

DESIGN AND DEVELOPMENT OF CNC MACHINE FOR SOFT MATERIAL

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering degree in Mechanical Engineering

By

P. NAVEEN KUMAR (40150030)

B. DEEPAK KUAMR (40150707)



DEPARTMENT OF MECHANICAL ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

**Accredited with grade “A++” by NAAC JEPPIAAR
NAGAR, RAJIV GANDHI SALAI, CHENNAI – 600119**

APRIL 2024



SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

Accredited "A++" Grade by NAAC | 12B Status by UGC | Approved by AICTE
www.sathyabama.ac.in

DEPARTMENT OF MECHANICAL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **B. DEEPAK KUMAR (40150707)** and **P. NAVEEN KUMAR (40150030)** who have done the project work and carried out the project entitled "**DESIGN AND DEVELOPMENT OF CNC MACHINE FOR SOFT MATERIAL**" under our supervision from November 2023 to April 2024.

[digital signature]
Internal Guide

Dr. RITESH KUMAR, M.TECH., Ph.D.,

Head of the Department

Dr. S. GANESAN., M.E., Ph.D.,

Submitted for Viva voce Examination held on 06/04/2024

Internal Examiner

External Examiner

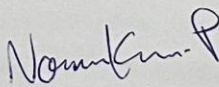
DECLARATION

We, **P. NAVEEN KUMAR (40150030)** and **B. DEEPAK KUAMR (40150707)** hereby declare that the Project Report entitled "**DESIGN AND DEVELOPMENT OF CNC MACHINE FOR SOFT MATERIAL**" was done by me under the guidance of **Dr. RITESH KUMAR, M.TECH., Ph.D.,** (Internal Guide) is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

DATE: 06-04-2024

PLACE: CHENNAI


B. DEEPAK KUMAR


P. NAVEEN KUMAR

SIGNATURE OF THE CANDIDATE

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to The Board of Management of Sathyabama Institute of Science and Technology for their encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my thanks to **Dr. S. GANESAN, M.E., Ph.D.**, Head of the Department, Dept. of Mechanical Engineering for providing me necessary support during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Dr. RITESH KUMAR, M.TECH., Ph.D.**, for his valuable guidance, suggestions, and constant encouragement paved way for the successful completion of my project work.

I wish to express my thanks to all Teaching and Non-teaching staff members of the Department of Mechanical Engineering who were helpful in many ways for the completion of the project.

ABSTRACT

An Arduino based 3 axis CNC (COMPUTER NUMERICAL CONTROL) drilling machine for printed circuit board is implemented using Arduino controller CNC machine for printed circuit board is implemented using open-source software for controlling the whole operations.

In recent years the process is carried out in the GACIPE research group is related to the development of the base technology of the manufacturing and metalworking industry. The machine tools that are vital for the consolidation and competitiveness of the industry in any country has been approached through two approaches: The design and construction of the new machine in this aspect, modelling of the structure and the displacement parameterization allows defining the precision of the movement and the rational use of energy.

The adaption and repowering of a used machine. In this approach the recovery and technological updating proposed to recover its performance, becoming an excellent alternative to improving and perfecting the production of a company. In both cases the CNC milling machine tools are controlled by free software.

This can be the invention for the electronic industries. Using this CNC machine, one will be able to draw a circuit layout on PCB (printed circuit board) or any other solid surface using simple algorithm and available components. At first the user needs to design PCB layout using eagle software which is directly generated G- code and then feed it to the machine using candle software. Arduino Uno with an AT mega 328 microcontroller is used as main controller for this system.

The microcontroller converts G-code into a set of machine language instruction to be sent to the motor driver of the CNC machine. This system can provide drill in less time and increase the flexibility. For drilling multiple holes in a component basically we use vertical or horizontal drilling machine. Even if these machines are efficient but are not suitable for small scale industry due to its higher cost.

Thus, small scale industries suffer a loss due to non-availability of these machines. Also, operational and maintenance cost is higher for these machines. Due to bulky structure of these machines, it occupies more space. Big scale manufacturer can afford such highly expensive machines but for small scale manufacturer can afford such highly expensive machines but for small scale mechanical job manufacturing industry, we have to think of low-cost solution that can deliver high class output. To overcome this problem, we need to design machine such that it will perform the function of drilling machine with lesser initial cost and easy in operation.

Thus, it will be easily affordable for small scale manufacturers. In this machine we arrange lead screw in X and Y axis for movement of the component on which the drilling operation is to be performed. The idea behind fabrication of low-cost CNC drilling machine is to fulfil the demand of CNC drilling machine from small scale to large scale industries with optimized low cost, smaller size, easily operable, easy interface, flexible and low power consumption. Index Terms - CNC, Drilling

TABLE OF CONTENTS

CHAPTER No.	TITLE	PAGE No.
	ABSTRACT	V
	LIST OF FIGURES	Viii
1	INTRODUCTION	1
	1.1 CNC MACHINE - INPUT, PROCESS AND OUTPUT	5
	1.2 CNC CONTROL PANEL	6
2	LITERATURE SURVEY	8
3	PROJECT ANALYSIS	12
	3.1 OBJECTIVE	12
	3.2 HETEROGENEOUS ARCHITECTURES	12
	3.3 HARSH ENVIRONMENT	13
	3.4 SYSTEM SAFETY AND RELIABILITY	13
	3.5 CONTROL OF PHYSICAL SYSTEM	14
	3.6 COST SENSITIVITY	14
	3.7 POWER MANAGEMENT	14
	3.8 EMBEDDED SYSTEM	15
	3.9 CLASSIFICATION	17
	3.10 HARD AND SOFT REAL TIME SYSTEM	17
4	METHODOLOGY	19
	4.1 DESIGN CALCULATIONS	20
	4.2 MACHINE COMPONENTS	25
	4.3 ARDUINO UNO	33
	4.4 CNC PROGRAMMING	36
5	CONCLUSION	38
	REFERENCE	40

LIST OF FIGURES

FIGURE No.	TITLE	PAGE No.
3.1	HETEROGENEOUS ARCHITECTURES	13
3.2	BLOCK DIAGRAM	16
3.3	SETUP OF CNC MACHINE	18
4.1	LOADING DIAGRAM OF Y-AXIS LEAD SCREW	21
4.2	FREE BODY DIAGRAM OF Y-AXIS LEAD SCREW	22
4.3	LOADING DIAGRAM OF X-AXIS LEAD SCREW	23
4.4	FREE BODY DIAGRAM OF X-AXIS LEAD SCREW	24
4.5	TABULAR COLUMN	24
4.6	LEAD SCREW	26
4.7	MOTOR	27
4.8	SPINDLE MOTOR	29
4.9	LAYOUT OF PIC	31
4.10	ARDUINO UNO	34
4.11	CAD MODEL	38

CHAPTER 1 INTRODUCTION

CNC milling is a specific form of Computer Numerical Controlled (CNC) machining. Milling itself is a machining process similar to both drilling and cutting, and able to achieve many of the operations performed by cutting and drilling machines. CNC machining centers are used to produce a wide range of components, and tooling costs involved have continued to become more affordable.

In general, large production run requiring relatively simple designs are better served by other methods, although CNC machining can now accommodate a wide range of manufacturing needs. CNC milling centers are ideal solutions to everything ranging from prototyping and short-run production of complex parts to the fabrication of unique precision of components. Open-source microcontroller platform PLC is used for control of the motors, and open-source software is used for executing the G code and M code for machining applications.

The ongoing development of technology and economy, new industrial requirements such as high precision, good quality, high production rates and low production costs are increasingly demanding. 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 ultra-precision products down to Nano scales in a much faster manner.

The traditional design philosophy of machine tools is multi functionality and highest precision possible. For example, a shank with spindle together with tailstock can be added onto a standard three axis vertical milling machine to become a multifunctional drilling-milling turning machine, meaning the machine tool is designed to be used for multiple instead of single purposes.

However, with the dramatic increase of industry varieties and the growing demand of 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.

The CNC drilling machine is mainly used for drilling holes with numerical control. The most products are special equipment, which are widely use din whole processing technology for the PCB and large porous tube sheet parts. These products are special equipment, and can be classified as CNC vertical drill, drilling center, CNC PCB drill, CNC deep-hole drill and other large CNC drilling machine. It is applicable to machining the parts with lots of precise holes in procedures of drilling, spreading, weaning and threading.

Especially, it's important to improve the machining accuracy and efficiency that choose a special CNC drilling machine to work the PCB and large porous tube sheet. While, the design of servo system is the most complex in the process of designing a special CNC drilling, and require plenty of time to program and debug. So, it not only consumes the valuable intellectual resources, but constrains to market the product timely.

Majority of integrated circuit boards. And, XPC Target introduced a host-target technical means, one PC as host computer, and another industrial computer as target computer, two computers connected with network cards and communicate through TCP/IP protocol. The systems by XPC Target can run on X86 computer real-time. It achieves simulation on board and rapid prototyping of control systems. In the process of design and construction of a machine tool at the initial stage of developing the overall concept an appropriate geometric kinematic structure (G-KS) must be selected. The correct solution of this task is particularly important in terms of the properties that are crucial for its future technical and operational indicators of the designed machine tool. Errors at this early stage cannot be improved by the subtlety of approach and diligent implementation of further stages.

The machine tool's geometric-kinematic structure or layout design can be defined as the over-all picture of its structure and functional features, including the set of movements necessary to perform cutting tasks and distribution of these movements among the major units and components. Description of layout design or structural design should indicate the location of these elements in the carrying system of the machine tool.

Modern industry demands more precise and complex products that meet high quality standards and protocols, using high-performance technological tools such as CNC machine tools. That according to Oxford Economics, the principal manufacturers and

consumers worldwide are China, United States. The United States, the European Economic Community, India, Brazil, and Japan. These countries have greater competitiveness in world industry. India last decade has had accelerated growth in the consumption and the production of machine tools above 8 percent per year.

That is a consequence of the incentives and policy change of the Indian government focused on the constitution of a park of machine tool development and the creation of a center of excellence machine tools and production technologies.

In Germany, the area of machines and equipment is the second most important industrial sector. The country has become a technological engine that distinguishes itself as a high-tech nation worldwide. The United States has distinguished itself as one of the leading exporters of machinery worldwide

,being the principal supplier to China in recent years, demonstrating the big industrial capacity to develop machine tools. That equipment that par excellence is the basis for catapult the industrial production of a country. In Latin American countries, MIPYMEs prioritize automation and technological development of machine tools, specifically in Colombia, MIPYMEs represent 94 percent of the industry, where most of the manufacturing processes of MIPYMEs in the metalworking sector are carried out in conventional machine tools. To control this machine, input is given from a CAM software in the form of G-codes. Then the G-codes are sent to controller board in form of signals through an USB interface. After that, signals are sent to stepper motors to produce motion accordingly. This machine can be customized mainly in two ways. First is dimensionally to suit specific-sized workpieces, and second is functionally which can be used as milling machines, laser cutters, and engravers and also to some extent as a 3D printer.

Process planning models to improve decision making and enhance knowledge management, research on Computer- aided Process Planning (CAPP) and Computer Numerical Control (CNC) are interdependently studied through machining-process-related parameters and variables. As a result, CNC capabilities for specific domain-knowledge areas become variables for the improvement of machining performance in industry. As examples, for more than two decades, generative CAPP-embedded CNC

processes which include turning, cutting & abrasive, prismatic-feature machining and machine tool selection have been developed.

It is observed that CAPP, being an integral strategy, is customized to fit widely implemented CNC processes while some algorithmic approaches, which are associated with generating code for NCs or CNCs, are transferable among search reasoning engines and their interface. The other critical research and development (R&D) on CAD-CAPP-CNC verification and validation evaluates the calculated path planning with a realistic case. A straight-forward point-to-point (PTP) based metaheuristic algorithm may be viewed as a variant CAPP with NC-driven laser cutting process implementations [9], [10]. Consequently, more tangible economic considerations become accountable, tractable and comparable for intelligent machining process assessments.

1.1 CNC MACHINE- INPUT, PROCESS AND OUTPUT

A CNC machine facility needs three pieces of equipments.

A Computer:

The computer is used to draw the design. However, the design is only a picture and the CNC machine cannot use this to manufacture the product. The computer software must also convert the drawing into numbers (coordinates) that the CNC machine can use when it starts to cut and shape the material. ***An Interface:***

A computer cannot be directly connected to a CNC machine. The computer is connected to an interface. This converts the signals from the computer to a form that the CNC machine understands.

The signals are in the form of digital signals when they are sent to the CNC machine.

CNC (computer numerical control) machine:

The signals from the interface control the motors on the CNC machine. The signals determine the way the vice moves. The vice moves in three directions X, Y and Z. (Horizontally, vertically and depth). The signals also control the speed of the cutting tool.

1.2. CNC CONTROL PANEL

A CNC machine is normally controlled by a computer and software. However, most CNC machines have a range of controls for manual use. It is rare for a CNC machine to be used manually as simple operations are best carried out on cheap /basic/ manual machines. When a CNC machine is used manually it is used below its capability and specification.

Reset Button:

The most important control button is usually the reset button. When the CNC machine is turned on, the reset button is pressed by the machine operator. This 'zeros' the cutter, moving the cutter to coordinates 0, 0, 0 on the X, Y and Z axis. In simple terms, the reset button moves the cutter to the corner of the machine, above the work table. If the reset button is not pressed, it is possible that the CNC machine will start cutting the material in the wrong place or even miss cutting the material and plunge into the work table. ***Manual Control:***

The cutter can be controlled manually although this is rarely needed. The 'X' and 'Y' buttons control the movement of the cutter along the horizontal surfaces. The 'Z' buttons control depth and up / down movement. ***Stop Button:***

Most control panels have stop buttons. When pressed the stop button the machine stops very quickly.

Speed and Feed:

On some CNC machines it is possible to manually vary the speed and feed of the cutter.

CHAPTER 2

LITERATURE SURVEY

1. Development of a feature-based open soft-CNC system ,Kamran Latif, Yusri Yusof, Aydin Nassehi, Qadir Bux Alias Imran Latif,2017

Modern computer numerical control (CNC) is intended to be more flexible, interoperable, adoptable, open, and intelligent. In realisation of such a CNC system, an

ISO standard known as STEP for numeric control (STEP-NC) or ISO 14649 was developed in 2004 to alleviate a number of challenges associated with the widely used CNC standard (ISO 6983). Implementation of STEP-NC was initially carried out on some commercial CNC systems via an indirect STEP-NC programming approach. However, this approach failed to meet all the requirements of a modern CNC system, due to the translation of data from the high level to low level, which is vendor-specific and machine tool dependent, thus detrimental to the basic resource independent philosophy of STEP-NC. This paper presents a new generation of CNC systems, based on the Open Architecture Control (OAC) technology supported by STEP-NC data model to fundamentally solve these challenges. The developed system employs a new set of techniques for STEP-NC data interpretation, graphical verification, execution, monitoring, and report generation that supersede the exiting techniques in scope and capability. Using these techniques, the proposed system provides a flexible, intelligent, and adaptable manufacturing.

platform that can provide unprecedented levels of scalability and resource allocation agility in modern manufacturing enterprises. A prototype implementation of the proposed model is based on STEP-NC interpretation, 3D simulation, machine motion control, and live video monitoring with automatic document generation modules has been used to verify and validate the system in conjunction with industrially inspired test components.

2. Design and Usability of the Touch-based Interface of CNC. H Yuan, S Hu, C Lao, Q Zhang... - 2019.

Usability problem refers to the difficulty in the user-centered interface design of industrial computer numerical control (CNC) presses. In the industrial field, the development of touch-based interface design satisfies the functional requirements but ignores the user-centered design concept. This study develops a touch interactive interface of CNC presses to improve its usability, and the application of usability theory in industrial numerical control. Usability correlation theory is used to conduct the usability experiment of the designed interactive.

3. Design and control of a CNC device designed for the application of viscous materials. P. Drgoña; R. Stefún; L'. Stefke 2018

This article deals with the design and practical realization of a CNC device designed for the application of viscous materials, such as a thermal conducting paste. According to the given specification, the choice of a suitable mechanical construction and the design of a mechanism for extruding the paste from the tube are solved. A separate part is the choice of a suitable drive and design of electronic circuits to control it. The last part contains the selection of the appropriate control program and its modification.

4. Research on self-maintenance strategy of CNC machine tools based on case-based reasoning. Li Kwangju; Sun Weifang; Liu Yanfeng; Zhao Yuan, 2021.

Self-maintenance strategy of CNC machine tool is one of the key technologies to realize intelligent manufacturing. The main difficulties of this technology are: how to effectively collect and summarize the possible faults of CNC machine tools;

how to collect and analyze the execution status of CNC machine tools in real time; how to put forward and set the feasible and best fault maintenance strategy and expert scheme according to the collected information. For this reason, this paper proposes a solution for CNC machine tool maintenance: first, the CNC system needs to have the function of fault maintenance strategy screening, when the machine failure occurs, the CNC system can quickly select the best matching maintenance scheme; second, the CNC system needs to save the function of fault early warning, according to the historical fault data, it can send early warning before the failure occurs. Information, timely remind the operation and maintenance personnel to protect. Finally, the practical application verifies the application effect of the autonomous maintenance strategy.

5. Research on CNC Machine Tool Monitoring System Based on OPC UA. Haoyu Yu; Dong Yu; Yi Hu; Chuting Wang, 2019.

As one of the core equipment of intelligent manufacturing, the condition monitoring of CNC machine tool is the key of intelligent Key manufacturing. In this paper, the heterogeneous data standardization specification is implemented by establishing an expandable CNC machine tool description model, the CNC machine tool monitoring system based on OPC Unified

Architecture (OPC UA) is designed, which is applied to Golding CNC system GJ430 for test verification, and the standardization communication of the NC system is implemented.

6. A Novel Two-Mode Integral Approach for Thermal Error Modelling in CNC Milling-Turning Machining Centre. Wenyu Lian; Lei Zhang; Kun- Chieh Wang; Hong-Yi Chen; 2022.

Thermal errors have the largest contribution, as much as about 70%, to the machining inaccuracy of computer-numerical-controlled (CNC) machining centres. The error compensation method so far plays the most popular and effective way to minimize the thermal error. How to accurately and quickly build an applicable

thermal error model (TEM) is the kernel work of thermal error compensation. On the basis of some comprehensive machine-learning schemes, past proposed TEMs had impressive merits for dealing with the thermal error modelling of single-function (milling or turning cutting) machine tools with only considering one set of thermal key points.

These proposed modelling methodologies become worse when applied to CNC compound milling-turning machining centres in actual cutting applications. This paper proposes a two-mode integral TEM based on the Lasso and the random forest regression schemes to quickly and accurately predict the thermal deformations of such a machine. The first mode is the thermal error modelling for milling cutting conditions, and the second mode is that for turning cutting conditions.

For data reduction, two different sets of temperature key points, one for temperature key points, one for milling and the other for turning, are obtained.

Then, on the basis of the random forest regression scheme, we separately establish two TEMs but concurrently use them to predict the tool-centre-point deformation of both milling as well as turning spindles. Further, we compare our proposed

TEM with several frequently-used machine-learning-based TEMs and the results show that our proposed TEM are the best among all, no matter in the modelling experiment or in the test experiment. The proposed TEM has a maximum prediction error of 6.08 [Math Processing Error] for milling cutting and that of 1.455 [Math Processing Error] for turning cutting in the modelling experiment. By our proposed two-mode integral TEM,

the thermal error of a multifunction milling-turning machining centre can be accurately predicted and quickly compensated.

CHAPTER 3

PROJECT ANALYSIS

3.1. 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

3.2. HETEROGENEOUS ARCHITECTURES:

Embedded systems often are composed of heterogeneous architectures (Fig 1.2). They may contain different processors in the same system solution. They may also be mixed signal systems. The combination of I/O interfaces, local and remote memories, and sensors and actuators makes embedded system design truly unique. Embedded systems also have tight design constraints, and heterogeneity provides better design flexibility.

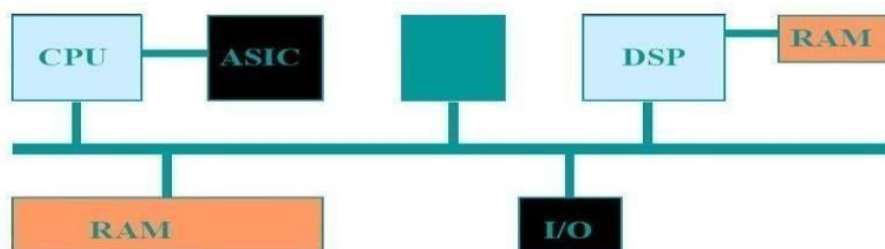


Fig 3.1 Heterogeneous Architectures

3.3. HARSH ENVIRONMENT

Many embedded systems do not operate in a controlled environment. Excessive heat is often a problem, especially in applications involving combustion (e.g., many transportation applications). Additional problems can be caused for embedded computing by a need for protection from vibration, shock, lightning, power supply fluctuations, water, corrosion, fire, and general physical abuse.

3.4. SYSTEM SAFETY AND RELIABILITY:

As embedded system complexity and computing power continue to grow, they are starting to control more and more of the safety aspects of the overall system. These safety measures may be in the form of software as well as hardware control. Mechanical safety backups are normally activated when the computer system loses control in order to safely shut down system operation. Software safety and reliability is a bigger issue. Software doesn't normally "break" in the sense of hardware. However, software may be so complex that a set of unexpected circumstances can cause software failures leading to unsafe situations.

Discussion of this topic is outside the scope of this book, but the challenges for embedded designers include designing reliable software and building cheap, available systems using unreliable components. The main challenge for embedded system designers is to obtain low- cost reliability with minimal redundancy.

3.5. CONTROL OF PHYSICAL SYSTEM:

One of the main reasons for embedding a computer is to interact with the environment. This is often done by monitoring and controlling external machinery.

Embedded computers transform the analog signals from sensors into digital form for processing. Outputs must be transformed back to analog signal levels. When controlling physical equipment, large current loads may need to be switched in order to operate motors and other actuators. To meet these needs, embedded systems may need large computer circuit boards with many non-digital components.

Embedded system designers must carefully balance system trade offs among analog components, power, mechanical, network, and digital hardware with corresponding

software. Small and low weight Many embedded computers are physically located within some larger system. The form factor for the embedded system may be dictated by aesthetics. For example, the form factor for a missile may have to fit inside the nose of the missile. One of the challenges for embedded systems designers is to develop non-rectangular geometries for certain solutions. Weight can also be a critical constraint. Embedded automobile control systems, for example, must be light weight for fuel economy. Portable CD players must be light weight for portability purposes.

3.6. COST SENSITIVITY:

Cost is an issue in most systems, but the sensitivity to cost changes can vary dramatically in embedded systems. This is mainly due to the effect of computer costs have on profitability and is more a function of the proportion of cost changes compared to the total system cost.

3.7. POWER MANAGEMENT:

Embedded systems have strict constraints on power. Given the portability requirements of many embedded systems, the need to conserve power is important to maintain battery life as long as possible. Minimization of heat production is another obvious concern for embedded system.

3.8. EMBEDDED SYSTEM:

A system is something that maintains its existence and functions as a whole through the interaction of its parts. E.g. Body, Mankind, Access Control, etc. A system is a part of the world that a person or group of persons during some time interval and for some purpose choose to regard as a whole, consisting of interrelated components, each component characterized by properties that are selected as being relevant to the purpose.

- Embedded System is a combination of hardware and software used to achieve a single specific task.
- Embedded systems are computer systems that monitor, respond to, or control an external environment.
- Environment connected to systems through sensors, actuators and other I/O interfaces.

- Embedded system must meet timing & other constraints imposed on it by environment.

An embedded system is a microcontroller-based, software driven, reliable, real-time control system, autonomous, or human or network interactive, operating on diverse physical variables and in diverse environments and sold into a competitive and cost conscious market. An embedded system is not a computer system that is used primarily for processing, not a software system on PC or UNIX, not a traditional business or scientific application. High-end embedded & lower end embedded systems. High-end embedded system - Generally 32, 64 Bit Controllers used with OS. Examples Personal Digital Assistant and Mobile phones etc. Lower end embedded systems - Generally 8, 16 Bit Controllers used with a minimal operating systems and hardware layout designed for the specific purpose.

BLOCK DIAGRAM OF CNC MACHINE :

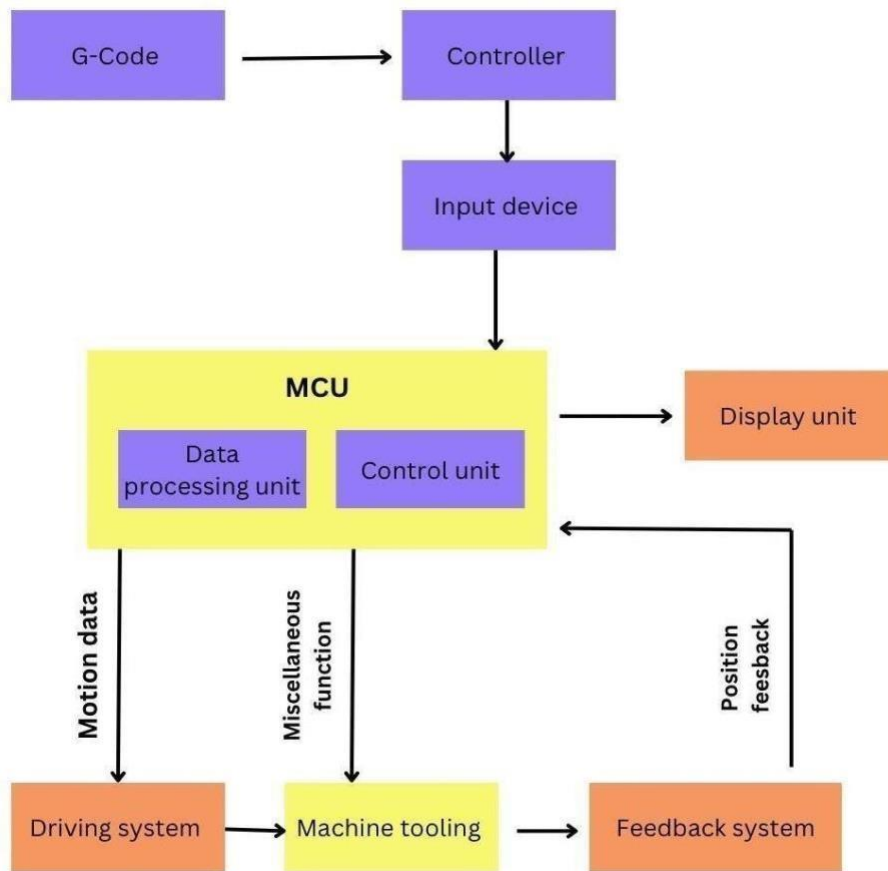


FIG 3.2 : BLOCK DIAGRAM

From the initial state of the project to the final fabrication the design considerations will be taken like the software consideration and the hardware components, sensor, input and output. The electronics usually uses either a microprocessor or a microcontroller. Some large or old systems use general-purpose mainframe computers or minicomputers. **3.9. CLASSIFICATIONS:**

Real Time Systems.

- RTS is one which has to respond to events within a specified deadline.
- A right answer after the dead line is a wrong answer
- RTS classification
- Hard Real Time Systems
- Soft Real Time System

3.10. Hard And Soft Real Time Systems:

- "Hard" real-time systems have very narrow response time.
- Example: Nuclear power system, Cardiac pacemaker.
- "Soft" real-time systems have reduced constraints on "lateness" but still must operate very quickly and repeatably.
- Example: Railway reservation system - takes a few extra seconds the data remains valid.

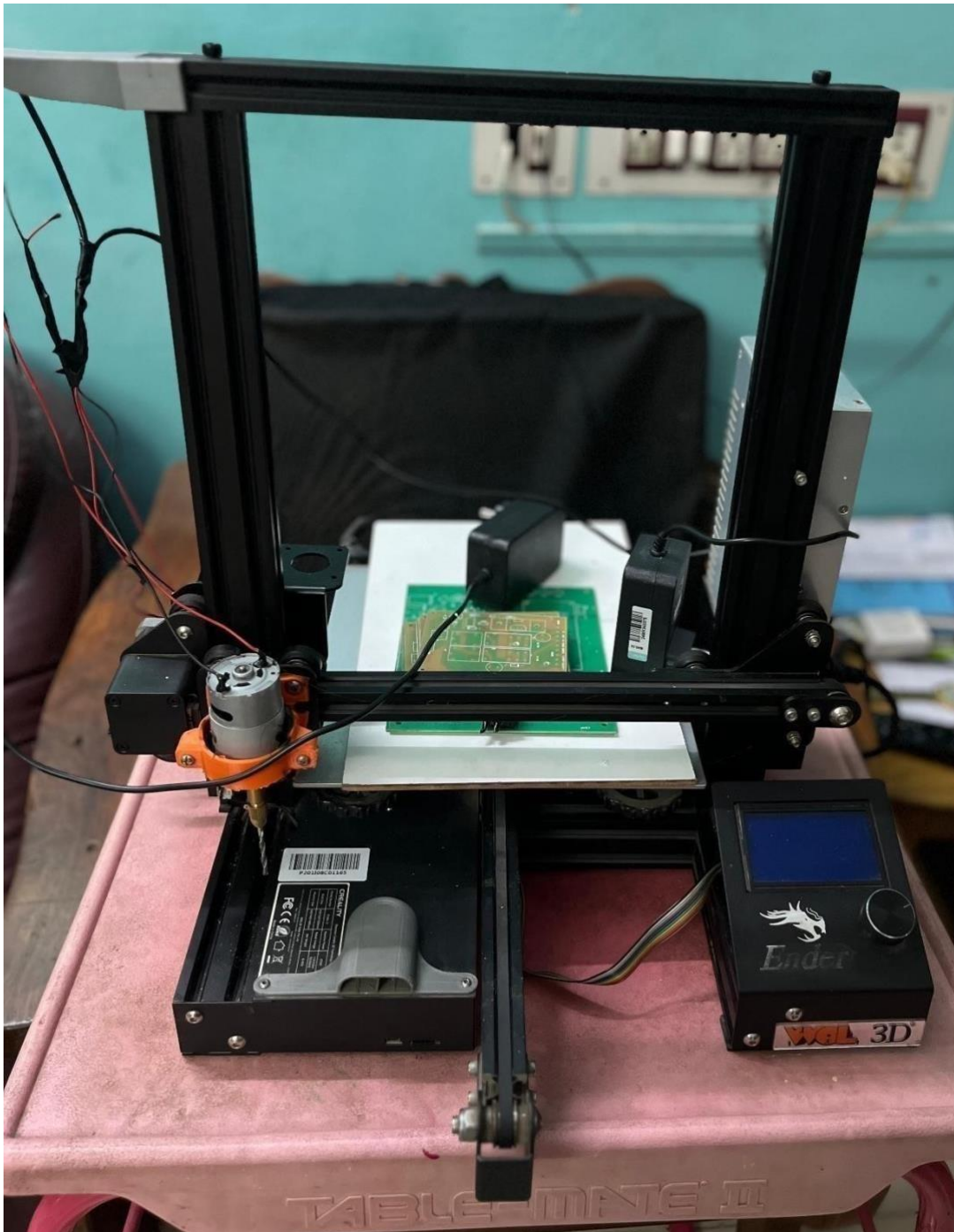


FIG 3.3; SETUP OF CNC MACHINE
CHAPTER 4

METHODOLOGY

An important advancement in the philosophy of NC machine tools was the shift toward the use of computers instead of proprietary controller units in the NC system of the early 1970s. This gave rise to the computer numerical control (CNC)

CNC is a self-contained NC system for a single machine tool including a dedicated minicomputer controlled by stored instructions to perform some or all of the basic NC functions. It has become widely used for manufacturing systems mainly because of its flexibility and less investment required. Replacing conventional NC hardware with software as much possible and simplifying the remaining hardware is one of the objectives of CNC systems. While most interpretation and interpolation functions can be replaced by proper software, the remaining hardware must contain at least servo amplifiers, transducer circuits, and interface components.

The software portion of a CNC system must consist at least of three major programs: a part program, a service program, and a control program.

The part program contains the geometry description of the part being produced and the cutting conditions such as spindle speed and feed rate. Computer Aided Manufacturing (CAM) software can be used to generate this part program. The service program is used to check, edit and to correct the part program. It usually has a user interface that allows the user to operate the machine easily.

The control program accepts the part program as input data and produces signals to drive the axes of motion. It performs interpolation, feed rate control, acceleration and deceleration, and position counters showing the current axes position. Most closed-loop CNC systems include both velocity and position control loops. The velocity feedback is usually provided by a tachometer and the position feedback is usually provided by an encoder or resolver.

CNC software can also retrieve velocity feedback from encoder by differentiating the input signal. The computer output in CNC systems can be transmitted either as a sequence of reference pulses or as a binary word. If the reference pulse sequence is generated, each pulse generates a motion of 1B LU of axis travel. The number of pulses represents position, and the pulse frequency represents axis velocity. In an open-loop system, these pulses are the control signal of a stepper motor. In a closed-loop system, these pulses can be fed as a reference signal.

4.1 DESIGN CALCULATIONS

DESIGN OF LEAD SCREWS FOR Y AXIS:

Lead screw length 300 mm is considered. Weight of the motor will act vertically downward direction to the shaft. Forces acting on the lead screw is weight of motor & weight of block to mount the motor is act on the lead screw at the center. Weight of the motor = 0.5 Kg. Weight of the block on which the motor is mount = 1 Kg, Hence, Total weight = Weight of the motor + Weight of the block on which motor is mount = 0.5 Kg + 1 Kg = 1.5 Kg = 14.715 N.

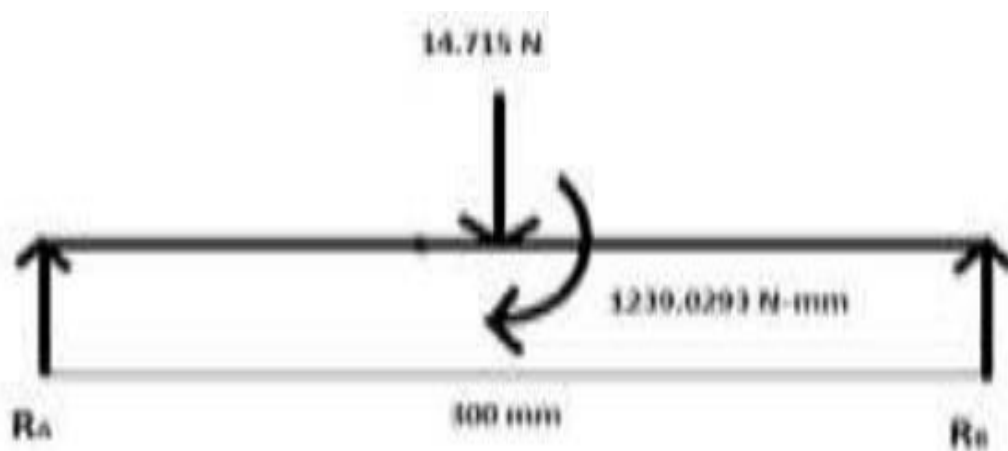


FIG 4.1 : LOADING DIAGRAM OF Y-AXIS LEAD SCREW

Now consider the Free Body diagram of the Lead Screw (shaft). It is assumed that the whole assembly is at center of the lead screw. On solving the FBD. $\sum F_Y = 0$

$$R_A + R_B = 14.715 \text{ N}$$

$$\sum M_A = 0$$

$$14.715 \times 150 + 1239.0293 - R_B \times 300 = 0 \quad R_B = 11.4850 \text{ N}$$

$$R_A = 3.225 \text{ N}$$

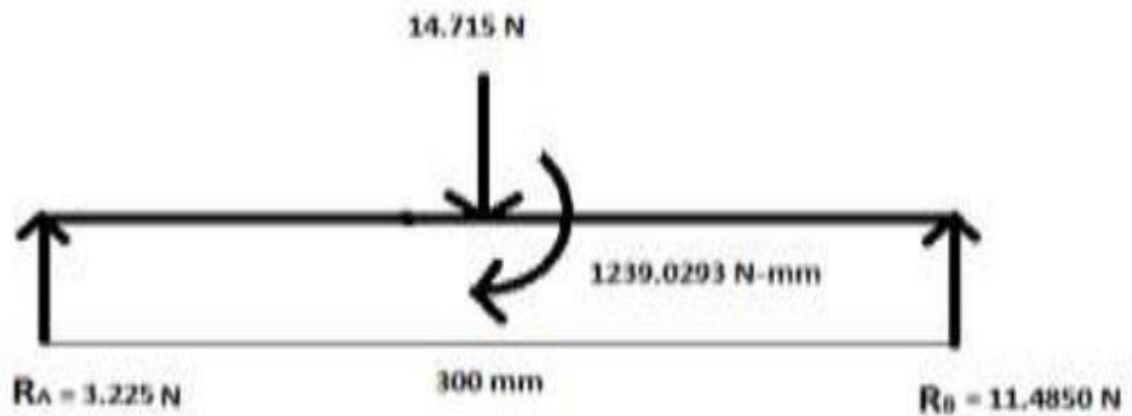


FIG 4.2: FREE BODY DIAGRAM OF Y-AXIS LEAD SCREW

DESIGN OF LEAD SCREWS FOR X-AXIS

The lead screw which guides the drilling head in x direction i.e., in horizontal direction. Forces acting on the lead screw is weight of the drilling head along with the motor & weight of block to mount the motor is act on the lead screw at the centre Weight of the Y axis lead screw and weight of lead screw holding block at the centre of lead screw.

Total weight = weight of the motor + weight of motor holding block + weight of Y axis lead screw + weight of Y axis holding lead screw block + Weight of both Side Supports

$$W = 0.5 \text{ Kg} + 1 \text{ Kg} + 1 \text{ Kg} + 0.75 \text{ Kg} + 0.5 \text{ Kg} + 0.5 \text{ KW} = 4.25 \text{ Kg} = 41.6925 \text{ N}$$

Now consider the Free Body diagram of the Lead Screw (shaft)

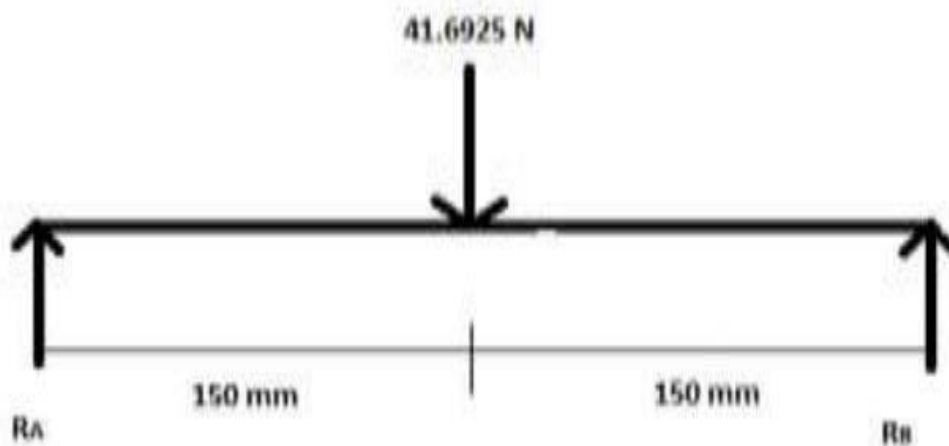


FIG 4.3 : LOADING DIAGRAM OF X AXIS LEAD SCREW

It is assumed that the whole assembly is at center of the lead screw, on solving FBD.

$$\sum F_Y = 0$$

$$R_A + R_B = 41.6925 \text{ N}$$

$$\sum M_A = 0$$

$$41.6925 \times 150 - R_B \times 300 = 0 \quad R_B = 20.84625 \text{ N}$$

$$R_A = 20.84625 \text{ N}$$

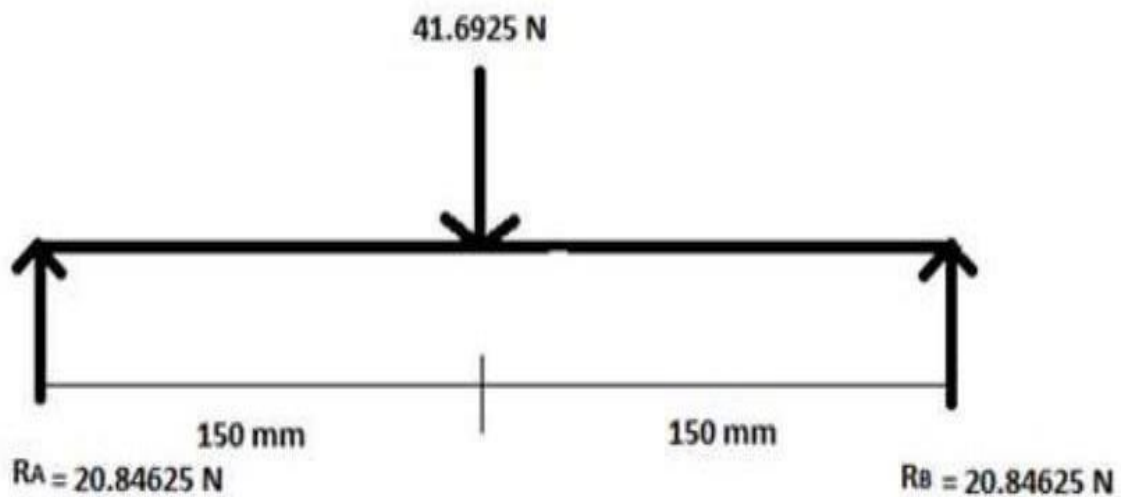


FIG 4.4 : FREE BODY DIAGRAM OF X-AXIS LEAD SCREW

Lead Screw	Length = 300mm, Dia. = 8mm
Long Guideways	Length = 300mm, Dia. = 8mm
Motor	12V DC Motor, 60RPM
Support Bearing	Ball Bearing = Deep Groove Inside Dia. = 6mm Race Width = 6mm
Support Bearing	Ball Bearing = Deep Groove Inside Dia. = 8mm Race Width = 7mm

FIG 4.5 : TABULAR COLUMN

4.2. MACHINE COMPONENTS:

LEAD SCREW:

Lead screws are quiet, smooth, resistant to corrosion, self-lubricating, and often less expensive. They are favoured in situations that require higher levels of customization. Because lead screws are normally virtually silent and vibration-free, they are often used for medical equipment like insulin pumps and in personal computing devices like desktop PCs.

Lead screws are self-locking, there is typically no need to apply additional brakes, even in situations where you're lifting a vertical load during an electricity outage. However, the higher the friction is on the sliding surface the more power is required to drive the load up or forward. Material of lead screw is mild steel. When selecting the lead screw, we want to have the smallest pitch size possible to increase our resolution.

The current market has various models and quality levels to choose from. C3 is the most precise level but also the most expensive. C7 is the cheapest and most used level. In level C7, 0802 is the smallest pitch size model. 0802 stands for 8mm diameter and 2mm pitch. We have 0802, 1002, 1004, 1204, 1604, 1605 to choose from. The cheapest one is 1605, but it has the largest pitch and diameter. The machine size will also be affected by using large diameter lead screws. 0802, 1002 offers the smallest pitch size but the price is almost tripled compared with the 1605 model. Among 1004, 1204, and 1604

model, 1004 is the most expensive model. 1204 is only slightly more expensive than 1604 and offers a much smaller diameter.

Therefore, 1204 C7 model is selected as the lead screw of our machine. The lead screw contains a preloaded circulating ball nut which eliminates backlash and reduces friction, as shown in figure. DC servo motors are chosen to be used as actuators. Therefore, we have to use lead screw mechanism to transfer rotary motion into linear motion.



FIG 4.6; LEAD SCREW

LIMIT SWITCHES

A Limit Switch is the simplest type of end stop a simple mechanical switch positioned to trigger when an axis reaches the end of its motion . Limit switches are used to protect the stepper motor and circuit by shutting the motors by triggering the switch when the axis reaches its end. The signal pins from limit switches are connected to the microcontroller board to sense the axes ends.

MOTOR

Selection of motors is carried out first because it is directly related to the driving mechanism as well as control method. Four different motors steppers,servos,linear and voice coils will be discussed. Stepper motor and servo motor are rotary motion motors, and linear motor and voice coils are linear motion motors Each of them has unique strengths and weaknesses which make them suitable in certain applications. For rotary

motion motors, a lead screw is always needed to transform rotary motion into linear motions.



FIG 4.7: MOTOR

Figure shows a typical linear voice coil motor. The actuating mechanism is similar to a solenoid. These motors consist of two separate parts; the magnetic housing and the coil. Applying a voltage across the terminals of the motor causes the motor to move to one direction. Reversing the polarity of the applied voltage will move the motor to the opposite direction.

The generated force is proportional to the current that flows through the motor coil. This force is almost constant in the specified stroke range of the motor. Voice coil motors do not need commutation and using a position sensor, positioning accuracies of less than one micron are achievable

However, due to limit of stroke distance and low force generation during movement, it is not suitable in our application because we require a stroke distance of at least 40mm in each axis and the force required during machining is high. However, it is widely used as actuator in the current micro machine tools (mMTs) since the precision of the motion is the highest among all four types of motors while the stroke and force required is small.

A stepper motor as shown in figure, is an electromechanical device which converts electrical pulses into discrete mechanical movements. The shaft or spindle of a stepper motor rotates in discrete step

Increments when electrical command pulses are applied to it in the proper sequence.

The motors rotation has several direct relationships to these applied input pulses.

The sequence of the applied pulses is directly related to the direction of motor shafts rotation. The speed of the motor shafts rotation is directly related to the frequency of the input pulses and the length of rotation is directly related to the number of input pulses applied. Servo motor internally contains a feedback sensor to tell its current position which allows precise control on angular position. The industrial servo motor speed output is proportional to the input current level. They look pretty similar to each other but the control method is completely different.

The basic difference between a traditional stepper and a servo-based system is the type of motor and how it is controlled. Steppers don't require encoders since they can accurately move between their many poles, whereas servos with few poles require an encoder to keep track of their position. Steppers simply move incrementally using pulses [open loop] while servos read the difference between the motor's encoder and the commanded position [closed loop], and adjust the current required to move. Stepper motor are the most affordable actuating solution for machine tools currently.

Lots of commercially available small CNC machines including CNC Baron and TORMACH stepper motors used to drive the axes together with an encoder to tell the current position.

The control is still open-loop while the encoder is used just as an evaluation device to make minor adjustments for small position offsets. Despite the price factor, servo motors have better precision, resolution, higher speed and acceleration, and more control techniques can be used. Nowadays the price of servo motors has dropped to almost equivalent to steppers.

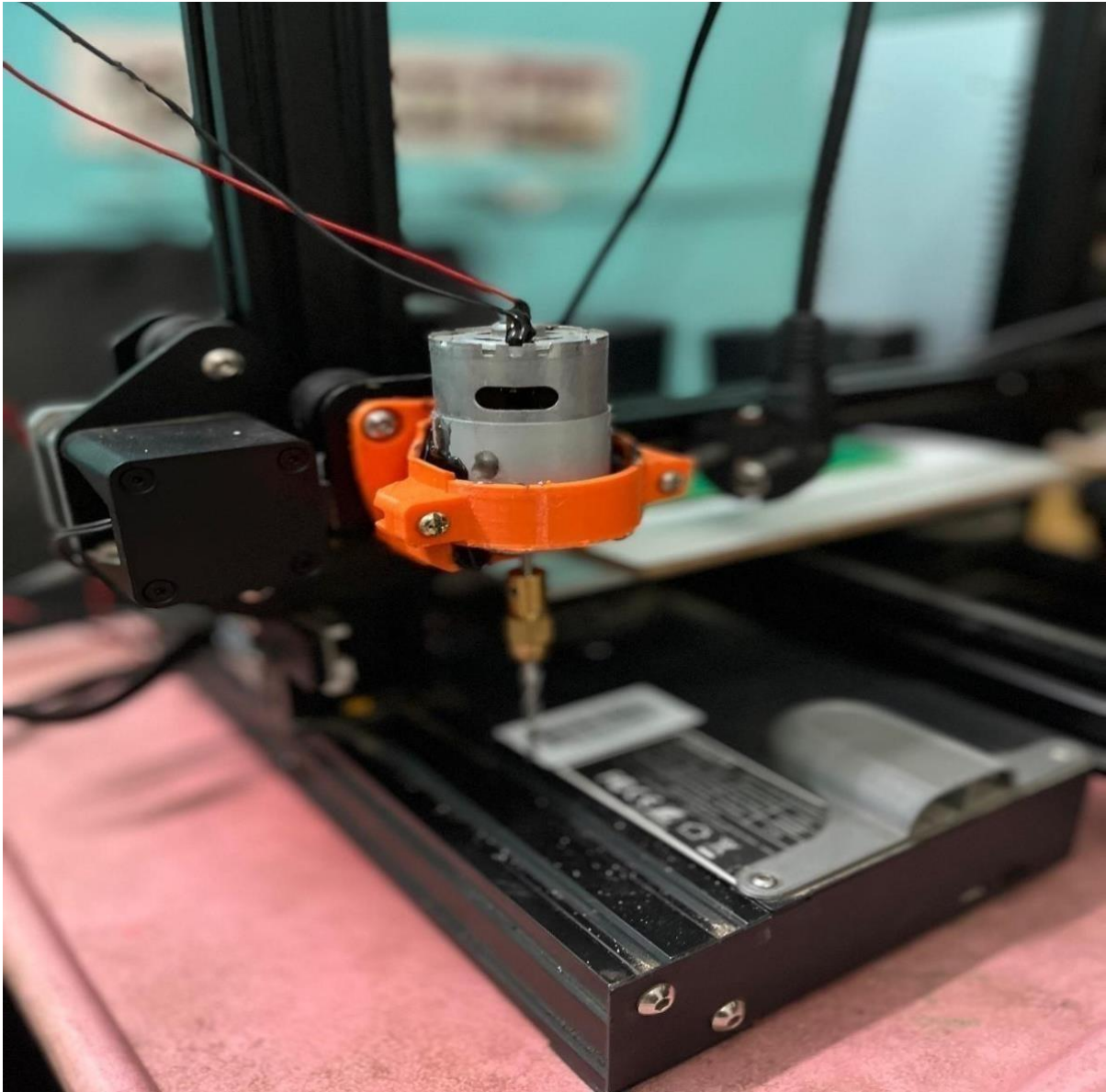


FIG 4.8: SPINDLE MOTOR

FEEDBACK SENSORS

Two types of encoders are compared in this session, rotary encoder and linear encoder, as rotary encoders are generally small and attached at the back of motors to sense the angle of rotation. It is cheap, easy to install, and gives unlimited range of travel. But due to the limit in size, the resolution in coding disk is very limited. For example, a 1000 pulse per rotation disk is considered as a relatively high-resolution encoder disk. Also, since it is not attached directly on table, some features such as backlash, lead screw wind up, and small vibrations of the table cannot be diagnosed.

Linear encoder is fixed directly onto the end effector so the position of end effector can be directly obtained. Pitch size information is no longer required in resolution

calculation. You can directly obtain the resolution information from product specification to decide whether this meets your requirements.

However, it only has limited travel range, is more expensive than rotary encoder and the installation procedure is more complex. Since the range of travel on our mini- CNC machine is relatively small, we can find small linear encoders within our budget and obtain the position information of the table directly. Therefore linear encoders with 1 micron resolution is selected as sensor on our machine.

SPINDLE

The next important component of the machine is the spindle. The desired spindle used on our machine should have less run out error, higher RPM for small tools, and be cheap. There are many DC motors available in Chinese market which can be used as our spindle axis.

The kit that was purchased contains one 300W DC motor, 48V power supply, amplifier and the mount bracket, as shown in figure. The spindle is specified to have 12000RPM and 5 microns run out error. We have calculated our maximum spindle speed. So this spindle can satisfy our requirements.

The rest of the accessories necessary for fabrication, including lead screw stand, shaft coupler, Z axis shaft and rolling bearing slide, Z axis shaft stand, base mounting leg, and limit switches.

The metal parts required to construct the main structure are arranged by their shapes and thickness in order to determine the cross section and the length of raw material to be purchased. This step can minimize the waste of material by minimizing the area consumed by various pieces of geometries.

The 7805 three-terminal positive regulator is available in the TO-220/D-PAK package and 5V fixed output voltage, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable

voltages and currents. Output Current up to 1A, Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24V, Thermal Overload protection, Short Circuit Protection, Output Transistor Safe Operating Area Protection.

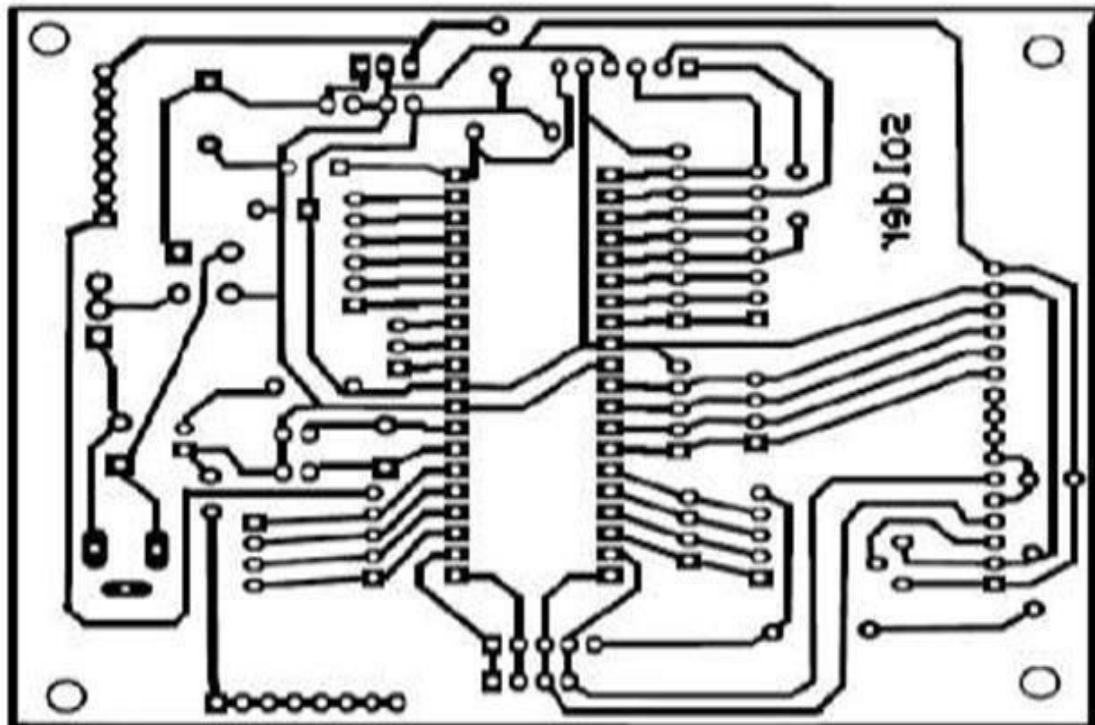


FIG NO: 4.9 LAYOUT OF PIC

MICROCONTROLLER

PIC is the family of Harvard architecture microcontroller made by microchip technology derive from the PIC 164. originally developed by general. instruments microelectronic division. the name PIC initially refers to “programmable interface controller”.PIC are popular with both industrial developers and hobbyists alike due to their low cost, wide availability, large user based, extensive collection of application notes, availability of low cost or free development tools and serial programming.

SPECIAL MICROCONTROLLER FEATURES:

- 100,000 erase/write cycle Enhanced Flash program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory typical
- Data EEPROM Retention > 40 years

- Self-reprogrammable under software control
- In-Circuit Serial Programming™ (ICSP™) via two pins
- Single-supply 5V In-Circuit Serial Programming
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving Sleep mode.
- Easy to handle with the easy step and less program process.

4.3. ARDUINO UNO

ARDUINO (ATMega328) MICROCONTROLLER

- It has 20 digital input/output pins
- 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.
- Microcontroller ATmega328
- Operating Voltage 5 V
- Input Voltage (recommended) 7-12 V
- Input Voltage (limits) 6-20 V
- Digital I/O Pins 14 (of which 6 provide PWM output)
- Analog Input Pins 6
- DC Current per I/O Pin 40 mA
- DC Current for 3.3V Pin 50 Ma
- Flash Memory 32 KB of which 0.5 KB used by bootloader.



FIG NO: 4.10 ARDUINO UNO

ARDUINO UNO AND ITS PROGRAMMING

- Arduino is a tool for making computers that can sense and control more of the physical world than your desktop computer. It's an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board.
- Arduino can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs.

- Arduino projects can be stand-alone, or they can be communicate with software running on your computer. The boards can be assembled by hand or purchased preassembled; the open-source IDE can be downloaded for free.
- The Arduino programming language is an implementation of wiring, a similar physical computing platform, which is based on the processing multimedia programming environment. **WHY ARDUINO ?**

There are many other microcontrollers and microcontroller platforms available for physical computing. Parallax Basic Stamp, Netmedia's BX- 24, Phidgets, MIT's Handy board, and many others offer similar functionality. All of these tools take the messy details of microcontroller programming and wrap it up in an easy-to-use package. Arduino also simplifies the process of working with microcontrollers, but it offers some advantage for teachers, students, and interested amateurs over other systems:

4.3. CNC PROGRAMMING TURNING

Tool Holder: PDJNL 25*25
 Insert: DNMG 150604
 N5 G54; N10 M42;
 N20 G95 S300 M4;
 N25 LIMS=600;
 N30 T01 D1 M8;
 N35G00 X80 Z0;
 N40 X70;
 N45 G01 Z-75 F0.2;
 N50 G00 X71 Z0;
 N55 X60; N60 G01 Z-50 R0.2;
 N65 X70; N70 G00 X200 Z200;
 N75 M30;

STEP TURNING

N5 G54; N10 M42;
 N15 G95 S300 M0.4;
 N20 T01 D1 M8;

N25 G00 X30 Z0;
 N30 G00 X40 Z0;
 N35 CYCLE95; CYCLE95 ("STEP TURN", 5, 0.1, 0.1) X40
 N40 G00 X200 Z200 M17;
 N45 M30; STEP TURN: (SUB PROGRAM)
 N05 G01 X0 Z0 F0.2;
 N10 G01 X20 Z-10; N15
 G01 X20 Z-30; N20 G01
 X30 Z-30; N25 G01 X30
 Z-45;
 N30 G01 X40 Z-45;
 N35 G01 M17;

TAPER TURNING

N5 G54;
 N10 M42;
 N15 G95 S300 M.4;
 N20 T01 D1 M8;
 N25 G00 X01 Z0;
 N30 G01 X80 Z-45 F0.2;
 N35 G00 X81 Z0;
 N40 G01 X60 Z-30 F0.2;
 N45 G00 X81 Z0;
 N50 X50;
 N55 G01 Z-68 F0.2;
 N60 X60 Z-15;
 N65 G00 X51 Z0;
 N70 X40;
 N75 G01 X50 Z-6.5 F0.2;
 N80 G00 X200 Z200;
 N85 M30;

CAD MODEL

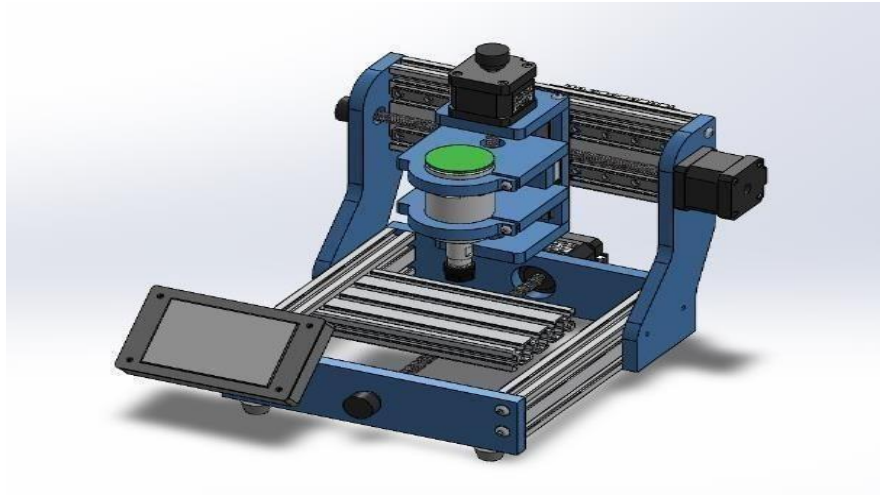
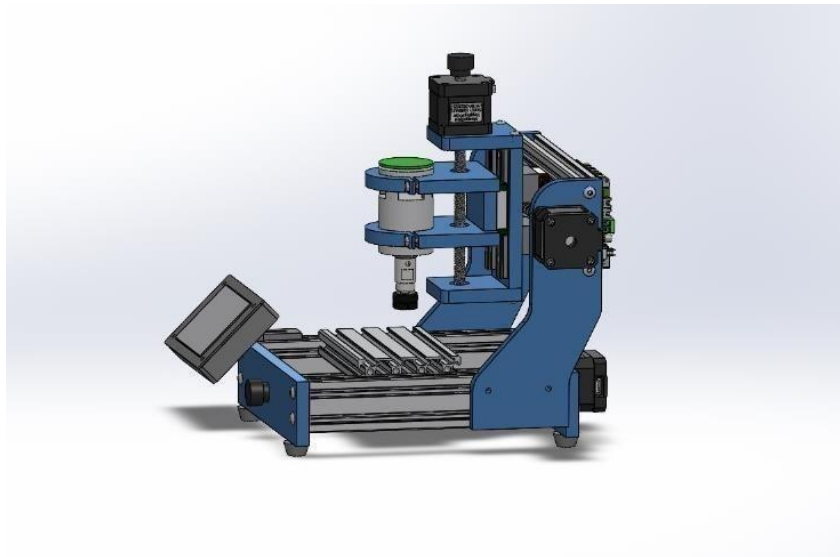


FIG 4.11 CAD MODEL



CHAPTER 5

CONCLUSIONS:

An Arduino based 3-axis CNC drilling machine for printed circuit board is implemented using Arduino controller, CNC router and open-source software for controlling the whole operations. This can be the invention for the electronic industries. This work has presented the result so development of a low-cost three-axis vertical CNC drilling machine suitable for adoption in small scale and large-scale Industries.

The total cost of the developed system is just about 1/20th of the existing commercial CNC machine used currently In the laboratory , though pedagogically our model

provides more scope for hands-on learning therefore better learning outcomes. It is hoped to extend this work in future to low-cost design and development of other CNC machines like lathe, router, and eventually customized open-source 3D printer.

Machine is easy to operate. It does not require skilled operator The machine reduces cost of production. The disadvantage of this machine is it cannot be used for large scale production and heavy object cannot be machined. The software used are MP lab for PIC Programming and Pick it 2 for IC Burning.

REFERENCES

1. "A CAPP/CAM expert system for a high productivity, high flexibility CNC turning centre," C. R. Bor, M. Petitti, F. Lombardi, and J.-P. Simon. 1990, pages 481-483, CIRP Ann.-Manuf. Technol., vol. 39, no. 1.
2. "Knowledge- edge management in process planning," CIRP Ann.-Manuf. Technol., vol. 56, no. 1, pp. 175-180, 2007. B. Denkena, M. Shpitalni, P. Kowalski, G. Molcho, and Y. Zipori.
3. "Process comprehension for shopfloor manufacturing knowledge reuse," Int. J. Prod. Res., vol. 52, nos. 23-24, pp. 7405-7419, 2013. X. Zhang, A. Nassehi, M. Safaieh, and S. T. Newman.
4. "An automatic feature- based cutting tool selection approach for turning process," International Journal of Current Engineering Technology, vol. 5, no. 5, pp. 1-18, Oct. 2015. O. Jaider, A. Rechia, A. El Mesbahi, and H. Zarkti.
5. "Determination of optimal path under approach and exit limitations," W. A. Khan, D. R. Hayhurst, and C. Cannings, Eur. J. Operational Research, 1999, vol. 117, no. 2, pp. 310-325
6. "A generative feature-based CAPP/CNC system for hydraulic manifold blocks," International Journal of Advanced Manufacturing Technology, vol. 19, no. 11, pp. 805-811, 2002.
7. S. Lu, T. Yu, and T. Liu, "Research on CAPP technology oriented to CNC," in

- Proceedings of the 9th International Conference on Control, Automation, and RoboticVision, December 2006, pp. 1-5.
8. "Application and execution of CNCBCAD&CAPP technology in INC," in Proc. Medit. Conf. Control Autom., Jun. 2007, pp. 1-5. S. Lu, X.-L. Cao, Z.-J. Cai, G.-R. Zeng, and T. Liu.
 9. Pierce point reduction and optimal torch route determination in flame cutting, J. Manuf. Syst., vol. 3, no. 1, pp. 81-89, 1984. [3] U. Manber and S. Israni.
 10. "Toolpath optimisation for minimising airtime during machining," by K.
 11. Castelino, R. D'Souza, and P. K. Wright. 2003, p. 173-180 in J. Manuf. Syst., vol. 22, no. 3. Application of genetic algorithm on IC substrate drilling route optimisation, C. Y. Tsai, C. H. Liu, and Y. C. Wang, Proc. Int. Conf. Adv. Mech. Syst., Sep. 2012, pp. 18-21.
 12. L. Chih-Ching, "A new approach to CNC tool path generation," Computer Assisted Design, vol. 30, no. 8, 1998, pp. 649-655.
 13. "CNC tool path planning for multi-patch sculptured surfaces," International Journal of Product Research, vol. 38, no. 7, pp. 1677-1687, 2000.
 14. V. M. Pedagopu and M. Kumar, "Integration of CAD/CAPP/CAM/CNC to increase the efficiency of CIM," Int. Rev. Appl. Eng. Res., vol. 4, no. 2, pp. 171- 176, 2014.
 15. J. Vedso, R. Geissbauer, and B. Misthal. (Aug. 1, 2016). Industry main results from industry 4.0 : Building the digital enterprise.
 16. Sriranga V Deshpande¹, P U Karthik, Naveen Kumar D, Dr Vijendra Kumar, Dr.K.S Badrinarayan, Department of mechanical engineering, Design and fabrication of 3-axis CNC Milling machine.
 17. Manjunatha C J, Manjunath K, Suresha P, Mechanical Dept, Sha-Shib College Of Engg & Technology /Vtu/Chickballapur / India, Design & development of portable milling machine.

- 18.S.B.Satpal, S.R.Gadilkar, S.M.Gaikwad, P.D.Karande, U.B.Kare, Department of Mechanical Engineering JSPM Narhe Technical Campus, Pune, Maharashtra, India, Review Paper On Design And Fabrication Of X-Y Gantry Mechanism For Chemical Handling In Chemical Industries
19. Mr. Prashil N Patel, Mr. Shreyas D Pavagadhi, Dr. Shailee G Acharya, Dept.of Mechanical Engineering, Sardar Vallabhbhai Patel Institute of
20. N. P. Maniar, D. P. Vakharia, Design & Development of Fixture for CNC Reviews, Practices & Future Directions.
21. M.Bhavani, V.Jerome, P.Lenin Raja, B.Vignesh, D. Vignesh, Department of
22. Mechanical Engineering, New Prince Shri Bhavani College of Engg and Tech, Chennai, Tamil nadu, India, Design and Implementation of CNC Router.
23. Sikandar Prajapati Aniket Jadhav Omkar Kekane Dilip Mahapatra Pro Vivek Sodaye, Department of Mechanical Engineering, Dilkap Research of Institute of Engineering and Management Studies University of Mumbai, India, Design and Fabrication of Desktop CNC Milling Machine.
24. Shubham Bhagat, Vednath Kalbande, Rajat Kakde, Department of Mechanical Engineering GHRCE, Nagpur, India, DBACER, Nagpur, India, Design & Fabrication of a CNC Lathe Machine Fixture for a Square Block.
25. Gautam Jodh, Piyush Sirsat, Nagnath Kakde, Sandeep Lutade, Department of Mechanical Engineering, DBACER, Nagpur, India, Design of low Cost CNC Drilling Machine.
26. Divyam Gupta & Purushottam Kumar Sahu PG, Scholar, Dept. of Mechanical Engineering, BMCT Indore, M.P., India, India, Design evaluation using CAE tools for a 3-axis vertical milling machine for sculptured surface machining.
- 27.1. PAS da Rocha R. Diogne de Silva e Souza, M E. de Lima Tostes, Prototype CNC machine design, 9th IEEE/IAS International Conference on Industry Application(INDUSCON), 2010, 1-5.

28. R E Breaz G, Racz O C, Bologa, Oleksik V S. Motion control of medium size CNC machine-tools: a hands-on approach, 7th International Conference on Industrial Electronics and Applications (ICIEA), 2112-2117, 2012, 8-20.
29. CNC Programming, Michael Mattson, Delmar Cengage Learning, 2010. Managing Computer Numerical Control Operations, Mike Lynch, Society of Manufacturing Engineers, 1995.
30. Hacı A, Jezernik K. The open CNC controller for a cutting machine, IEEE International Conference on Industrial Technology, 2003; 2(1231-1236):10-12
A knowledge-centric Machine Tool Design & Development Process Management
31. Framework", International Journal of Production Research, 2014, vol. 52, no20, 6033-6051, by Linyan liu, Barrets s.calwell, Huifen wang, Ying li
32. "Design and Implementation of Three dimensional CNC machine", International Journal of Computer Science and Engineering, Nov.2010, vol 02, 2567-2570, by Venkata krishna pabalu, Prof.K.n.h. shrinivas.
33. "Fabrication of Low cost 3 axis CNC Router", International Journal of Engineering Science Invention, ISSN (online):2319-6734, ISSN (print) 2319-6726 vol3 issue6, june2014 Dr.J.B.Jayachandraiah, O vamshikrishna, P,Abdullah khan,R.ananda Reddy.
34. Improvement on CNC gantry Machine structure design for higher machining speed capability- international journal of mechanical Aerospace industrial and mechatronics engineering vol 9 Nov 2015 by Ahmed a.d.sarhan s.r.besharaty , javedakbaria, m.hamdi
35. "Selection of Milling Machine Kinematic Structure Preliminary Selection of Structure Variants", Archives of Mechanical Technology and Automation, vol- 32 no.12012 65-75, by Grzegorz Szwengier
36. "Selection of Kinematic Structure for Portable Machine Tool", Advances In Manufacturing Science and Technology, vol.36, no.1, 2012 by Monika Nowak, DanielJastrzeb

37. PAS da Rocha R. Diogne de Silva e Souza, M E. de Lima Tostes, Prototype CNC machine design, 9th IEEE/IAS International Conference on Industry Applications(INDUSCON), 2010, 1-5.
38. R E Breaz G, Racz O C, Bologa, Oleksik V S. Motion control of medium size CNC machine-tools: a hands-on approach, 7th International Conference on Industrial Electronics and Applications (ICIEA), 2112-2117, 2012, 8-20.
39. CNC Programming, Michael Mattson, Delmar Cengage Learning, 2010.
40. Managing Computer Numerical Control Operations, Mike Lynch, Society of Manufacturing Engineers, 1995.
41. Hacı A, Jezernik K. The open CNC controller for a cutting machine, IEEE International Conference on Industrial Technology, 2003; 2(1231-1236):1
43. Shubham Bhagat, Vednath Kalbande, Rajat Kakde, Department of Mechanical Engineering GHRCE, Nagpur, India, DBACER, Nagpur, India, Design & Fabrication of a CNC Lathe Machine Fixture for a Square Block.
44. Gautam Jodh , Piyush Sirsat , Nagnath Kakde , Sandeep Lutade, Department of Mechanical Engineering , DBACER , Nagpur , India , Design of low cost CNC Drilling Machine.
45. M. Bhavani, V. Jerome, P. Lenin Raja, B. Vignesh, D. Vignesh, Department of Mechanical Engineering, New Prince Shri Bhavani College of Engg and Tech Chennai Tamil nadu India Design and Implement of CNC Router Sikandar Prajapati Aniket Jadhav Omkar Kekane Dilip Mahapatra Pro.