# Methodology for Selecting Components for Fabricating CNC Milling Machine for Small Scale Industry

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

***Key words:*** Computer Numerically Controlled, CNC Milling Machine

## I. INTRODUCTION

CNC (computer numerically controlled) mills cut objects out of durable materials and are widely used in modern manufacturing. They enable rapid prototyping in workshops and improve the speed and efficiency of factory lines. In modern CNC systems, end-to-end component design is highly automated using computer-aided design (CAD) and computer-aided manufacturing (CAM) programs. The programs produce a computer file that is interpreted to extract the commands needed to operate a particular machine via a post processor, and then loaded into the CNC machines for production. Since any particular component might require the use of a number of different tools – drills, saws, etc., modern machines often combine multiple tools into a single "cell". In other installations, a number of different machines are used with an external controller and human or robotic operators that move the component from machine to machine. In either case, the series of steps needed to produce any part is highly automated and produces a part that closely matches the original CAD design. With the on-going development of technology and economy, new industrial requirements such as high precision, good quality, high production rates and low production costs are increasingly demanded. Most of such requirements, including dimensional accuracy, conformance to tolerances of finished products and production rate can be met with better machine tools. With the help of CNC technology, machine tools today are not limited to human capabilities and are able to make ultra-precision products down to nano scales in a much faster manner. The traditional design philosophy of machine tools is multifunctionality and highest precision possible. However, with the dramatic increase of industry varieties and the growing demand of miniature products, these general purpose machine tools are not efficient, either in terms of machine time or cost, in manufacturing products with special sizes and precision requirements. There are several advantages of using small machines to produce small sized objects. With a smaller machine size, space is saved. The energy required to operate the machine is reduced as well. It now requires less material and components to make the machine, hence bringing down the cost greatly. The weight of moving component also comes down so that during operation, the vibration and noise, as well as pollution to the environment, are markedly reduced. As the machine becomes denser and lighter, it becomes more portable. The layout of the manufacturing plant can be more flexible. The productivity and manufacturing speed also increases due to possible faster operation.

## II. LITERATURE REVIEW

Given the limitations of commercial CNC machines for large scale deployment in educational environments, several authors have studied the development of such machines on a smaller, low-cost scale. For example, Pabolu and Srinivas [4] have designed and implemented a three axis CNC machine using an 8-bit microcontroller. The development is in .Net platform using C# programming language on a Windows XP computer, but the motors have limited power. Andrei and Nae [5], [6] have developed a simpler commercial size CNC router (worktable dimensions: 624x824 mm) running with Mach3 software on a desktop PC, but requiring a parallel port.

A low-cost, design and evaluation of a CNC machine for modeling and educational purposes is proposed by Pahole, et al. [7]. The working dimensions are 180x140x250 mm. The static rigidity and positional accuracy of the machine are experimentally measured, and the commercial Mach3 machine control software is used with a parallel port-equipped personal computer. Sherring da Rocha, et al. [8] have presented a prototype CNC machine under development running on a PC with Lab VIEW which has advantage of ease of visual programming tools. The PC is interfaced with low-cost embedded microcontrollers through the serial port.

The CNC machine designs above rely on the use of stepper motors of limited power in open loop mode. Xu, et al. [9] discuss results of research on an open CNC system using Windows PC with a four-axis motion controller. Wang, et al [10] have developed a CNC system using real-time Ethernet for connection to machine hardware under the Windows NT operating system, with the non-real-time aspect of the operating system accounted for, e.g., by buffering of packets sent. As Windows OS is not guaranteed to provide real-time performance, the use of RTLinux for a software-oriented CNC system with a prototype controller is presented in [11].

 

## III. OUTCOME OF LITERATURE

A major new development in computer technology is the availability of low-cost open source hardware, such as the Arduino microcontroller platform and the Raspberry PI single board computer. An advantage of open source hardware is that a wide variety of ready-to-use software is available for them on the Web; therefore the prototyping and development times are drastically reduced. Moreover, a wide range of low-cost interfaces, sensors, and accessories such as Arduino shields are also available on the Internet, along with clear instructions, examples, and applicable program code.

Predating the open source hardware, several useful open source software tools have been available in the area of CAD/CAM/CNC software, though these are not so versatile or powerful as the well-established commercial versions. However, for the development of low-cost educational models of CNC machines, such tools may be quite adequate from the viewpoint of machine control. Therefore, in this the development of a Design & Fabrication of CNC mill machine (using Arduino-based control System) is presented.

## IV. OBJECTIVE

- Most milling machines are costly and difficult to use, keeping them out of reach for individuals and small businesses. High initial cost and requirement of skilled labour for operating the CNC machine not suitable for use in small or medium scale industries.
- In many Indian engineering educational institutions the CAD/CAM and Manufacturing Technology Laboratories are equipped mainly with large commercial CNC machines which are prohibitively expensive and moreover are overdesigned considering the pedagogical needs of undergraduate students. They come with costly annual maintenance contracts and are time-consuming and expensive to repair in the case of breakdowns. Many of these arguments hold well in the case of polytechnic colleges in India, which are heavily hands-on and are in need of affordable laboratory CNC machines.
- The idea behind study Design & fabrication of low cost CNC mill machine is to full fill the demand of CNC machine from small scale to large scale industries with optimized low cost.
- Easily operable.
- Easy interface.
- Flexible.
- Low power consumption.
- Clear, easy to follow design.
- Comprehensive construction and operation manual.
- It should be available for educational purpose at low cost.
- It will be easy to maintenance.

## V. PROPOSED METHODOLOGY

This system can be divided in to three modules. As shown in fig. 2 Mechanical system gets necessary control signals from electronics system which ultimately results in desired actuation of motors. Electronics system gets command or a set of commands from software system and generates controls for mechanical system.

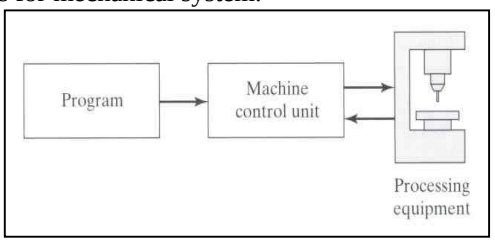


Fig. 1: Basic CNC Methodology

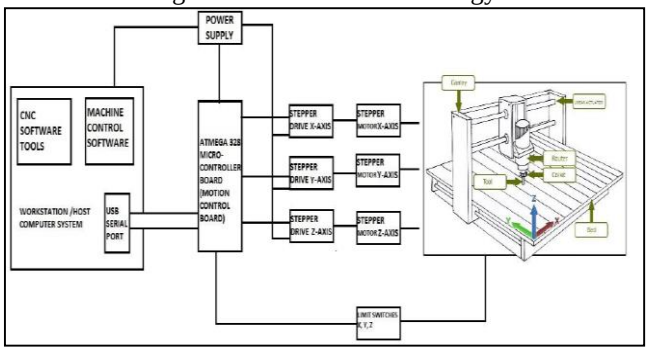


Fig. 2: Block Diagram of Overall Process

The working methodology of system is well explained in the above fig 2 the detail explanation is given by dividing the system into three modules.

### *A. Mechanical System*

The mechanical system which is assembled in such a way that the 3-axis movement is achieved by using the linear rails assembled with linear bearings. Stepper motors are mounted to the each axis which is source of motion acted according to the control signal generated from the electronics circuit. Each stepper motor is coupled through the shaft couplers to each of the Lead/Ball screw of each axis which is responsible for converting the rotational motion of the stepper motor to linear motion. The linear motion of each axis is carried away smoothly by the linear rail assembly connected to the each axis which is capable of load carriers and allows linear motion in each axis. The controlled motion in each axis is achieved directly by controlling the rotation of the stepper motor. The speed of the motion in each axis can also be controlled by direct control of the speed of the stepper motor by giving required control signals. Thus the tool path of the spindle fixed to the end effectors is controlled in each axis for smooth carving or cutting action of work piece

### *B. Electronics System*

Electronics system is responsible for generating control signal to the stepper motors which guides the motion of tool path in each direction or axis. Electronics system is comprises of

- Power supply
- Microcontroller board and
- Stepper motor driver board

### *C. Software System*

Mach3 turns a typical computer into a CNC machine controller. It is very rich in features, works on most Windows PC's, and is customizable for many applications. Mach3 is the most intuitive CNC control software available.

Main features include:

 

- Allows direct import of DXF, BMP, JPG, and HPGL files through Lazy-Cam
- Visual G-code display
- Generates G-code via Lazy-Cam or Wizards
- Fully customizable interface
- Customizable M-Codes.

## VI. PROJECT MACHINE SET-UP

Machine structure is the "backbone" of the machine tool. It integrates all machine components into a complete system. The machine structure is crucial to the performance of the machine tools since it is directly affecting the static and dynamic stiffness, as well as the damping response of the machine tool. A carefully designed structure can provide high stiffness, result in higher operation bandwidth and more precise operation. A small-scale machine tool generally requires even higher stiffness than the ordinary large-scale machine tool since it is usually operated at higher speeds.

- Granty style closed frame structure is chosen for our project setup which provides a strong ridged structure loop, symmetry, and good thermal stability, which provides better stiffness than the open frame structures generally used for easy access to the work zone, with the same order-of-magnitude in size. Closed frame structures typically are used in precision machines such. Therefore it is much easier to move the tool with respect to a fixed work piece. This structure consumes less material, hence is very less expensive to build. Most machines designed for cutting flat steel plate use a gantry design because it is an easy way to move cutting tools in an Z-X coordinate system.
- The rail system that the gantry rides on forms one axis, usually the Z-axis. The gantry bridge itself forms the other axis, usually the Y-axis. By motorizing each axis and coordinating the motion of the two axes simultaneously, we can move a torch in any pattern necessary to cut shapes out of steel plate. Thus, a gantry design lends itself to CNC shape cutting, which primarily uses a Z-X coordinate system for programming parts.
- A gantry cutting machine will ride on some sort of rail system in the Z-axis, either floor mounted, pedestal mounted, or sometimes integrated onto the side of a table. The rails are designed to provide accurate motion for the machine, and are strong enough to support the weight of the entire machine and all of the equipment mounted to it.
- Depending on the size of the machine, these rails can be as simple as a small strip of metal, or as complex as a recirculating ball bearing linear rail system, or as large as a railroad train rail.

A gantry cutting machine will also have some sort of guiding system in the X-axis too, which is mounted to the bridge structure itself. The X-axis guiding system will usually be smaller than the Z-axis rails, because they only have to carry the weight of a small carriage and cutting tool, not the entire gantry. Gantry machines may have one tool carriage or many tool carriages. Sometimes the tool carriages will each have their own drive motor that moves them in the X-axis, and sometimes there will be only one motor that drives the X-axis, and all of the tool carriages will be connected together by a steel band, tie rod, wire rope, or similar mechanical device.

## VII. DESCRIPTION OF COMPONENTS

### *A. Ball/Lead Screws*

A ball screw is a mechanical linear actuator that translates rotational motion to linear motion with little friction. A threaded shaft provides a helical raceway for ball bearings which act as a precision screw. As well as being able to apply or withstand high thrust loads, they can do so with minimum internal friction.

- Steel ball
- Screw shaft
- Ball nut
- Seal (both sides of ball nut)
- Recirculation parts (return tube, etc.)

### *B. Ball Bearings*

A ball bearing is a type of rolling-element bearing that uses balls to maintain the separation between the bearing races. The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads.

### *C. Linear Rods*

Linear rods are rigid strong Mild Steel shafts which are used to carry the load without affecting the motion and supports linear movement. Linear rods with linear bearing assembly are used to carry the loads and support the structures in linear motions the total load of the structure is taken away by the linear rod bearing assembly and therefore the load on ball screw is reduced and causes precise smooth linear motion.

### *D. Linear Ball Bearings*

A linear bearing is to provide free motion in linear direction. The load is carried away by the linear bearing and reduces friction slides over linear rods. A linear-motion bearing or linear slide is a bearing designed to provide free motion in one direction. There are many different types of linear motion bearings. A rolling-element bearing is generally composed of a sleeve-like outer ring and several rows of balls retained by cages. The cages were originally machined from solid metal and were quickly replaced by stampings. It features smooth motion, low friction, high rigidity and long life. They are economical, and easy to maintain and replace.

### *E. Shaft End Supports*

Shaft supports are used to support linear rods /shafts rigidly without slip. Shaft support blocks are used for end or intermittent support where loads are light and slight shaft deflection is not a concern.

### *F. Shaft Couplings*

A Shaft Coupling is a device used to connect two shafts together at their ends for the purpose of transmitting power. Couplings do not normally allow disconnection of shafts during operation, however there are torque limiting couplings which can slip or disconnect when some torque limit is exceeded. The primary purpose of couplings is to join two pieces of rotating equipment.

 

### *G. Stepper Motor*

A stepper motor is a brushless, synchronous electric motor that converts digital pulses into mechanical shaft rotation in a number of equal steps. The motor's position can then be commanded to move and hold at one of these steps without any feedback sensor (an open-loop controller). A NEMA 23 stepper motor is a stepper motor with a 2.3 x 2.3 inch size is chosen to drive the motion of the axes. NEMA 23 stepper motors are high torque about 19KG-Cm holding torque .NEMA 23 stepper motors have 1.8 degree step angle with 2.5A rated current**.**

### *H. Stepper Motor Driver Board*

Driving a stepper motor is a bit more complicated than driving a regular brushed DC motor. Stepper motors require a stepper controller to energize the phases in a timely sequence to make the motor turn. ULN-2003 is micro-stepping drive designed for smooth and quiet operation is chosen to drive the NEMA 23 stepper motor ULN-2003 achieves micro-stepping using a synchronous PWM output drive. Mismatched motors and drivers can result in disappointing performance. Or worse: damage to the motor and/or controller.

### *I. Microcontroller Board*

Atmega 328 p Arduino Development board is used as the motion control board. Atmega 328 p is a 16 bit 24 pin ARM Architecture microcontroller. The microcontroller is flashed with the GCODE interpreter firmware written in optimized "C" language. Motion control is carried away through output pins connected to the stepper motor drives according to the firmware code in microcontroller. Inputs like RESET, FEED HOLD, CYCLE START/RESUME and axis Limits are given to the Inputs of microcontroller.

### *J. 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 pin from limit switches is connected to the microcontroller board to sense the axes ends.

## VIII. CONCLUSION

With the increasing no. of small scale industries demand for small scale, high precision parts in various industries, the market for small scale machine tools has grown substantially. Using small machine tools to fabricate small scale parts can provide both flexibility and efficiency in manufacturing approaches and reduce capital cost, which is beneficial for small business owners. In this paper, a small scale three axis CNC milling machine's component discuss and analyzed under very limited budget.

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