**THREE AXIS CNC MACHINE**

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**ABSTRACT**

A Three Axis CNC (Computer Numerical Control) Machine is a fundamental tool in the modern manufacturing and fabrication industry, offering a high degree of automation, precision, and repeatability. This project presents the design, construction, and operational principles of a three-axis CNC machine, focusing on its mechanical structure, electronic control systems, software integration, and real-world applications. The machine operates on three independent axes—X, Y, and Z—enabling it to manipulate a tool or workpiece in a three-dimensional space

The primary objective of this project is to develop a cost-effective, reliable, and versatile CNC system that can be employed in educational institutions, small manufacturing units, and research labs. The project begins with the mechanical design, which involves constructing a rigid frame using materials such as aluminum extrusions or mild steel to ensure durability and stability during operation.

**Keywords:** CNC Machine, automation, precision, cost-effective, reliable .

**INTRODUCTION**

The development of NC machine tools has continued for over fifty years in the manufacturing industry. Currently, the technology is reasonably mature and different companies have developed their unique strengths on different products. Europe is the largest machine tool manufacturer in the world.

1. **METHODOLOGY**

This section outlines the systematic approach used in the development of the Three-Axis CNC machine, from concept to execution. It includes the methodology framework, development phases, and the tools and technologies applied.

**2.1 Methodology Framework**

The development follows a waterfall-based engineering methodology, which progresses through distinct, sequential phases: requirement analysis, system design, implementation, testing, and deployment. This ensures clarity, proper documentation, and efficient resource allocation.

**2.2 Development Phases**

In this initial phase, all functional and non-functional requirements of the CNC machine were identified:

* Functional Requirements: 3-axis movement (X, Y, Z)
* G-code interpretation and execution
* User interface for operation and control
* Non-Functional Requirements: Cost-effectiveness
* Ease of use and maintenance
* Portability (compact desktop design)

User needs, technical specifications, and environmental constraints were considered to define the system goals.

**WORKING PRINCIPLE**

The Three-Axis CNC machine works on the principle of automated tool movement based on G-code instructions. The process is as follows:

1. Design Creation: A part is designed in CAD software and converted into toolpaths using CAM.
2. G-code Generation: CAM software exports the toolpath as G-code.
3. G-code Execution: The user sends this G-code to the CNC machine via a G-code sender.
4. Motion Control: The Arduino running GRBL interprets the G-code and sends step/direction signals to stepper drivers.
5. Material Removal: The spindle removes material as per movement along X, Y, and Z axes.

Each axis is independently controlled, and combined motion enables precise 2D/2.5D shapes.



**Figure 1:** A simplified block diagram representation of the system

1. **RESULTS AND DISCUSSION**

The CNC machine was tested through multiple phases, from dry runs to actual material machining. The results demonstrate the effectiveness, reliability, and precision of the system.

**A. Functional Validation**

The machine successfully executed multiple G-code programs for engraving, drilling, and 2.5D milling tasks.

All three axes responded correctly to movement commands with proper homing and limit detection.

The spindle operated reliably, maintaining consistent RPM under moderate load conditions.

**B. Accuracy and Repeatability**

Positional accuracy: ±0.2 mm (within acceptable tolerance for non-industrial use).

Repeatability: Axes returned to programmed positions consistently.

Machined parts closely matched CAD models in dimension and geometry.

**C. Materials Processed**

Successfully machined: Wood (MDF, plywood) – Clean cuts, minimal edge chipping

Acrylic – Precise engraving and shallow cuts

Aluminum (soft grades) – Light milling at low feed rates

**D. Operational Performance**

User interface (Universal G-code Sender) was easy to operate with real-time control.

GRBL firmware handled G-code parsing and motion planning effectively.

System was stable during extended operations with minimal heating issues .

1. **CONCLUSION**

In this research project, a medium-sized CNC router machine specifically designed for wood engraving applications was successfully developed and tested. The machine was built using a combination of cost-effective materials and components, with a primary focus on maintaining reliable performance and operational accuracy. The goal was to produce a CNC router that would be affordable for small-scale workshops or educational environments while still delivering results comparable to more expensive commercial units.

The machine is based on a three-axis configuration (X, Y, and Z), allowing it to perform detailed and complex movements necessary for high-precision engraving tasks. Mechanically, the machine utilized aluminum extrusions for the frame, stepper motors for axis control, and linear motion components like lead screws and guide rails to achieve smooth and accurate movements. These materials were selected not only for their affordability but also for their strength and resistance to wear over time.

The control system is built around the Mach3 software platform, a widely used CNC control application that offers a user-friendly interface and powerful functionality. Mach3 was responsible for interpreting the G-code and sending precise signals to the motor drivers and spindle. This software integration enabled efficient machine operation and real-time control, proving to be an excellent choice for this type of machine. All the main points of the research work are written in this section. Ensure that abstract and conclusion should not same. Graph and tables should not use in conclusion.

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