A Working 3 Axis - Mini Cnc Machine

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Abstract- *This project speaks about the design and realization of a complex 3- axis CNC machine based on a microcontroller with serial communication, which is combined with a spindle drill. This machine can be used for drilling, milling and cutting on acrylic and wood objects. The instructions are fed by the operator using a combination of G and M Code programs on the computer, which is sent to the microcontroller. The CNC machine interprets the program and performs execution on the workpiece as per the point coordinates. Drill spindles will be used to create designs on the workpiece as per the instructions given by the operator in the form of the program. After testing, the CNC machine can be used for drilling, milling and cutting on acrylic and wood objects with 98.62% of carving accuracy and 97.67% of depth accuracy. This machine works on a workpiece with a maximum size of 20 x 25 cm.*

Keywords- CNC, Programming, Microcontroller, Drilling, Milling and Cutting

I. INTRODUCTION

CNC stands for Computerised Numerical Control. CNC Machining is about automating the machine tool operations for more precision and ease in manufacturing.

Today, computer numerical control (CNC) machines are found almost everywhere, from small job shops in rural communities to Fortune 500 companies in large urban areas. Everyone involved in the manufacturing environment should be well aware of what is possible with these sophisticated machine tools. Especially, working with automatic mechanical equipment demands precise, accuracy, speed, consistency and flexibility. In this case it takes the help of embedded computer applications to do the job. One of the mechanical equipment combined with microcomputer that has been widely used is a CNC machine.

Research on the manufacturing of CNC machines and the fundamentals of embedded algorithms using microcontrollers have been widely practiced with the aim of producing high performance and economical CNC machines. A fundamental research by D. Awari [1], conducted a study for the selection of parts to build a CNC milling machine that not only performs the job, but also is economically feasible for a small scale industry. Another research work on CNC machine by M.A.A Ali [2], explains the use of a controlling system for CNC machines to perform milling and drilling operations on a PCB board. The main objective of this work is to produce efficiency, mitigate errors, and also enhance the accuracy of the operations performed. From the review of the research discussed above, it can be concluded that the research on a CNC machine, both hardware manufacture and algorithm development is active in order to build a good performance and economical CNC machine.

Therefore, in this paper is discussed a design of an economical 3-axis CNC machine based on microcontroller as its main control. In this CNC machine, a spindle drill is mounted, that can move automatically with the help of stepper motors. This machine can be used as a tool to create designs by performing operation such as Drilling, Milling and Cutting on acrylic and wooden workpieces. This paper also discusses the results of testing the CNC performance parameters in detail.

II. LITERATURE STUDY

1. 3 axis CNC machine controllers by Mohd Abdul Rahman, University of Malaysia, Pahang, 2013

This study focuses on the programming of 3 Axis CNC machines where user can key in the data through Visual Basic software and as the results, CNC 3 axis machine will move according to the user data input. These project required 3 stepper motor as the motor is use to move the machine into X, Y and Z directions. The motor then will connect to the output of transistor. The inputs of the transistor are connecting to the parallel port that will connect to the computer. The most important part in this project is the programming. The movement is control by the program that will be written on C programming that was built in Visual Basic software. This program will determine how many rotations that the motor will rotate as the rotating motor will cause the distance of the machine move according to its axis. The programs also will activate the address on the parallel port so that parallel port will send the signals to the input controller. As a result, the motor will move and the machine also will go to its locations depends on the user data input.
We inferred the idea of using parallel ports and will be using a

GRBL shield embedded with an Arduino Uno to interpret the CNC programming using G codes.

2. Fabrication of Low Cost 3-Axis CNC Router Dr.B. Jayachandraiah, O. Vamsi Krishna, P. Abdullah Khan, R. Ananda Reddy.
Volume 3 Issue 6‖ June 2014 ‖ PP.01-10

This paper discusses the development of a low cost CNC router 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 micro- controller 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.

Finally, from this paper we understood the different requirements and the problems involved in making a working CNC model. It helped us understand the basics of the CNC while also showing us the importance of all the different aspects which we come across while building a CNC machine. The study was very helpful and served as backbone for our project. It showed us the importance of miniaturization and how in recent times it has taken more priority due its small scale high precision parts. A small scale three axis CNC milling machine is designed and analysed under very limited budget

III. DESIGN AND METHODOLOGY

The main tools used in the mechanical design consists of multiplex board, linear bearing, linear shaft, stepper motor, ball bearing, coupling beam, lead crew and nut, spindle drill and power supply.

Figure 1 shows the 3-Dimensional design of the CNC machine made using NX software.

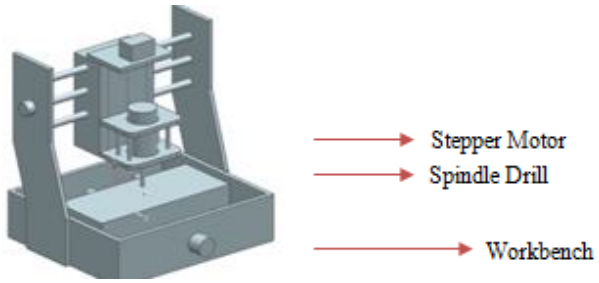

Figure 1: CNC machine viewed from top left corner

The design we put together is a basic relatively cost effective working model of the CNC machine. It supports translation in three axes X Y and Z. Translatory motion is carried out by two movable supports connected to a base frame which hold the entire structure of the machine.

The design is a that of a stationary bed CNC machine. The advantage of using a stationary bed is that the design of the CNC can be versatile and over size of the machine is limitless. The material used is medium density firewood or MDF. We are using MDF because it is stronger than wood, cheaper than aluminium and easier to work with than metals. We are using an Arduino controller kit. Due to its open source, it's design schematics, PCB files and codes for the CNC are easily available and can be downloaded at any instant.

The spindle is housed in the tool station which is supported by the smooth steel rods that are connected to the vertical MDF supports. The stepper motors are connected to the tool station via the steel rods that allow movement of the tool in the required direction.

The lead screws are used to translate turning motion to linear motion. Lead screws are used to couple with the stepper motors to control the translation of the machine tool along the 3 axes. The pitch of the lead screw and the basic length unit should be considered while selecting the lead screw. The basic length unit is minimum distance the machine tool will move. It can be found by dividing the pitch with the number of pulses per resolution.

The electronic system used in the CNC machine based on a microcontroller are the power supply which is used as a voltage source for the CNC machine. A personal computer was used as means to run various software's like Universal G-Code Sender, Xloader and Arduino IDE, and also to send program instructions to Arduino Uno ATMega 328p microcontroller using serial communication. A 12V 30A DC power supply was used as the voltage source to run the 3 *Nema* 17 Stepper motors which is controlled by Arduino Uno ATMega 328p microcontroller. The 3 *Nema* 17 stepper motors will move the spindle drill in the direction of the X, Y and Z axes to perform Drilling, Milling or Cutting operations on the workpiece as per the instructions from the program coded by the operator.

The following are the specifications of microcontroller based CNC machine that has been built.

Dimensions (XYZ) : 38x40x57 cm
Workspace area : 20x25 cm

Material : Medium Density fireboard
Stepper Motor : *Nema* 17 12V 1.7A
Driving system : Lead screw 8mm diameter
Controller : Arduino Uno (ATMega 328p)
Function : Drilling, Milling and Cutting.
Supply : 220V, 50Hz
Interface : USB port
Motor speed : 1000 rpm
Software : Universal G-Code Sender, Xloader and Arduino IDE

Figure 2: Front view of the assembly of the building frames, lead screws and stepper motors.

Figure 3: Rear view of the assembly of the building frames, lead screws and stepper motors.

IV. TESTING AND ANALYSIS

To be able to test the CNC machine in performing drilling, milling and cutting on acrylic and wood objects, the first step that must be prepared was programming. Then prepare the wood board in size of the design to be formed and then clip above the CNC machine cross section so it won't change position during the workmanship. Upload the program using Universal G-Code Sender software into the Arduino using serial communication.

ACCURACY TEST:

The accuracy test was conducted to determine the level of precision of CNC machine in making the shape as programmed. This test input was a 6 lines design with 50mm length, which will be formed on a wood with 1mm depth. using 4mm drill bit, with 1000 rpm spindle speed.

TABLE 1: ACCURACY TEST

SL NO.	DESIGN	MEASUREMENT RESULT	ACCURACY
1	20mm	20.2mm	99.00 %
2	20mm	20.5mm	97.56%
3	20mm	20.3mm	99.52%
4	20mm	20.2mm	99.00%
5	20mm	20.4mm	98.03%

From testing result on Table 1, it was obtained a test result in a form of 5 lines with 20mm length in average and 98.62% accuracy level.

Figure 3: Accuracy test specimen

DEPTH MEASUREMENT TEST:

This measurement was conducted to determine the level of precision on the depth of CNC machine when working. Testing was creating 7 lines, each of which has 5cm length and 2mm depth using a 4mm endmill drill bit with a spindle speed of 1000rpm.

Table 2 shows that the line carving produced by the CNC machine with 5mm depth has a precision accuracy of 97.67%.

TABLE 2: DEPTH MEASUREMENT

SL NO.	DESIGN	MEASUREMENT RESULT	ACCURACY
1	5mm	5.1mm	98.03%
2	5mm	5.2mm	96.15%
3	5mm	5.1mm	98.03%
4	5mm	5mm	100%
5	5mm	5.2mm	96.15%

Figure 4: Depth Measurement test specimen

V. CONCLUSION

The CNC router machine was successfully built using ATmega328p microcontrollers combined with 3 Nema 17 stepper motors, with 20x20cm cross-sectional area and using GRBL shield. The CNC machine can be used for drilling, milling and cutting on acrylic and wood objects with 98.62% carving accuracy and 97.67% depth accuracy. The process of synchronizing the 3 stepper motors was controlled using GRBL library and Universal G-Code Sender Software.

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