Design and Construction of a Low-Cost, Three-Axis Computer Numerical Control Machine

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Abstract- Over time, there has been a significant expansion in the applications of CNC machining. Majority of the CNCs that are now available are gigantic and costly. As a result, this work uses an Arduino-based electronic system to design and build a straightforward, reasonably affordable, three-axis Computer Numerical Control (CNC) machine without sacrificing the high precision associated with such machines.

I. INTRODUCTION

Machines such as lathes, mills, grinders, etc. are controlled by computers through a technology known as computer numerical control (CNC) machining. Soft automation of high-quality products is made possible by CNC machines in a secure, repeatable, and accurate manner. CNC refers to the automation of machine tools through the use of computers to carry out pre-programmed commands for the machine. This contrasts with devices that are mechanically mechanized by cams alone or manually operated by levers or wheels (Prabhanjay, Vikas, Mayur, & Wasim, 2017; Siti, 2013; Bhavani, Jerome, Raja, & Vignesh, 2017).

Due to their high efficiency, flexibility/expansion choices, and decreased production material waste, CNC machines are increasingly being used for all types of applications (both industrial and personal) (Khan, Mehtab, Hasan & Hussain, 2014; Mohammad, Ansary & Mondol, 2017). Sincethey can perform a wide range of tasks, including but not limited to cutting, milling, engraving, boring, welding, spinning, plotting, turning, drilling, grinding, punching, etc., CNC machines are multipurpose. They have the ability to perform all of these tasks at once (Balasubramanyam & Prasanthi, 2014; Sutarman, EdiHermawan, & Sarmidi, 2017).

According to Torjus (2014), CNC system uses a microprocessor to process a set of program instructions before sending output control data to a machine tool. Additionally, a transducer attached on the machine tool provides feedback, and using the instructions and feedback, ensures that the machine tool operates with the appropriate speed, motion, and operation.

The planned CNC machine uses three main software packages—computer-aided design (CAD), computer-aided manufacturing (CAM), and control software (in this case, Mach3—to accomplish its overall goal. Using CAD, the machine's user may create two- and three-dimensional objects that the CNC machine can cut, drill, and do other things to. Using CAD, product designs and models are graphically created. These designs and models can then be examined, changed, and improved for the best usage and application. The design (created in CAD software) is translated by CAM into the G-Code programming language. Computer-Aided Design (CAD), Computer- Aided Manufacturing (CAM), and control software (MACH3 in this example) are the three main software packages used by the intended CNC machine to accomplish its ultimate goal. The CNC machine's user can design two- and three-dimensional items in CAD to be cut, drilled, and used for various purposes by the CNC machine. For the best end use and application, product designs and models are graphically created using CAD. These designs and models can then be evaluated, changed, and polished. The design (created in CAD software) is converted by CAM into a language called G-Code.

Due to chemical exposure risks and time requirements, the conventional manual technique of producing PCBs through the chemical etching process is risky. Additionally, many PCBs are wasted as a result of mistakes with incorrectly placed holes. These issues are anticipated to be resolved by the planned CNC machine, which creates PCBs of exceptional quality and accuracy without wasting any PCB materials. With the help of this machine, laser cutting of components for enclosures and final packing is also possible (Pandey & Sharma, 2017; Prabhanjay, Vikas, Mayur & Wasim, 2017; Basniak & Catapan, 2012).

- Related works

Many years ago, Numerical Control (NC) was the precursor to what is now known as a CNC. In programmable automation, numerical control refers to the use of numbers, letters, and symbols to direct a process. It is a technique for managing production operations through the machine tool's direct insertion of coded numerical instructions. NC is not a machining technique but rather a machine control philosophy.

Amir K (2018) developed a small, a three-axis, inexpensive CNC machine. The use of stronger motors, a worktable and edge reinforced with materials like cast iron or aluminum, and expanded CNC control programming with role-playing before actual operation were all made.

John T. Parsons of the Parsons Corporation, a maker of helicopter rotor blades, attempted to mechanically construct a curve by milling cutters by providing coordinate motions. It was his pioneering effort that led to the development of numerical control. However, Parsons came up with the idea of using punched cards that had a coordinate positioning system to operate a machine tool in 1947. In 1948, Parsons presented this idea to the US Air Force, which had been looking for ways to speed up the production of its aircraft and missiles and had financed a number of projects at MIT's servomechanisms laboratory. After conducting extensive study, MIT took over the entire project in 1951. In 1952, they were able to exhibit the first NC prototype, and the following year they were able to illustrate the prospective uses of NC. In order to obtain results, John Parsons collaborated with Frank L. Stullen, a colleague at Parsons Corporation (Ambrizal, Farooqi, Alsultan & Yusoff, 2017; Singh, Verma & Jain, 2014). This is vital to remember.

The first CNC was created later, when John Runyon was successful in producing punch cassettes under computer control. In 1959, the MIT team demonstrated a completely automated machine that produced aluminum ashtrays, which was the actual birth of CNC machining. Modern CNC machines were created when servomechanisms were improved with analog and digital processors, changing the machining process. The development of these modern CNC machines coincided with the development of computers in the 1980s. The machines were initially complicated, multipurpose, took up a lot of room, and used a lot of energy. However, more recently, portable designs with specific tasks have emerged, which have reduced size, cost, energy consumption, and space. These more compact CNC machines can be constructed or customized for specific tasks and are just as effective and precise as traditional machines. They are suitable for individuals using them for personal use, small-scale business owners, and teachers (Patil & Mishra, 2017; Wei, 2013).

II. METHODOLOGY

Several hardware elements make up the CNC machine system, as shown in Figure 1.

A low-cost, three-axis CNC machine is designed and constructed in three fundamental stages, each of which is executed as follows:

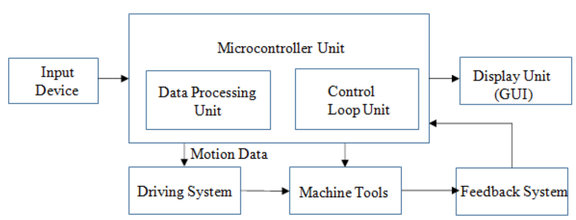

Figure 1: Hardware Components of a CNC Machine System

CONSTRUCTION OF MECHANICAL FRAME: In order to construct a mechanical frame/structure that could withstand static, dynamic, and thermal loads, SolidWorks was used to model the frame/structure. The following materials were utilized based on this design. Medium- density fiberboard (MDF) was used to create a rigid material that works well for drilling and cutting. It was selected because it is extremely durable and dimensionally stable, which means that it does not contract or expand in response to variations in the humidity or weather. MDF is simple to work with, does not splinter like plywood, and has a flat surface that is good for cutting and painting. Additionally, screws, bolts and nut, and bearings that permit friction-free movement wereused.

When a CNC machine is not coupled with CAD/CAM software, input devices are utilized to input part programs into the CNC control unit. Some examples of CNC input devices include floppy disk drives, USB flash drives, Ethernet communication using LAN cables, conversational programming, and serial communication by connecting a computer using an RS-232-C serial port. The Machine Control Unit (MCU), the mind of the CNC machine system, is composed of the Control Loop Unit (CLU) and the Data Processing Unit. Its CNC control software allows it to perform a variety of jobs, including:

It interprets the programs' G-code and M-code instructions.These coded instructions are decoded by it.

It generates axis of motion commands by applying geometric interpolations that are linear, helical, and circular to the G-code.

It supplies the driving system with axis of motion commands, which the driving system utilizes to drive the axis mechanisms via amplifier circuits.

The feedback system sends position and velocity feedback data for each driving axis to it.

It implements the M-code for the machine tool's auxiliary/unique control operations, such as tool changing, spindle operation, coolant on/off, etc.

Simply expressed, the MCU handles all of the CNC machine system's controlling tasks.

All CNC machine tools have a spindle and sliding table for holding the workpiece or cutting tool and regulating its speed and position. The X-Y axis is used to control the sliding machine table's movement in both directions. While the Z-axis of the machine tool is used to control the spindle'srotating motion.

Speed and position transducers, which serve as sensors to continually track the instantaneous speed and position of the cutting tool at any given point, make up the feedback or measuring system. They then provide feedback signals to the MCU using this data. The Machine Control Unit then creates control signals by comparing the feedback signals with the reference signals and sending them to the driving system to correct position and speed errors.

The driving system in a CNC machine is composed of drive motors, ball lead screws, and amplifier circuits. The MCU sends feedback signals (position and velocity) from each drive axis to the amplifier circuits. The improved position and speed control signals from the circuits are then used to turn on the drive motors. The ball lead screw is rotated by the actuators of the drives motors, which then position the sliding machine table and spindle at the correct geometric set points. Overall, the drive unit physically realizes the planned tool path created by the MCU.

Display Unit: To enable interaction between operators and the CNC machine, this unit makes use of application software. Programs, control commands, and other helpful operational data for the CNC machine can all be shown using the GUI. Commissioning engineers and operators can configure, oversee, and control the CNC machine using the information displayed.

All power-consuming gadgets are primarily powered by a solar power system. Additionally, a 1 kVA inverter was added for continuous power delivery. Cable: This is available in a range of sizes, including 6mm2 for connections to solar power systems. Nut screws are used to attach the stepper motors to the machine structure. The X, Y, and Z axes were coupled to the three stepper motors. After all the electrical connections have been made, each stepper motor is tested individually. Following microcontroller programming, the individual stepper motor drivers are connected to thecentral driver board, which is then connected to the Power Supply (SMPS) once more. Finally, thesupplied solar power system is connected to the SMPS.

Software packages that convert from one file to the other, give specialized instructions to the machine and control the machine parameters. These are CAD, CAM and MACH3. The flow of operation of these software packages is shown in Figure 2.

Software programs that convert between different file types, direct the machine specifically, and regulate machine settings. They are MACH3, CAD, and CAM. Figure 2 depicts the way these software packages operate.

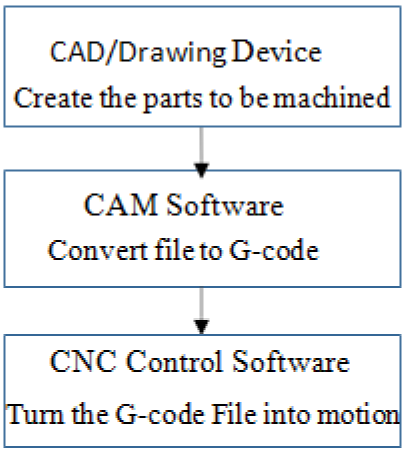

Figure 2: Sequence of Programming

The CNC machine's control unit that executes the G-code and M-code programs is known as the Machine Control Unit (MCU). The programming gives the MCU the necessary tool routes, cutting tool speeds, workpiece feed rates, as well as other pertinent data like tool changes, coolant usage, and when to end the running program.

The processing equipment is a collective term for the many machine tools used in machining processes like turning, milling, drilling, etc. In order to carry out particular machining operations, a range of CNC machines are available, such as lathes (used for turning), mills, drills, grinders, plasma cutters, laser cutters, and many more.

III. RESULT AND DISCUSSION

Gcode Sender is used for transferring the G-code data to an Atmega 328, which acts as a coordinated equipment interpreter. A G-code program can be imported into Gcode Sender, which will then send it line by line to the Atmega 328 microcontroller. The USB communication between the PC and microcontroller will be used to send the Gcodes across the serial ports. Programming called GRBLl Controller is designed to send GCode to CNC machines. Fig. 3 depicts the construction of the CNC milling machine with computer controller screen window.

Figure 3: The CNC milling machine with computer controller screen window

The machine process makes use of a graphical user interface (GUI), such as "EASEL," which is visual software that runs on a PC and creates and designs images that are then transformed to code files that are utilized to run the design into GRBL Controller. Fig. 4 displays the Easel Software milling text "FEDERAL POLYTECNIC ILARO"

Figure 4: Milling text by Easel Software

CONCLUSION

The selling price for 3-axis micro CNC machines has significantly gone up as a result of the rising demand for small-scaled, highly accurate parts in many industries. The CNC machine has attained the required level of precision and accuracy for manufacturing small parts, which require both flexibility and efficiency in the manufacture and assembly.

In this study, a small, low-cost, three-axis CNC machine was designed and built. Numerous standard

CNC techniques were used to lower overall costs throughout the structural design phase, making them affordable for consumers and small businesses. Success in choosing body parts and accuracy in calibration, testing, and constructions has led to their discovery and testing. The gantry type structure was determined to be the most acceptable construction and was created using AutoCAD software. In order to meet the specifications, delicate components such liner guides, stepper motors, microcontrollers, and modules are carefully selected from a vast array of options.

In conclusion an affordable, three-axis Computer Numerical Control (CNC) machine without sacrificing the high precision associated with such machines is constructed in this work.

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