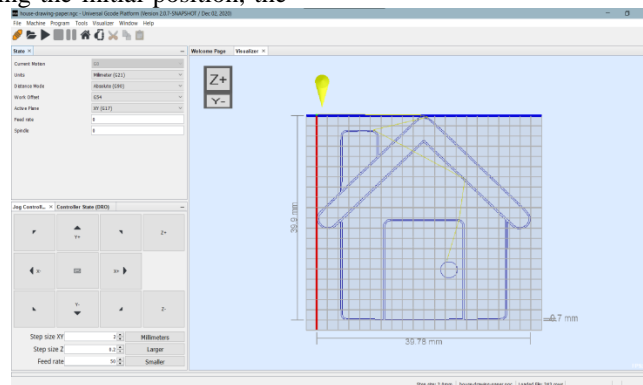


Fig. 8 UGS – Window after set up

Table 4 Comparison of work area, power consumption and cost

| S. No. | Website | Work Area (mm x mm) | Power Consumption | Price (In rupees) |
|--------|---|---------------------|-------------------|-------------------|
| 1. | Amazon - Axis draw Drawing Machine XY Plotter | 297 x 210 | 60W | 13000 |
| 2. | Alibaba - DIY LY Draw Bot Pen drawing robot machine | 297 x 210 | 24W | 15900 |
| 3. | Amazon - XY Plotter Pen Drawing Robot | 310 x 256 | 12 W | 35000 |
| 4. | Our product | 350 x 350 | 29W | 10000 |

VII. OUTPUT

Figures 9, 10, 11 are the sketches drawn using the machine

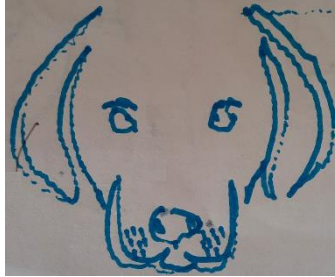


Fig. 9 Face of Dog



Fig. 10 House



Fig. 11 Lord Ganesh

VIII. Result and Discussion

Table 3 Cycle time

| Figure no. | Picture name | Height (mm) | Width (mm) | Feed rate (mm/min) | Time taken |
|------------|--------------|-------------|------------|--------------------|---------------|
| 9 | Face of Dog | 50 | 50 | 120 | 7 min 2 sec |
| 10 | House | 30 | 30 | 120 | 3 min 47 sec |
| 11 | Lord Ganesh | 60 | 45 | 120 | 13 min 25 sec |

Table 3 shows the cycle time for drawing each picture. As the size of the picture increases the cycle time will also increase accordingly. The waviness in the picture is due to the bend

in the y-axis lead screw and could be considerably eliminated by replacing the lead screw with a proper one. The cycle time is high because rapid traverse could be achieved as the torque

required is high. The cycle time can be reduced by upgrading the motor if required.

Table 4 shows the comparison of work area, power consumption and cost between the existing products and this product. Clearly the work area of the existing products is small compared to our machine. Despite the work area being small the price of these products is also high and as the work area increases, the price of the product shoots up. Though in this research work, the work area has been increased, power consumption has also been managed quite satisfactorily.

IX. CONCLUSION

With a unique design, the need of two motors has been replaced with one. Due to this unique design, a large work area with less torque requirement has been achieved. Although the cycle time is high, the objective of this project, which is to reduce the cost and the power consumption has been done successfully. This product has a high scope in places (such as poster making, spray painting with modifications in z-axis) where the accuracy and the cycle time is not a major issue.

X. REFERENCES

- [1] IS: 1893(Part 1): 2016 "Criteria for Earthquake Resistant Design of Structures", Part-1 General Provisions and Buildings, Fifth Revision, Bureau of Indian Standard, New Delhi, India.
- [2] ALACI, Z. KALITCHIN, M. KANDEVA, F. CIORNEI: Method and Device for the Study of Damping of Environmental Friendly Foam Type Materials. In *J Environ Prot Ecol* **21**(4), 1298 (2020)
- [3] SAP 2000 Manual (Version 14), "CSI Getting Started with SAP2000", Computers And Structures, Inc. Berkeley, USA.
- [4] JAGADALE S.H. AND SHELKE N.L., 2016, "Analysis of Various Thicknesses Of Shear Wall With Opening And Without Opening and Their Percentage Reinforcement", *International Journal of Research in Engineering, Science and Technologies*, Vol. 1, pp. 212-218.
- [5] BAGHERI B. et al., 2012, "Comparative Study of The Static and Dynamic Analysis of Multi-Storey Irregular Building", *International Scholarly and Scientific Research & Innovation*, World Academy of Science, Engineering and Technology Vol:6.
- [6] LAVANYA PRABHA, S., GOPALAKRISHNAN, M., NEELAMEGAM, M.: Development of high-strength nano-cementitious composites using copper slag, *ACI Materials Journal*, 2020, 117(4), pp. 37–46.
- [7] MOHAN, A , VIJAYAN, D.S. , REVATHY, J., PARTHIBAN, D., VARATHARAJAN, R.: Evaluation of the impact of thermal performance on various building bricks and blocks: A review, *Environmental Technology*

- and Innovation, 2021, 23, 101577(2021)
- [8] M. THOLKAPIYAN, A.MOHAN, VIJAYAN.D.S: A survey of recent studies on chlorophyll variation in Indian coastal waters, *IOP Conf. Series: Materials Science and Engineering* 993 (2020) 012041, 1-6.
- [9] AJAY HIRAPARA, DHANANJAY PATEL, 2017, "Analysis Of Light Weight Formers In Concrete Slabs Using Voids" *International Journal of Advance Engineering and Research Development (IJAERD)* Volume 4, Issue 4.
- [10] AWADH EWAYED AJEEL, TAMARA ADNAN QASEEM, SALWA RAHMAN RASHEED, 2018, "Structural behavior of voided reinforced concrete beams under combined moments" *Civil and Environmental Research Vol.10*, No:1.
- [11] GEE-CHEOL KIM, JOO-WON KANG, 2012, "Calculation of Voided Slabs Rigidities" *International Journal of Civil and Environmental Engineering Vol:6*, No:5.
- [12] JOO-HONG CHUNG, HYUNG-SUK JUNG, BAEK-IL BAE, CHANG-SIK CHOI AND HYUN-KI CHOI, 2018, "Two-Way Flexural Behavior of Donut-Type Voided Slabs" *International Journal of Concrete Structures and Materials*.
- [13] THAAR S. AL-GASHAM, ALI N. HILO, MANAL A. ALAWSI 2019, "Structural behavior of reinforced concrete one-way slabs voided by polystyrene balls" *Case Studies in Construction Materials*, Vol 11.
- [14] GOPALAKRISHNAN, R., MOHAN, A., SANKAR, L. P., & VIJAYAN, D. S. (2020). Characterisation On Toughness Property Of Self-Compacting Fibre Reinforced Concrete. In *Journal of Environmental Protection and Ecology* (Vol. 21, Issue 6, pp. 2153–2163).
- [15] LAVANYA PRABHA, S., DATTATREYA, J.K., NEELAMEGAM, M., SESHAGIRI RAO, M.V., Investigation of bolted RPC plate under direct tension, *Journal of Structural Engineering* (Madras), 2009, 36(5), pp. 333–341
- [16] MOHAN, A., TABISH HAYAT, M.: Characterization of mechanical properties by preferential supplant of cement with GGBS and silica fume in concrete, *Materials Today: Proceedings*, 2020, 43, pp. 1179–1189.
- [17] DHARMAR, S., GOPALAKRISHNAN, R., MOHAN, A.: Environmental effect of denitrification of structural glass by coating TiO₂, *Materials Today: Proceedings*, 2020, 45, pp. 6454–6458
- [18] CHEONG, K.H. AND LEE, S.C.: "Strength of Retempered Concrete", *ACI Materials J.* 90(3), 203–206 (1993)
- [19] KIRUTHIKA, C., LAVANYA PRABHA, S., NEELAMEGAM, M.: Different aspects of polyester polymer concrete for sustainable construction Materials Today: *Proceedings*, 2020, 43, pp. 1622–1625
- [20] PRABHA, S.L., SURENDAR, M., NEELAMEGAM, M.: Experimental investigation of eco-friendly mortar using industrial wastes, *Journal of Green Engineering*, 2019, 9(4), pp. 626–637