Design and Development of Mini CNC Machine for Small and Medium Scale Industries.

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Abstract— Increase in the rapid growth of technology significantly increased the usage and utilization of CNC systems in industries but at considerable expense. The idea of fabricating a low cost CNC milling machine came forward to reduce the cost and complexity in CNC systems. This discusses the development of a low cost CNC milling machine which is capable of 3-axis simultaneous interpolated operation. The lower cost is achieved by incorporating the features of a standard PC interface with micro-controller based CNC system in an Arduino based embedded system. The system also features an offline G-code parser and then interpreted on the micro-controller from a USB. Improved procedures are employed in the system to reduce computational overheads in controlling a 3-axis CNC machine, while avoiding any loss in overall system performance.

Index Terms— Arduino Uno micro-controller board, Flexible coupling, GRBL software, NEMA 17 Stepper motor, Screw rods, SC10UU bearings and T8 lead screw.

1 INTRODUCTION

In modern CNC systems, end to end component design is highly automated using computer aided design (CAD) and computer aided manufacturing (CAM) programs. The programs produce a computer file that is interpreted to extract the commands needed to operate a particular machine via post processor, and then loaded into the CNC machines for production. Since any particular component might require the use of number of different tools- drills, saws etc., modern machines often combine multiple tools into a single "cell". In other installations, a number of different machines are used with an external controller and human or robotic operators that move the component from machine to machine. In either case, the series of steps needed to produce any part is highly automated and produces a part that closely matches the original CAD design.

With the on-going development of technology and economy, new industrial requirements such as high precision, good quality, high production rates and low production costs are increasingly demanded. Most of such requirements , including dimensional accuracy, conformance to tolerances of finished products and production rate can be met with better machine tools. With the help of CNC technology, machine tools today are not limited to human capabilities and are able to make the ultra-precision products down to nano scales in a much fast manner.

The traditional design philosophy of machine tools is multi functionality and highest precision possible. However with the dramatic increase of industry varieties and the growing demand of miniature products, these general purpose machine tools are not efficient, either in terms of machine time or cost, in manufacturing products with special sizes and precision requirements. There are several advantages of using small machines to produce small sized objects. With a smaller machine size , space is saved. The energy required to operate the machine is reduced as well. It now requires less material and components to make the machine, hence bringing down the cost greatly. The weight of moving component also comes down so that during operation, the vibration and noise, as well as the pollution to the environment, are markedly reduced. As the machine becomes denser and lighter, it becomes more portable. The layout of the manufacturing plant can be more flexible. The productivity and manufacturing speed also increases due to possible faster operation.

2 RESEARCH METHOD

The first step in the operation of CNC machine was calibrating the tool, it was aimed to know whether the stepper motor and any other system were working according to the program that has been configured. Followed by setting the starting position of the spindle drill on the CNC machine using Universal G-code Sender software both automatically and manually by hand spinning. Spindle drill speed can be set up to a maximum speed of 12000 rpm (rotation per minute). After the CNC machine is calibrated, the design with the *G-code extension format was uploaded using Universal G- code Sender to Arduino Uno with serial communication. The microcontroller will read the data as a command and provide logic to the A4988 motor driver. The data received by the motor driver was used to drive 3 Nema 17 X, Y and Z axis stepper motors, so that a pattern will be formed on the object.

3 OBJECTIVE

• The idea behind fabrication of low cost CNC Milling Machine is to full fill the demand of CNC machines to small scale and medium scale industries with optimized low cost.
• The main objective of the project is to develop a prototype of 3-axis CNC milling machine using Arduino-based control system. It is presented with the following specifications

- Low cost
- Easily operable
- Easy interface
- Flexible
- Low power consumption.

4 METHODOLOGY

There are three phases in the CNC system development architecture, they are design and fabrication phase, control box design and wiring phase and software development and testing phase.Design and fabrication phase consists of different stages like mechanical design, 3D design of X, Y and Z axis using Solid works, 2D conversion of overall assembly and fabricating the parts.
Mainly the structure of the CNC system is created using aluminum profiles.The structural design of the machine including wiring connection and the software adopted to generate codes and C+ language. Finally, but not last is Development the base of the design that has been achieved.

5 DESIGN

Design of mini CNC milling machine is created by using solid works. The model consists of 3-axis where the parts for all the 3-axis is designed using solid works and finally assembled to get the exact model of mini CNC milling machine.

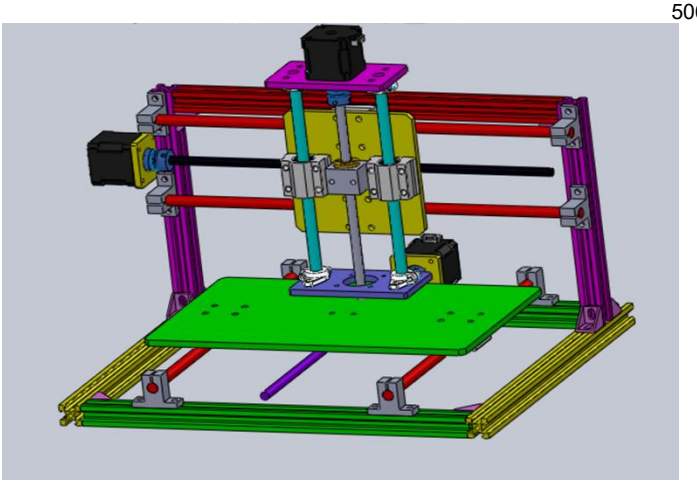

Fig 1 Design assembly of 3-axis mini CNC machine

6COMPONENTS

6.1 MECHANICAL COMPONENTS

20X20 aluminum profile: The Astro Industrial Duty Aluminum 2020H European Standard Anodized Profiles made of High Grade tempered Aluminum Alloy 6063 - T5. The dimensions are as per European Standard and the structural cross section thickness is minimum of 1.5 mm.Acrylic Components: Acrylic sheet is a material with unique physical properties and performance characteristics. It weighs half as much as the finest optical glass, yet is equal to it in clarity and is up to 17 times more impact resistant. Cast acrylic sheet is made in over 250 colors, in thicknesses from .030" to 4.25' and can transmit ultraviolet light or filter it out, as required.Flexible Coupling:This flexible type motor coupling can connect your driving shaft with the driven shaft while it is very efficient in eliminating any misalignment to the possible extent. Minimum backlash is another great advantage of this Flexible Coupling OD:20mm x L:25mm Bore: 5x8mm. Rod: These are the smooth rods used for 3D printer kits. They're made of chrome-plated high-carbon steel and provide smooth, consistent motion when paired with linear bearings. These smooth rods are manufactured for use in 3D printers, Hydraulics as well as in CNC / linear motion applications, are stand up to frequent use without a problem. SK10 end support: SK10 10mm linear bearing rail support XYZ Shaft End Support is used mainly to support Hard Chrome Plated Rods in CNC Routers, CNC Engraving machines, 3D Printing Machines, Cashew Nut Shelling Machines, Pick and Drop Machines, Robots for Industrial Automation. SHF10 end support: The Horizontal Shaft Support – SHF10 for 3D Printers is used to fix Φ10mm optical axis.

6.2 ELECTRONIC COMPONENTS

Arduino Uno micro-controller:Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It is intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments.Stepper motor driver A4988 can also be interfaced with Arduino through CNC Sheild as shown in (fig8)

NEMA 17 Stepper motor: This NEMA 17 5.5 kg cm Stepper Motor can provide 5.5 kg-cm of torque at 1.5 AMPERE current per phase(fig9). Switched mode power supply: A switched-mode power supply (SMPS) is an electronic circuit that converts power using switching devices that are turned on and off at high frequencies, and storage components such as inductors or capacitors to supply power when the switching device is in its non-conduction state (fig10).

Fig 8Arduino microcontroller board

Fig 9 A4988 can also be interfaced with Arduino through CNC Shield

Fig 2 Aluminum profile

Fig 3 Acrylic components

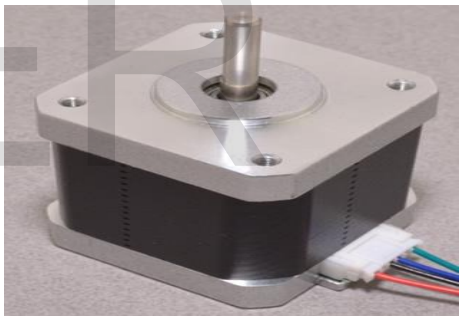

Fig 10 NEMA 17 Stepper motor

Fig 4 Flexible coupling

Fig 5 Rod

Fig 6 SHF10Fig 7 SK10

Fig 11 Switched mode power supply

Power Supply:12V SMPS (Switch mode Power Supply) is used for stepper motor driver. 2V SMPS is used to power the microcontroller board (Arduino Uno3). The microcontroller is flashed with GCODE interpreter firmware written in optimized 'C' language.

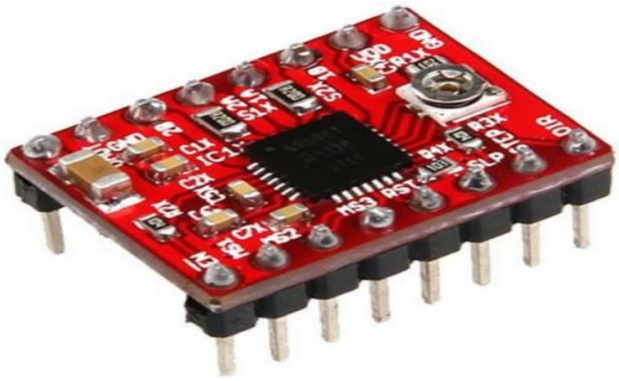

Fig 12 Stepper motor driver

Stepper motor drivers: It's kind of driver that receive steps signal from microcontroller and convert it into voltage electrical signals that turn the motor. This driver is called Easy Driver V4.5 as shown in Figure.4 that required 6V – 30V supply to power the motor which can power any type of step motors.

7SOFTWARE DEVELOPMENT

The CNC machine uses GRBL software for motion control of the axis. GRBL converts any design given or G-code, where certain commands are used that stepper motor driver will easily understand.

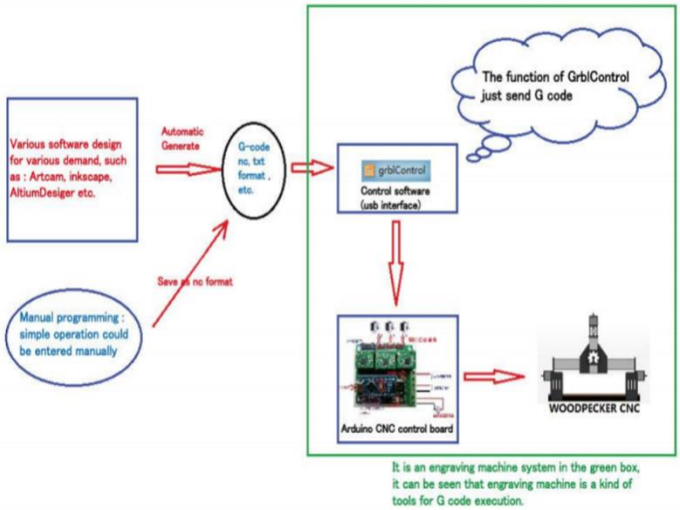

Fig 13 Block representation of GRBL software interface with CNC & Computer.

Above block diagram shows the interface software with CNC machine & how CNC works from the G-Codes & M-codes.

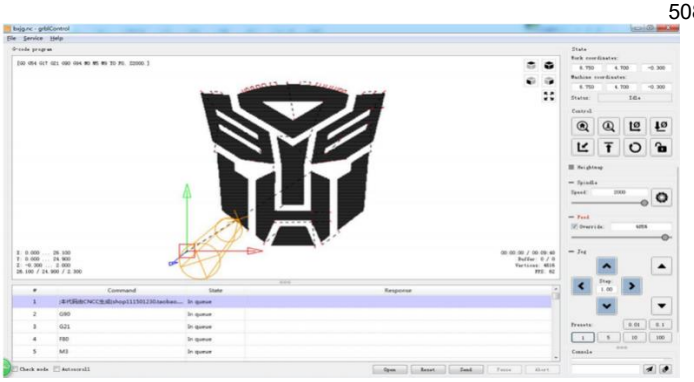

Fig 14 GRBL Software

8CALCULATIONS

Screw rod calculations:

Helix Angle :α=tan^(-1)〖l/πD〗
Where l:lead in mm
D:pitch Dia i.e D=given dia-P/2
P:pitch in mm

Torque:T=FD/2 ((μπD+l cosα)/(πD cos〖α-μl〗))
Where μ:coeffecient of friction
F:force / load carrying capacity

Problem:
Given dia=8mm
Lead=8mm
T=280Nmm

α=tan^(-1)〖8/(π×7)〗 =19.99≈20

280= (F×7)/2 ((0.07π7+8 cos20)/(π7 cos20-0.07×8))

F=177.58N
F=18.10kg
But practical load carrying capacity, F=9.05kg.

9ACKNOWLEDGEMENT

The satisfaction and excitement that accompany the successful completion of any task would be incomplete without the mention of the people who made it possible, whose consistent guidance and encouragement crowned our efforts with success.

We consider ourselves proud to be a part of REVA University family, the institution which stood by our way in all our endeavors.

We express our sincere thanks to Dr. K S Narayanaswamy Director and Professor, School of Mechanical Engineering, for his support and encouragement.

We express profound thanks to Prof. Somesh G H, Assistant

Professor, School of Mechanical Engineering, for his valuable support & for his inspiration, guidance, constant supervision, direction and discussions in successful completion of this project.

We are thankful to the project coordinators, teaching and non-teaching staff members of School of Mechanical Engineering for their co-operation extended towards this work.

10 CONCLUSION

From this project, we learned the principle of CNC machine. We gained better understanding in the modes of operation of CNC machine. There is various type of modern CNC machines use

in industry. Automatic generation of different preparatory (G codes) and miscellaneous function (M codes) is used in CNC part programming for completing a successful CNC program. Specifically, CNC milling machine works with a computer numerical control that writes and read G-code instructions to drive machine tool to fabricate components with a proper material removal rate. G-codes are commands for CNC machines to follow so that they can operate on their own without human control. Zero set up is very important step to obtain an accurate geometry of the work piece. From this project, we would conclude that it gives an idea for the beginners to understand on how the CNC machines work virtually.

- The mini CNC milling machine is brought out by designing the required parts using Solid Works 2016 edition.
- It is further assembled with the brought out parts. The final assembly of mini CNC milling machine consists of many sub solid assemblies.
- By preparing the bill of materials we will able to know the required parts and materials which can be used in this prototype, the parts are manufactured and brought out to virtual assembly.
- Assembly stage consists of structure of the model, wiring, control box design, software development, testing and study of G-codes and M-codes.

In this project we would conclude that it can be run without human control and it can be designed at low cost for medium and small scale industries.

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