B.TECH. PROJECT REPORT

On

In House Design and Fabrication of Three Axis CNC Milling Machine and Application

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DISCIPLINE OF MECHANICAL ENGINEERING

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In House Design and Fabrication of Three Axis CNC Milling Machine and Application

A PROJECT REPORT

Submitted in partial fulfilment of the
Requirements for the award of the degrees

Of
BACHELOR OF TECHNOLOGY
in
MECHANICAL ENGINEERING

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CANDIDATE'S DECLARATION

We hereby declare that the project entitled **"In House Design and Fabrication of Three Axis CNC Milling Machine and Application"** submitted in partial fulfilment for the award of the degree of Bachelor of Technology in 'MECHANICAL ENGINEERING' completed under the supervision of **Dr. Yuvraj K Madhukar (Assistant Professor),** IIT Indore is an authentic work.

Further, we declare that we have not submitted this work for the award of any other degree elsewhere.

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CERTIFICATE by BTP Guide

It is certified that the above statement made by the students is correct to the best of my/our knowledge.

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Preface

This report on "In House Design and Fabrication of Three Axis CNC Milling Machine and Application" is prepared under the guidance of Dr. Yuvraj Kumar Madhukar.

Through this report we have tried to give detailed information on design, fabrication and analysis of three axis CNC milling machine. The report contains illustrated pictures of developed setup and various 3D objects manufactured with the help of the three axis CNC milling machine.

We have tried to the best of our abilities and knowledge to explain the content in a lucid manner.

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Abstract

CNC machine has wide applications in the field of manufacturing, since it is used for the manufacturing of complex parts in minimum time and with great accuracy. It uses micro stepping motor drive and Mach3 control board to produce electrical signal output in order to run the stepper motors by which all 3- axis can move simultaneously. The sample part needs to be machined with required G-code which is given by using SolidWorks Cam module which is then fed to the Mach 3 milling software. With the help of G-code we controlled various machining parameters like feed rate, cutting velocity, depth of cut etc. The preliminary set of experiments were conducted to achieve the optimization of supply voltage, current, feed rate, cutting velocity, depth of cut etc.

We designed, implemented and tested the CNC setup for the production of various complex contours. It is used for manufacturing of complex components like propeller, flywheel etc. on the plywood and metal with the help of rotating milling cutter tool and it is controlled by a pc controller.

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CHAPTER 1. INTRODUCTION

Now a days many machines used in industrial world are working on a principle of CNC machine. It is the automation of machine tools that are operated by a computer-controlled programs to perform a desired product shape. In this kind of machine a user can decide various cutting parameters of machine like feed, depth of cut etc. depending on the job to be machined, with the help of controller which controls the axial movements of the three axes. This machine has various applications of different kind, since it is easy to use, adapt and apply. Although such kind of machine were developed initially for automation in industries and control of machine tools. A Controller takes codes from a computer and converts the code with the help of software into short electrical pulses to drive the motors. The signal from the computer is then used to control motors.

The main part of the system is a Mach3 control board which converts G code into electrical signals to be fed to the driver. The main advantage is that whole system works offline, and hence whole system is very efficient and cost effective, making it cheap for small size workshops and individuals.

Figure 1: CNC milling machine setup

1.1 MOTIVATION

- The motivation comes from the idea where any user can implement, control the working of CNC milling machine with his own requirements.
- This kind of machine would facilitate manufacturing complex geometric shapes with less material wastage compared to traditional machining processes.
- We aimed at developing a small sized CNC setup which is easy to operate and cost effective so that it can be used by small industries in manufacturing various metallic objects.
- This opportunity to create a physical machine will serve as a way to gain hands on experience with working on different materials, making use of different tools to create different component parts.

CHAPTER 2. DESIGN AND DEVELOPMENT OF EXPERIMENTAL SETUP

2.1 Preparation of CNC setup:

The CNC machine is designed and fabricated in different phases:

2.1.1 Construction of mechanical structure:

The main component of machining tool is the machine setup. Setup combines all parts of a machine into one whole system. The CNC setup is important to the effectiveness and efficiency of the machine because dynamic strength of the machine and its damping capacity is directly derived from it. Precisely designed structure can withstand high vibrations and large cutting forces. The maximum movements of X, Y and Z axis is the lengths of respective axes from initial (start) point. The X axis moves left-right along guideways while Y axis move front-back and Z axis travels along vertical guideways. The machine encompasses less amount of material hence it is very cost effective and economic to build which is constructed to cut wood, aluminum and soft materials.

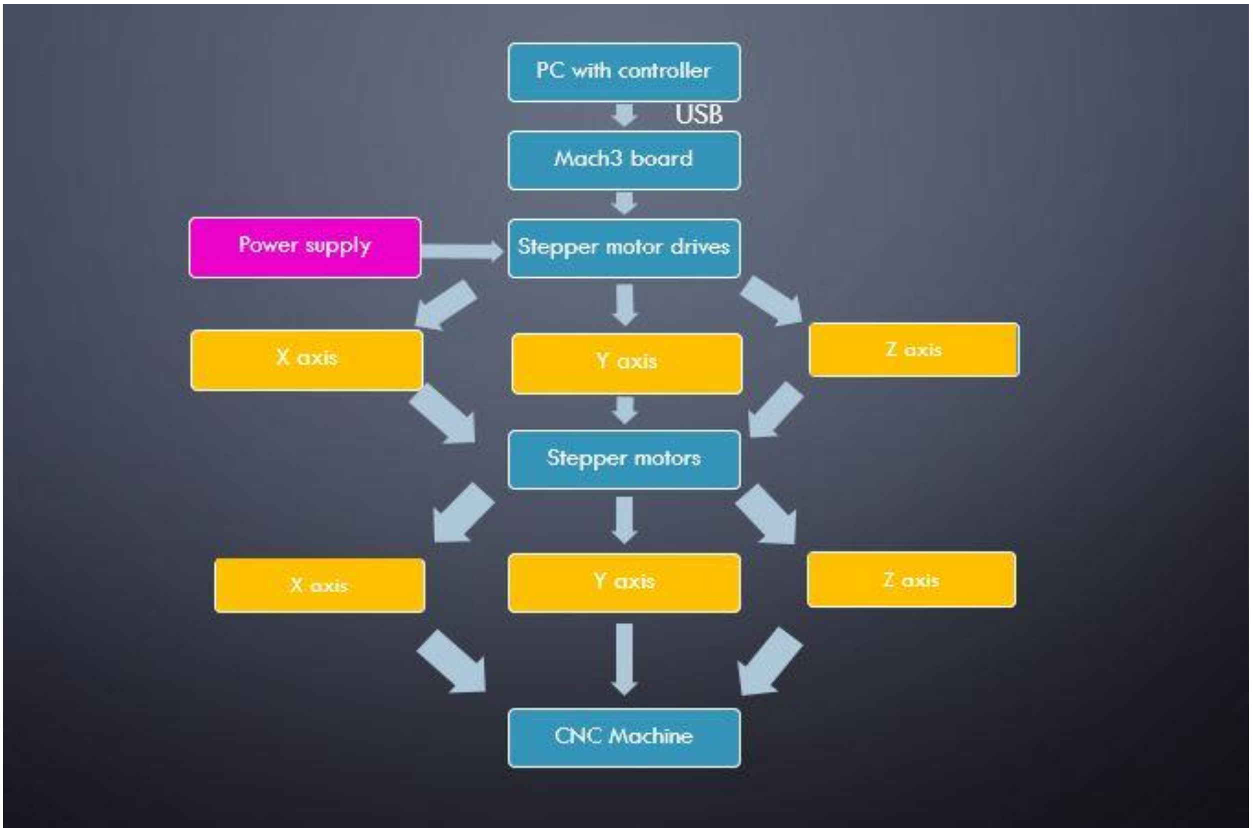

Figure 2: CNC system with block diagram

2.1.2 Connection and Assembly of electronic accessories:

A Stepper motor drive (Rhino drive) is connected to motor bearing which is ultimately connected with lead screw which converts rotational motion into linear movement of axis. Control Board: Mach3 control board is selected as a controller in this project, which is used to control the motion. The Mach3 is a microcontroller board which has 12 digital input/output pins with limit switch access and emergency stop input. It also incorporates spindle control (relay mode) and anti-jamming design with high reliability. Mach3 consists of everything needed to control and support the CNC. We just need to connect it to computer with USB and a DC power source is used to provide the required power.

2.1.3 PC controller and evaluating system:

Mechanical structure gets necessary electrical signals from drive system which ultimately results in desired actuation of motors. Software system controls the electronic system with the help of G-code and generates controls for mechanical system. The CNC machine uses Mach3 milling software for the control of axial movement. Mach3 basically converts any given G-code, to generate certain signals which are easily read by stepper motor drive. Mach3 controller is very user friendly software which supplies the necessary G-code to the machine tool and provides effective control over the machine with the help of Rhino driver.

2.2 Fabrication of individual components:

Required raw materials and other control system components like stepper motors, micro-controller etc. were purchased. The individual components of the assembly post designing were manufactured using the traditional machining processes like Milling, Grinding and Welding etc. Dimensional tolerances were provided to account for errors during machining.

The following table shows the individual components and sub-assemblies:

1. Stepper Motor:

Figure 3

2. Stepper Motor Driver:

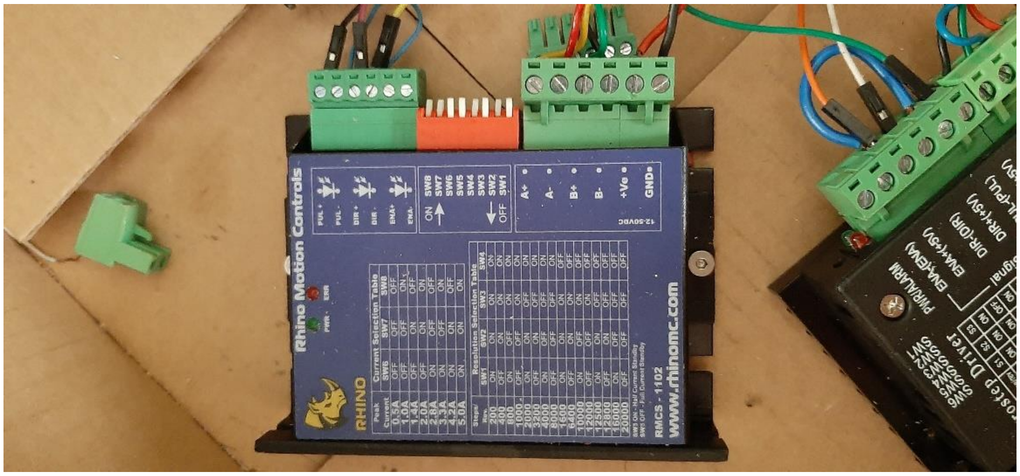

Figure 4

3. Micro-controller:

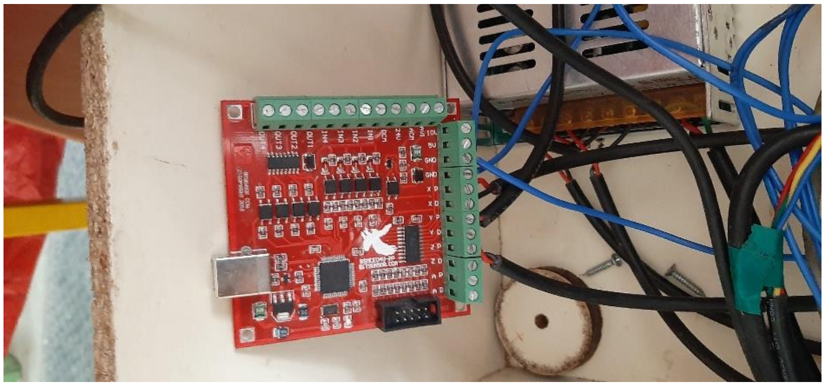

Figure 5

4. Bread Board:

Figure 6

5. Milling tool holder:

Figure 7

6. Power Supply:

Figure 8

7. Cast Iron Base:

Figure 9

8. Stainless Steel Guideways:

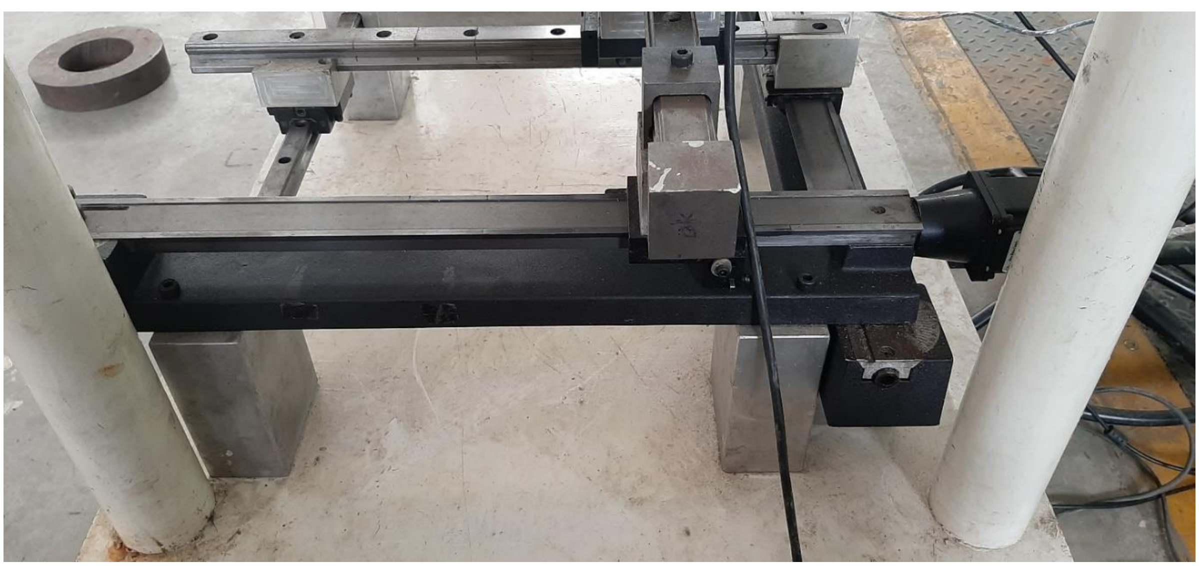

Figure 10

9. Linear Bearing:

Figure 11

10. Tray to collect chips:

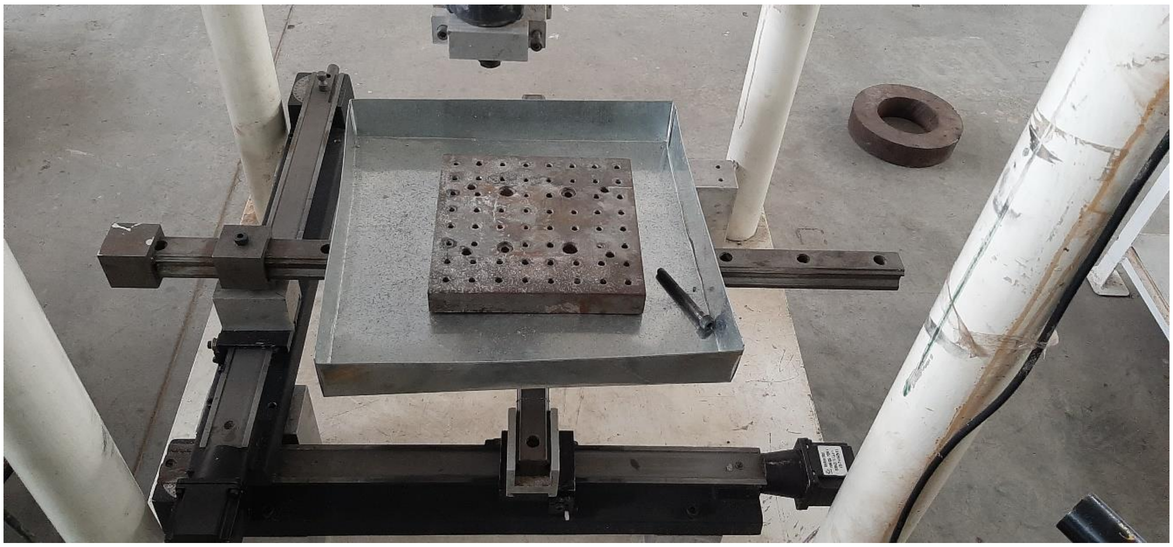

Figure 12

Fabricated components were used to get X, Y and Z sub-assemblies and the sub-assemblies were further assembled to get the final setup. After the assembly, all the three coordinate axes were actuated using stepper motors. Stepper motors were controlled using microcontroller and encoders, which consists the control system.

Chapter 3. Results and Discussions

3.1 Setup preparation:

A robust setup of CNC consists of a cast iron base to withstand the forces and vibration of machine. The three axes are made of aluminum casting. The tool holder is a milling motor with a collet. The solid cast iron setup gives the machine its strength to withstand vibrations and forces. The axes guideways are made of stainless steel which provide smooth motion. Tool fixture system consists of cast iron slab mounted over a linear bearing which holds the work piece.

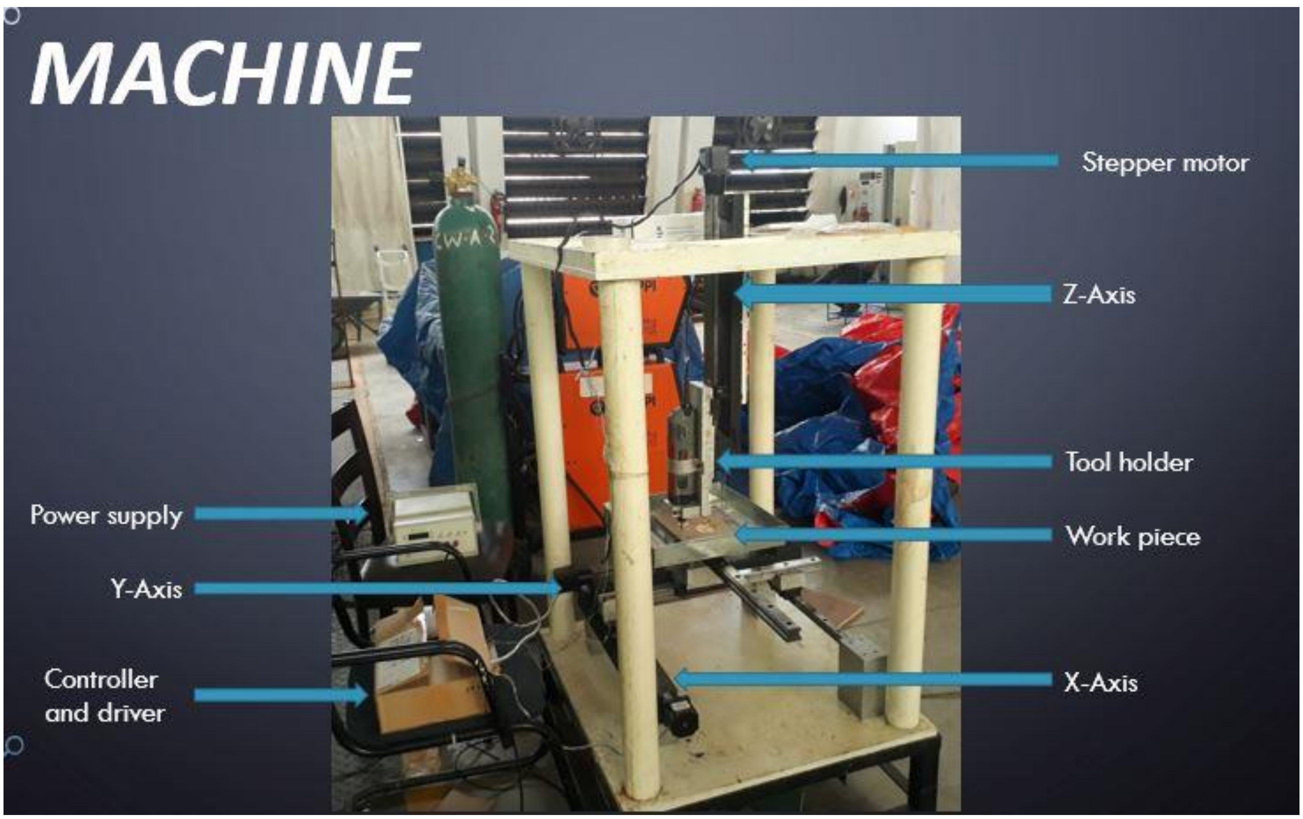

Figure 13: Front view of the Setup

After the hardware and software of the system were designed, it is the time to implement and test the design to check their performance and their reliability.

3.2 Effects of Individual Parameters:

The optimal current rating of a stepper motor is 2-5 Amp and Voltage of 3-5 V. The current and voltage rating of rhino drive is 2-5A and 15-50V resp. It was observed that a large voltage caused premature heating of motor so we used optimum voltage of 16V and current of 2A. A DC power supply was used to supply this optimal current and voltage at a continuous rate. The maximum current rating of Rhino drivers is 5A so a current rating of 2A is in its specification range. The rhino drivers supplied the motors with optimal current and voltage.

Motor Specifications:

- Maximum torque-10.2 kg-cm
- Step angle- 1.8 Degree
- Rated Voltage: 3.3VDC
- Phase current: 2Amp

Tool Specifications (Flat End Carbide Milling Cutter):

- Cutting and shank diameter- 3mm
- Flute length-25mm
- Shoulder length-20mm
- Overall length-50mm
- No of flutes- 2

Simple G-Code example-

```
G17 G20 G90 G94 G54
G0 Z0.25
X-0.5 Y0.
Z0.1
G01 Z0. F5.
G02 X0. Y0.5 I0.5 J0. F2.5
X0.5 Y0. I0. J-0.5
X0. Y-0.5 I-0.5 J0.
X-0.5 Y0. I0. J0.5
G01 Z0.1 F5.
G00 X0. Y0. Z0.25
```

This simple program will draw a 1" diameter circle about the origin. Use this program to test your CNC machine and confirm your axis directions are set correctly.

3.3 Design of basic geometries:

A solid rectangular slab of cast iron is used as a base to support the wooden block of dimension 15*15cm and thickness 2cm.

Figure 14: Simple Geometry

Optimal Cutting Parameters:

- Max. depth of cut- 1mm
- Min depth of cut- 0.5mm
- XY federate- 133.33mm/min
- Z federate - 100mm/min
- Spindle speed- 3000rpm

3.4 Printing IITI on Plywood:

IITI logo of total thickness 1cm was inscribed on plywood

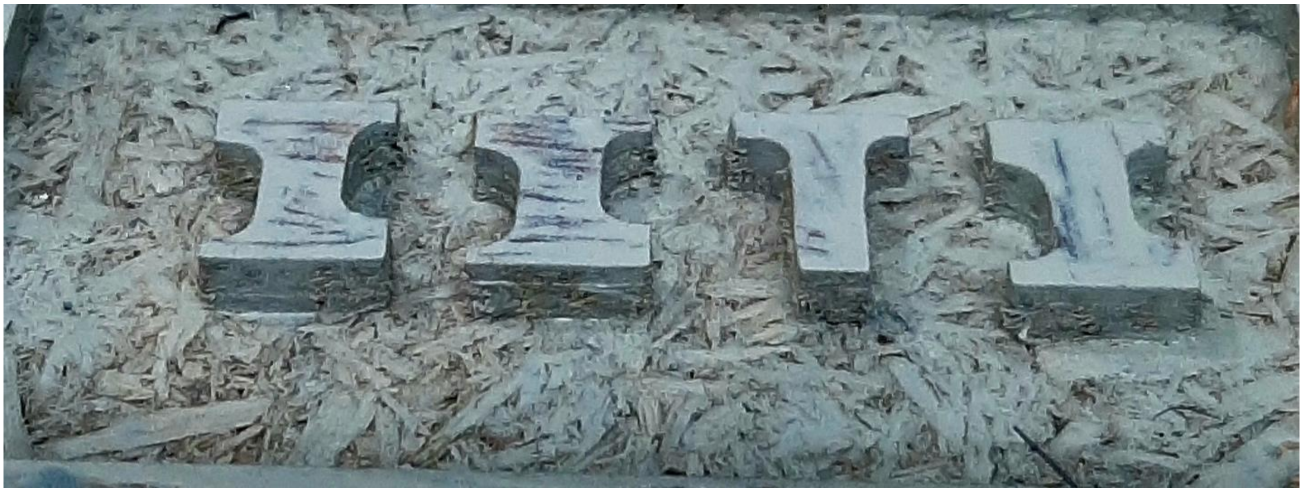

Figure 15: IITI inscription on wood

Effect of cutting parameters –

It was observed that a large value of depth of cut and feed rate caused heating of cutting tool which may cause a large wear of cutting tool so it was necessary to select the optimal combination of feed rate and depth of cut so minimize the heating and subsequently the wear rate of tool. Total thickness is 1cm and dimensions are 7*4cm**.**

Optimal Cutting Parameters-

- Max. depth of cut- 1mm
- Min depth of cut- 0.5mm
- XY federate- 150mm/min
- Z federate - 100mm/min
- Spindle speed- 3000rpm

3.5 Design of simple propeller on wood –

A wooden slab of dimension 15*10cm and thickness 2cm is used a blank material to undergo machining. Since wood is used in this case we can increase federate and depth of cut slightly. Total thickness is 6mm.

Figure 16: Design of a simple propeller

Cutting Parameters-

- Max. depth of cut- 1.5mm
- Min depth of cut- 0.5mm
- XY federate- 100mm/min
- Z federate - 100mm/min
- Spindle speed- 3000rpm

3.6 Design of 3 stage pyramid on wood:

A wooden slab of dimension 15*15 cm and thickness 2cm is used as blank material to undergo machining. Total thickness is 6mm while maximum diameter is 5cm.

Figure 17: 3 stage pyramid

Cutting parameters:

- Max. depth of cut- 1mm
- Min depth of cut- 0.25mm
- XY federate- 100mm/min
- Z federate - 100mm/min
- Spindle speed- 3000rpm

3.7 Manufacturing of simple propeller on aluminum:

Aluminum slab of dimension 10*15cm and thickness 1cm is used as blank material. Since aluminum is a soft metal it is necessary to decrease the federate and depth of cut to avoid overheating and wear of cutting tool. It was observed that when a large feed rate is used the tool slips on work piece surface probably due to large cutting forces applied on tool which cause vibrating motion. Turpentine oil is used as a cutting fluid. Total thickness of propeller is 6mm and maximum diameter is 7cm.

Figure 18: Simple aluminum propeller

Cutting parameters-

- Max. depth of cut-0.05mm
- Min. depth of cut -0.03mm
- XY federate-15mm/min
- Z feerate-15mm/min
- Spindle speed-3000rpm

3.8 Design of a simple flywheel on wood:

Figure 19: Design of a simple flywheel

Cutting parameters:

- Min. depth of cut -0.5mm
- Max. depth of cut-1mm
- XY feed rate-150mm/min
- Z feed rate-100mm/min
- Spindle speed-3000rpm

Chapter 4. CONCLUSION:

In this project a small scale 3-axis CNC milling machine was fabricated and designed inexpensively. We developed a better idea about the working of CNC machine and its applications. There are different kinds of modern CNC machines used in industry. It is very important to understand G-code and M-code programming to successfully implement the machine. G-codes are nothing but programs that a machine tool can follow so that there is no need for human intervention.

- Various component parts were manufactured with minimum cost, high efficiency and with minimum time.
- The effect of various parameters like depth of cut, feed rate on material removal rate is observed.
- The effect of various parameters on heating of cutting tool and wear was observed.
- The CNC milling was used for cutting, sketching on plywood, aluminum to form 2D and 3D shapes.

4.1 Future scope of work:

- System can be further incorporated with additional 4^{th} axis to manufacture more complex parts.
- Due to time constraint the mechanical properties of the fabricated parts have not been studied which can be considered for future scope.
- This work can be further extended to fabricate components of real life application such as machine parts, propellers etc.

Chapter 5. REFERENCES:

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