Available online at www.ejournals.uofk.edu

UofKEJ Vol. 9 Issue 1 pp. 1-4(February 2019)

UNIVERSITY OF KHARTOUM ENGINEERING JOURNAL (UofKEJ)

Design and Manufacturing of a Low Cost 3 Axis CNC Router Machine

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Abstract: Computer numerical controlled machines (CNC) are playing a huge role in the Industry today. It is capable of producing complex parts in large volumes along with keeping high level of accuracy. This paper presents a simple design of a 3 axis CNC routing Machine. The machine is driven by stepper motors utilizing lead screws and guides manufactured in a local workshop using conventional manufacturing techniques. The machine is controlled by Mach-3 open source software connected to the machine via parallel port and a breakout board which is connected directly to stepper motors. The hand calculation for the design of the lead screws and the sizing of the motor were carried out. The 3D model was built using Computer aided design software. After the fabrication experimental tests were conducted to measure the performance and the accuracy of the CNC.

Keyword: *Computer numerical controlled machines, Computer Aided Manufacturing, Computer Aided Design.*

1. INTRODUCTION

Computer numerical controlled (CNC) machining is the process of manufacturing machined parts in a production environment, as controlled and allocated as a computerized controller that uses motors to drive each axis [1]. The controller can control different parameters such as feed, depth of cut, speed and direction of the motors, turning spindle on/off and turning coolant on/off.

The need for extra precision machines, with high productivity, raised during the World War II when The US force was searching for a solution to ensure all US planes are manufactured identically, and since then the NC and then CNC machines has developed to the stage we see today.[1]

The CNC machines are used in wide range of industries such as classical machine tools (turning, planning, milling, drilling, boring, reaming), advanced machine tools (such as electric discharge machining EDM, electron beam machining EBM, laser beam machining LBM, etc..) as well as other fabrication machines such as welders, gas cutting, bending, metal forming, etc.[2]

The major difference between the numerically controlled (NC) and the computerized numerically controlled (CNC) machining is the way how various data are entered. For example, the method of applying a certain feed rate is Different and the same can be said about turning the coolant on or off.[2] The CNC machining is superior to the conventional machining in many ways such as Consistency of Products, faster work piece machining, lowered skill level of machinist, more complex parts to be machined and flexibility. As the CNC machines are taking over the future of industry, one of the huge drawbacks of the CNC are their relatively high cost and so it is becoming very difficult for a workshop owner here in Sudan to import a CNC machine from outside the country, In addition the maintenance and the spare parts are of a big concern because there are no authorized agents to carry out the maintenance operations required and the supply of spare parts**.**

2. OBJECTIVE

The objective of this study is to manufacture a low cost small scale 3-axis CNC router machine for academic purposes.

3. METHODOLOGY:

The basic principles of the theory of metal cutting were studied and assumptions were made to analyze the forces affecting the different elements of the machine and hence predict the power required to move the cutting tool in each of the three axes.

The motors were selected taking into account in addition to cutting forces, the weight of both the work piece and the machine carriage.

Using CAD software, a 3D model of the structure of the machine was obtained. Electrical system components were designed in a simple manner that could compensate the error generated during operation.

4. MECHANICAL DESIGN:

The moving machine parts are driven by stepper motors directly coupled to lead screws. There are two common design tradeoffs in CNC machines, in the first one the gantry is fixed while the work table moves back and forth. In the second one the gantry moves while the work table is fixed. The second design exhibits high capabilities in manufacturing long parts while maintaining its precision. However, in the latter design excessive vibration may occur so the fixed gantry design was chosen. [3][4][5].

The overall dimensions of the prototype:

Length: 1 m

Width: 0.5 m

Height: 0.5 m

The prototype was designed to work on wood.

Fig.1. CNC ROUTER 3D MODEL

4.1 LEAD SCREWS:

Lead = 2.5 mm

Outer diameter (Do) = 20 mm

Inner diameter (Di) = 17 mm

Mean diameter (Dm) =18.5 mm

Lengths: X axis: 1000 mm

Y axis: 540 mm

Z axis: 200 mm

The screw is supported on its end by plain bearings designed to carry both radial and axial loads generated by the cutting forces, reactions to cutting forces, friction and travel of the machine table and work piece. The table is fastened to the nut of the lead screw.

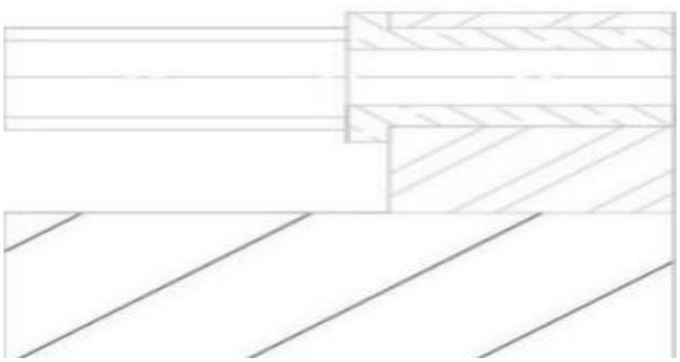

Fig.2. BALL SCREW FASTENING

4.2 LINEAR MOTION GUIDE:

Guides were designed so that the linear bearing can slide Easily on it.

Guides specification: Outer diameter (Do) = 20 m

Lengths:

X axis: 1080 mm

Y axis: 620 mm

Z axis: 280 mm

The guides are fastened with set screw on its ends

4.3 BEARING SEAT:

Due to some limitations we couldn't find linear bearings with a seat so we designed a custom seat for the bearing to be mounted on the table, bearings were fastened with a pair of snap rings.

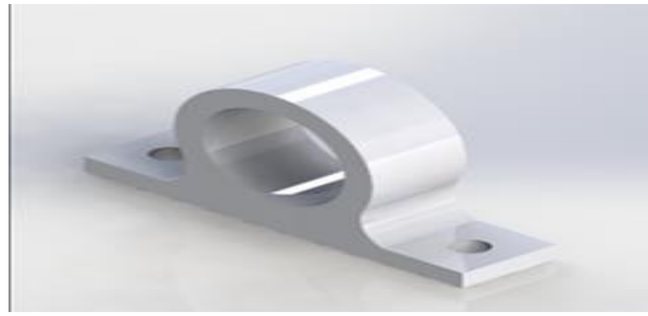

Fig.3. BEARING SEAT 3D MODEL

5. CONTROL SYSTEM DESIGN:

The control system consists of the following components:

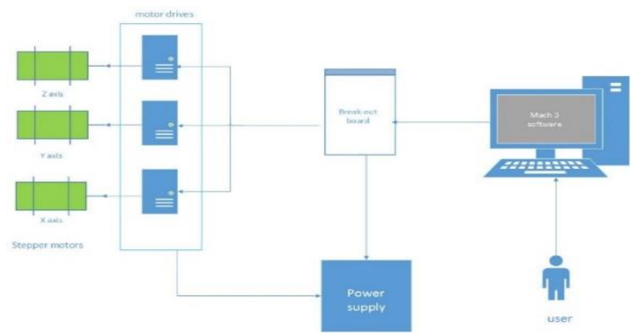

Fig.4. CONTRO SYSTEM SCHEMATIC

5.1 MACH 3 SOURCE SOFTWAER

Mach 3 is a software package that runs on a Pc and turns it into a very powerful and economical machine controller. [6] The developer of this software is Art soft USA and it's available in a free version and a commercial vision the free version is limited to 500 G-code lines. Mach 3 communicates with the machine hardware through one or two parallel ports the one we use to connect the printer. Via this port mach3 generates step pulses and direction signals to perform the steps defined by a G-code part program and sends them to the ports.

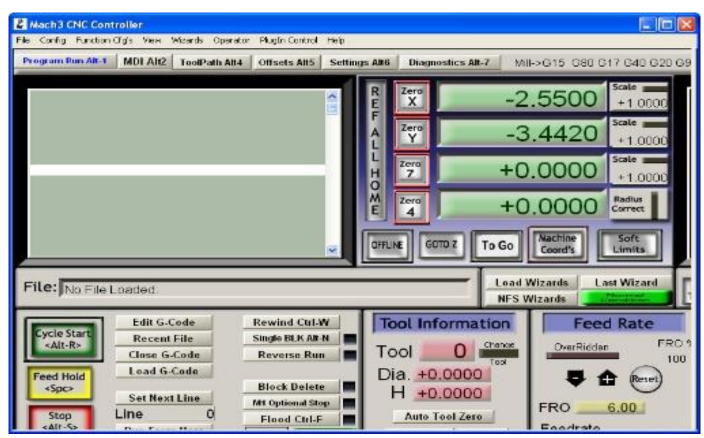

Fig.5. MACH 3 INTERFACE

5.2 BREAK OUT BOARD:

Breakout boards are common electrical components that take a bundled cable and “break out” each conductor to a terminal that can easily accept a hook-up wire for distribution to another device they are a common item in electronic projects and enable easy, clean installation of electronic devices. The break out board is positioned between the computer and the servo drives and it has two functions: It offers circuit protection so that the motherboard of the computer remains undamaged if a shortage occurs. And it breaks out the parallel port signals into pins that can be easily wired and connected to the machine [7].

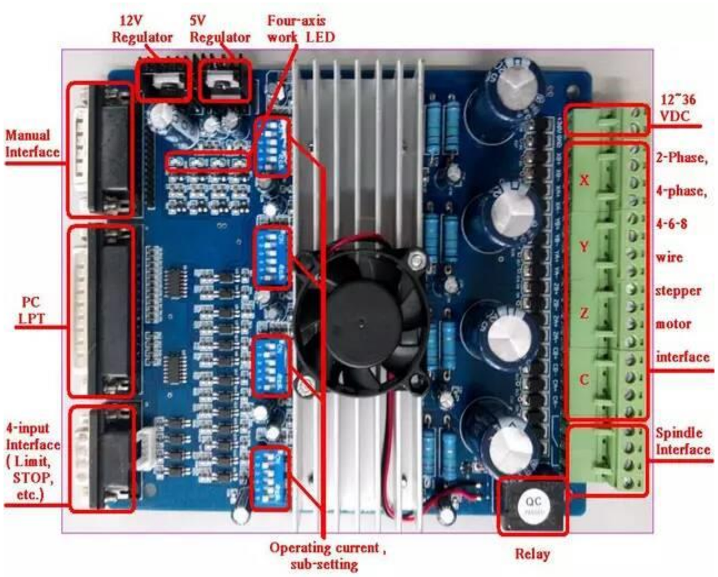

Fig.6. BREAK OUT BOARD SCHEMATIC

5.3 STEPPER MOTOR:

For the purpose of precise movement along with reasonable price NEMA 23 stepper motors were chosen to be directly coupled with the Lead screws in the 3 axis.

The motors are controlled via motor drives built in the breakout board, to control either the speed or the angular displacement.

The breakout out board is powered by 19 V power supply and the motors are powered through the breakout board.

5. MANUFACTURING:

The square thread of the power screw was cut in an AKUMA lathe 1.5m center distance and 300mm swing over bed

Fig.6. LEAD SCREW and BEARING Assembly

Also by the same lathe, the nut and the plain bearings were manufactured, both made out of bronze.

Fig.7. LEAD SCREW and nut Assembly

The guides were cut to the desired length, faced and turned in a lathe and then holes were drilled and threaded.

Fig.8. SEMI ASSEMBLED X and Y AXIS

The machine frame was fabricated and the guides and the power screws were mounted on it.

Fig.9. SEMI ASSEMBLED X and Y AXIS

RESULTS:

A simple g-code program was written to check the machine accuracy. After running simulation, the G-code was sent to machine using Mach-3. After completing the job, measurements were conducted to ensure that the final product dimensions are the same as the drawn design.

Table 1. Price Break Down

Category	Price in SDG
Electrical components	2,400
Materials and other components (Steel, bronze, bearing, etc.)	3,340
Machining	5,000
Total	**10,740 SDG**

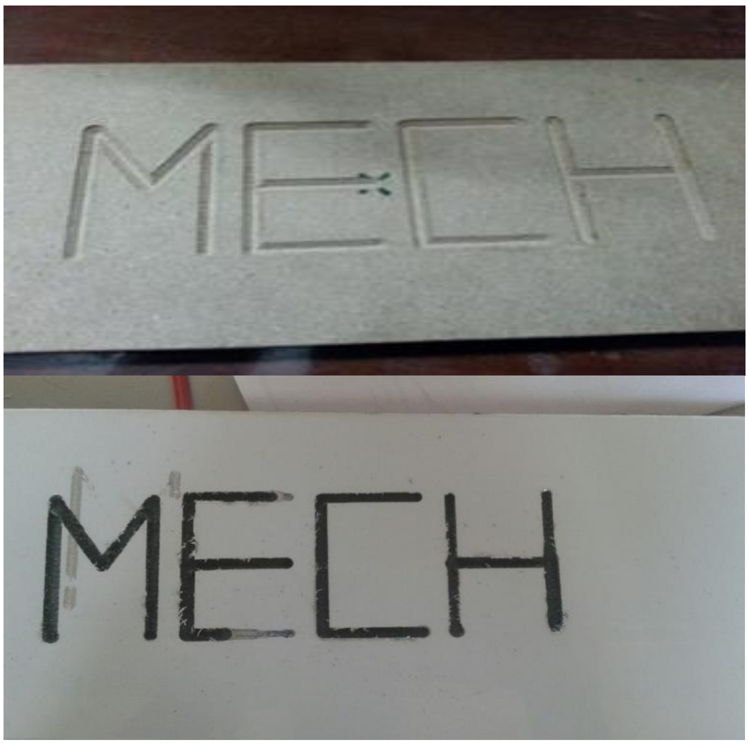

Fig.10. JOB DONE ON THE WORKPIECE

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