ISSN : 2455-9679
SJIF Impact Factor : 6.008

IJRTSM
INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

"DESIGN & FABRICATION OF MINI CNC MILLING MACHINE"

Tilak Milind Khachane [1], Vedant Prakash Mestry [2], Mr. Pankaj Shirsath [3], Dr. Yogesh Agrawal [4], Mr. Yogeshkumar Falak [5]

[1-5] *Department of Mechanical Engineering, Sandip Institute of Technology and Research Centre, Nashik, India*

ABSTRACT

Computer Numerical Control (CNC) machines have transformed modern manufacturing by enhancing precision, automation, and efficiency. However, conventional CNC machines are expensive, bulky, and complex, making them less accessible for students, hobbyists, and small-scale workshops. This project focuses on the design and fabrication of a Mini CNC Machine, providing a compact and cost-effective solution for applications such as engraving, PCB milling, and small-scale prototyping. The fabrication process involves laser cutting, assembly, electronic integration, and calibration to minimize backlash and ensure precise operation. Performance testing is conducted by executing tool paths to evaluate positioning accuracy, repeatability, and surface finish quality. The results demonstrate that the mini-CNC machine achieves high precision, making it an affordable and efficient alternative to commercial systems. This project highlights the feasibility of developing a low-cost, portable, and user-friendly CNC machine. Future improvements may include an increased work area, higher spindle power, and enhanced automation features, further expanding its applications in education and small-scale manufacturing.

Key Words: *Arduino Uno, micro-controller board, Flexible coupling, GRBL software, NEMA 23 Stepper motor, Hot Rolled (HR) steel sheets, cylindrical linear guide rod, 8.8 grade hex bolts,Iead Screw.*

I. INTRODUCTION

CNC (Computer Numerical Control) milling machines have revolutionized the manufacturing industry by providing high precision, automation, and efficiency in machining operations. These machines are widely used in industries such as automotive, aerospace, and electronics for cutting, drilling, and shaping various materials with minimal human intervention. CNC milling machines automate the machining process using programmed instructions, significantly improving productivity, accuracy, and repeatability.

Despite their advantages, conventional CNC milling machines are often large, expensive, and complex, making them inaccessible for small-scale workshops, educational institutions, and hobbyists. Many students and small manufacturers struggle to afford high-end CNC machines, limiting their ability to learn CNC programming and manufacturing techniques. There is a growing demand for cost-effective, compact, and user-friendly CNC machines that can perform essential milling operations without the high costs associated with industrial-grade machines.

This project aims to design and fabricate a mini CNC milling machine that offers an affordable and efficient solution for small-scale machining applications. The machine will be capable of performing precise milling operations on soft materials such as wood, plastic, and aluminium. The primary goal is to provide a low-cost alternative to industrial CNC machines while maintaining essential functionality and accuracy

By fabricating a mini CNC milling machine, this project aims to Make CNC technology more accessible to students, hobbyists, and small manufacturers. Provide an affordable solution for precision machining and prototyping. Improve efficiency and accuracy in small-scale machining operations. Enhance learning opportunities in CNC programming and

ISSN : 2455-9679
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automation.

The development of a low-cost, compact, and efficient mini CNC milling machine has the potential to bridge the gap between expensive industrial CNC machines and manual machining tools. This project will provide a practical and affordable solution for students, small businesses, and hobbyists interested in CNC machining. By successfully designing and fabricating this machine, the project will contribute to the growing demand for accessible CNC technology in education and small-scale production.

II. Literature Review

Mr Prashil N Patel, Mr Shreyas D Pavagadhi, Shailee G Acharya This paper describes about the Design and Development of portable 3-Axis CNC router machine based on microcontroller which was used to reduce cost and complexity of the bulky sized engraving machine.

K Bangse, A Wibolo, I Kadek Ervan Hadi Wiryanta The purpose of this research was to designing and fabrication a Computer Numerical Control (CNC) based router machine for wood engraving machine.

Eko Prianto, Herlambang Sigit Pramono, Amelia Fauziah Husna, Ilmawan Mustaqim, Roni Kristianto This study examines the theoretical and technical processes involved in the design, construction, assembly, and testing of electromechanical subsystems in order to create a low-cost, high-precision, three-axis mini-CNC router machine that is durable, safe, and has an easy-to-use interface.

Massachusetts Institute of Technology, 2000 A preliminary design of a low-cost, three-axis, computer numerically controlled (CNC) router was completed with the goal of bringing the advantages of numerically controlled machine tools to the woodshop. To reduce cost, a novel single rail design was employed. The number of custom parts was kept to a minimum and, where necessary, every effort was made to minimize manufacturing cost.

Mudawi I Adam, Amr Elhussein, Awab Khogali. This paper presents a simple design of a 3 axis CNC routing Machine. The machine is driven by stepper motors utilizing lead screws and guides manufactured in a local workshop using conventional manufacturing techniques.

III. Objectives

• 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.

IV. 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

ISSN : 2455-9679
SJIF Impact Factor : 6.008

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 17X, Y and Z axis stepper motors, so that a pattern will be formed on the object.

V. 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.

5.1 DESIGN

A detailed 3D model of the Mini CNC Milling Machine was created using Fusion 360 to visualize and refine the design before fabrication. The CAD model included all critical components, such as the machine frame, linear rails, lead screws, spindle motor mount, and motion transmission system. Various iterations of the CAD model were evaluated to enhance weight distribution, stability, and overall efficiency.
The CAD modeling phase also allowed for precise calculations regarding material usage, placement of fasteners, and weight distribution to prevent excessive vibrations. Various constraints were tested, including space optimization, accessibility for component integration, and minimizing deflection during machining operations.

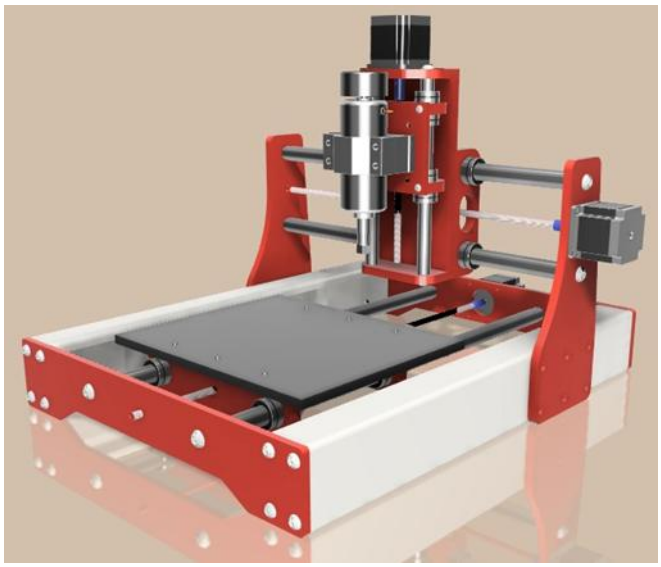

Fig.1 Proposed Design

5.2 COMPONENTS

5.2.1 MECHANICAL COMPONENTS

For this project, Hot Rolled (HR) steel sheets were chosen as the primary frame material. The selection was based on multiple factors including strength, availability, cost-effectiveness, and fabrication suitabilityThe HR steel sheets used ranged in thickness from 3 mm to 16 mm, depending on the load-bearing requirements of specific components. Critical sections such as the base and vertical columns were fabricated using thicker sheets (12 mm to 16 mm) to withstand high stress and vibration, while less critical parts were made from thinner 3 mm to 6 mm sheets to minimize weight and material cost. It is shown in (fig2), cylindrical linear guide rods of 20 mm and 16 mm diameter were used, along with LM20UU and LM16UU linear ball bearings. It is shown in (fig3), A lead screw of 8 mm diameter with 4 starts and a 2

ISSN : 2455-9679
SJIF Impact Factor : 6.008

mm pitch per start has been used along each axis to drive the linear movement. It is shown in (fig4), 8.8 grade hex bolts and nuts were used throughout the assembly of the mini CNC milling machine. The "8.8" designation refers to the bolt's strength class—the first number (8) indicates the ultimate tensile strength of 800 MPa, and the second number (.8) means that the bolt can withstand 80% of that value as yield strength, which is 640 MPa. This makes 8.8 bolts suitable for load-bearing connections, especially where vibrations and mechanical stresses are involved. It is shown in (fig5)

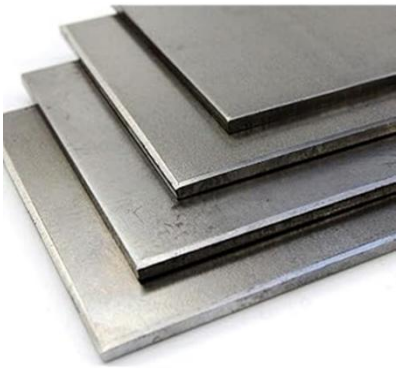

Fig 2 Hot Rolled (HR) steel sheets

Fig 3 cylindrical linear guide rod

Fig 4 lead screw

Fig 5. 8.8 grade hex bolts

5.2.2 ELECTRONIC COMPONENTS

Arduino Uno Micro-Controller:- Arduinois 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 (fig6)

Fig 6 Arduino Uno Micro-Controller board

ISSN : 2455-9679
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NEMA 23 Stepper Motor :- NEMA 23 stepper motor is selected due to its ideal balance of torque, size, and cost-effectiveness. NEMA 23 motors are widely used in CNC applications as they provide higher torque compared to smaller variants like NEMA 17, making them suitable for driving heavy loads and maintaining positional accuracy in all three axis (X, Y, and Z) (fig 7).

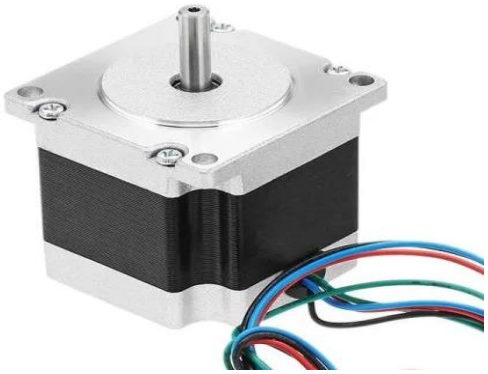

Fig 7 NEMA 23 Stepper Motor

Power Supply :- A 24V 10A DC power supply was selected. This provides a total output of 240W, which is sufficient to run the stepper motors, TB6600 drivers, and control electronics simultaneously. The 24V output is ideal for CNC applications, as it strikes a good balance between speed, torque, and heat generation in the motors and drivers (fig 8).

Fig 8 Power Supply

Microcontroller :- A GRBL-based microcontroller was selected for open-source compatibility and cost-effectiveness. It interprets G-code and controls motor movements with precision. The microcontroller was programmed to handle complex machining tasks with optimized motion planning algorithms. (fig 9).

Fig 9 A GRBL-based microcontroller

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5.3 SOFTWARE DEVELOPMENT

GRBL is an open-source software that translates G-code commands into motor movements. It was implemented to control the stepper motors, ensuring accurate positioning of the CNC machine. UGS was used as the primary interface to send G-code commands to the CNC machine. It provides real-time visualization, machine control, and error feedback.

VI. 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 Fusion 360.
- 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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