Design of low Cost CNC Drilling Machine

Gautam Jodh [1], Piyush Sirsat [1], Nagnath Kakde [1], Sandeep Lutade [1]

[1]Department of Mechanical Engineering, DBACER, Nagpur, India

Grj_12345@yahoo.in, 9975451867

ABSTRACT - This paper aims at describing the design of a computer numeric control drilling machine. The said machine is designed with a view to keep the cost of the machine at minimum, hence making is suitable for use in small or medium scale industries. Along with the design of the mechanical components, the electronics and the software has also been designed. The said machine has also been fabricated and successfully tested.

Keywords— Drilling machine, CNC drilling machine electronics, CNC machine design, computer numeric control, low cost automation, CNC software, CNC graphical user interface.

INTRODUCTION

A drilling machine is a device for making holes in components. The manually operated type of drilling machine creates problems such as low accuracy, high setup time, low productivity, etc. A CNC machine overcomes all these problems but the main disadvantage of a CNC drilling machine is the high initial cost and requirement of skilled labour for operating the machine. Hence, there arises a need for a low cost CNC machine which can not only drill holes with high accuracy and low machining time but also have low initial cost. The need for skilled operator is eliminated by providing a software with a more user friendly graphical user interface.

COMPONENTS

The machine consists of the following components

i. The mechanical components

It includes the structure of the drilling machine i.e. the base, support structure, beams, lead screw, bearing, gears, etc.

ii. The electrical system

The electrical system consists of the motor, motor control unit, power unit and interfacing.

iii. The control or computing system

The control or the computing system positions the tip of the drill at the required position and the provides the depth of cut.

DESIGN CONSIDERATIONS

A. Work piece size

As a basis for further development of the drilling machine, the maximum component size (maximum travel along the axis) is selected as

X = 400 mm.
Y = 400 mm.
Z = 200 mm.

B. Configuration selection

The different configurations are considered from fabrication point of view, and it is found that the gantry configuration is most suitable because of the following qualities.

1. Provides better rigidity.
2. Better accuracy.
3. Ease of operation and programming.

C. Drilling machine components

The drilling machine is divided into three sub systems. These are

1. The mechanical structure.
2. The Electrical system.
3. The Program.

MECHANICAL SUB ASSEMBLIES

The machine structure is further divided into following sub assemblies.

1. Frame sub-assembly.
2. Y axis sub-assembly.
3. X axis sub-assembly.
4. Z axis sub-assembly.

A. Frame sub assembly

Four L cross section beams welded together to form each of the top and bottom part of the frame. Four more beams are bolted vertically to these portions to form the frame structure.

Two beams are placed horizontally along X axis and bolted to the vertical beams to form the guides for the X axis base.

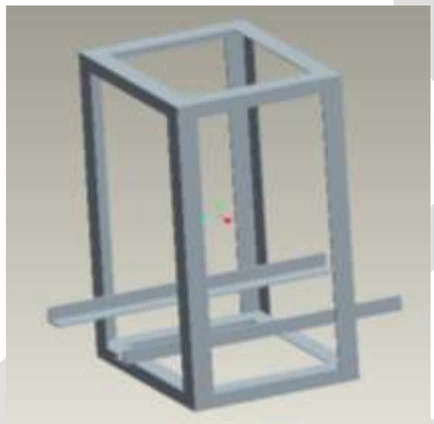

Fig.1 Frame sub assembly

B. X axis sub assembly

Two bearings are placed on either sides of the X axis screw. These bearings are then supported in the bearing seat provided in the side plates. A mid plate is provided which has internal threading for contact with the screw. Two guide rods are fit between the two side plates.

Each of the side plates has two M6 taps at the bottom to screw them to the frame.

The motor is screwed to the motor support plate which is in turn attached to the guide rods. The shaft of the motor has a radial hole which is used to couple the motor to the screw.

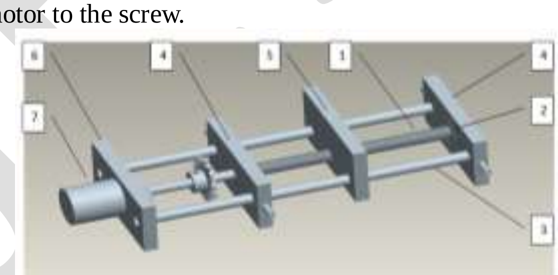

Fig.2 X axis sub assembly

1	Screw
2	Bearing
3	Guide rod
4	Side plate
5	Mid plate
6	Motor support plate
7	Motor

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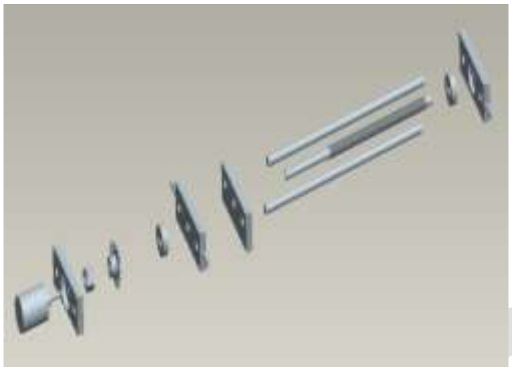

Fig.3 X axis sub assembly (Exploded view)

C. Y axis sub assembly

The Y axis is similar in construction to the X axis sub assembly. The mid plate has two M6 taps for the attachment of Z axis sub assembly.

D. Z axis sub assembly

The Z axis is also similar in construction to the X axis sub assembly. The mid plate has a provision for the attachment of the drill motor.

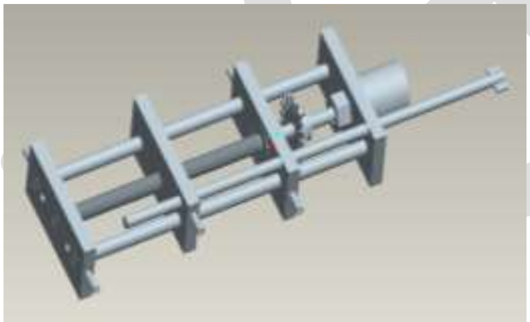

Fig.4 Z axis sub assembly

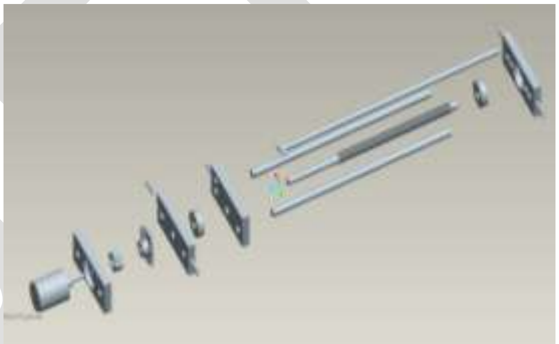

Fig.5 Z axis sub assembly (Exploded view)

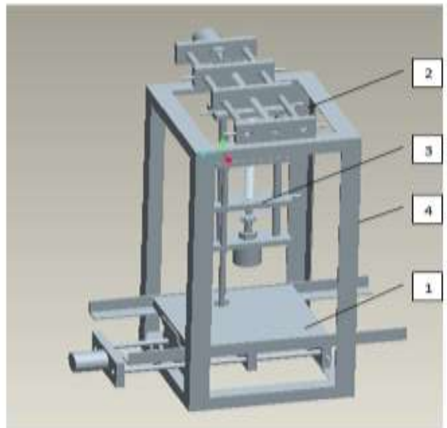

Fig.6 Final assembly

1	X axis sub assembly
2	Y axis sub assembly
3	Z axis sub assembly
4	Frame sub assembly

DESIGN CALCULATIONS

A. X axis lead screw

The movement required is = 400mm
For safer side selecting length of screw as = 500mm
Size = M10 x 1
Pitch, p = 1 mm
Major diameter, do = 10 mm
Mean diameter, d = do- p/2
= 10-1/2
= 9.5 mm

B. Y axis lead screw

The movement required is = 400mm
For safer side selecting length of screw as= 500 mm
Size = M10 x 1
Pitch, p = 1 mm
Major diameter, do = 10 mm
Mean diameter, d = do- p/2
= 9.5 mm

C. Z axis lead screw

The movement required is = 200 mm
For safer side selecting length of screw as= 300 mm
Size = M10 x 1
Pitch, p = 1 mm
Major diameter, do = 10 mm
Mean diameter, d = do- p/2
= 9.5 mm

POWER CALCULATION

The load on the Y axis is maximum, hence the power required at Y axis sub assembly will be maximum. Hence the power required at Y axis lead screw is considered for selecting the motor. The power required is calculated next.

Co-efficient of friction, $\mu = 0.0015$

$\tan \alpha = p/(\pi d)$

$= 1/(\pi x10)$

$= 0.0318$

$\tan \phi = \mu$

$= 0.0015$

Mass on lead screw in Y-direction, m_y = 5 kg

External force, Fey = m_y x g

=5 x 9.81

=49.05 N

Frictional force, F_{fy} = μ x m_y x 9.81

(selecting μ=0.0015)

= 0.0015 x 5 x 9.81

= 0.0736 N

Total force , $F_{ty} = F_{ey} + F_{fy}$

F_{ty} = 49.05 + 0.0736

=49.1236 N

Tangential force required at the circumference of screw is,
$F_y = F_{ty} \times [\tan\alpha \tan\phi] / [1 - \tan\alpha \times \tan\phi]$

=49.1236 x [0.0318+ 0.0015] / [1-0.0318x0.0015]

= 1.636 N

On the basis of tangential force torque required for screw rotation is,
$T_Y = F_Y \times d/2 + \mu \times F_{TY} \times R$

= 1.636 x 10/2 + 0.0015 x 49.1236 x (10/2)

= 8.5484 N-mm

= 0.0854 Kgf-cm

Speed of lead screw, NY
N_Y = 30 rpm.

Angular speed, $W_Y = 2\pi N/60$

= 3.14 rad/sec

Power, $P_Y = T_Y \times W_Y$

= 0.0854 x 3.14

= 0.2681 W

BEARING SELECTION

The lead screw is supported using two bearings, one at each end. A total of six bearings are used. Diameter of the non threaded portion of the lead screw is 10mm. Hence the bore of the bearing is required to be 10mm. Based on the standard bearings available, the 1900 series bearing is selected. The specifications of this bearing are

Outer diameter = 30 mm
Bore = 10 mm
Thickness = 9 mm

ELECTRICAL AND ELECTRONIC SYSTEM

A. Motor selection

The power required to operate the CMM has been calculated in the previous section. Assuming frictional losses and factor of safety, the following motor is selected

Type	-	Stepper motor
Holding torque	-	18 Kg.cm
Current	-	3 Ampere
Voltage	-	12 Volt
Torque	-	2 kgf.cm

Three Motors are used, one for each axis. Additional fourth motor is used to which the drill is attached.

B. Power supply

Current of 3 ampere is supplied to each of the four motors using adapter whose input rating of 100 – 240V and 0.4 Ampere (max) while output rating is 12 volt and 3 Ampere

Fig.7 X axis sub assembly

Fig.8 Z axis sub assembly

Fig.9 Final assembly

SOFTWARE SYSTEM

The working of the different buttons is explained next

A. Reset axis button

When the 'Reset axis' button is clicked

Motors for all the three axis start to rotate in counter clockwise direction. They start to bring the axis to their respective home position.

The motors stop when the respected proximity sensors are activated. This indicates that the home position has been reached.

B. Co ordinate input

The required X and Y co ordinates are entered in the respective text boxes. The depth of drill operation required is entered in the text box labeled " Z co ordinate". When "start machine" button is clicked, motor for each axis starts to rotate in clockwise direction. The motors stop when the value indicated in the respective dialog boxes is reached.

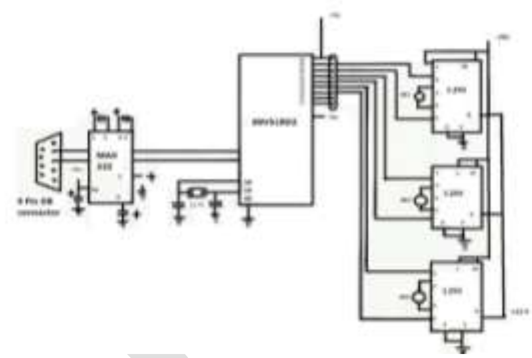

Fig. 10 Circuit diagram

OPERATING THE MACHINE

A. Drilling machine connections

The block diagram of system is provided.

The adapter is connected to AC power supply and the point provided on the machine circuit board.

The RS 232 cable is connected to the corresponding port on the machine circuit board and the PC.

The power to the machine is switched on using the ON/OFF switch provided on the circuit board.

B. Steps

Open the exe file of the program. The program screen appears.

Start the program from the drop down menu in the tool bar at the top left corner.

Click on the 'Reset axis' button. This will move the CMM to its home position.

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Enter the desired values of X, Y and depth of cut in the respective text.
Click 'Start' button.
The machine X and Y motors start and position the drill on the desired position.
The drill motor starts and then the Z axis motor starts, thus providing the depth of cut.

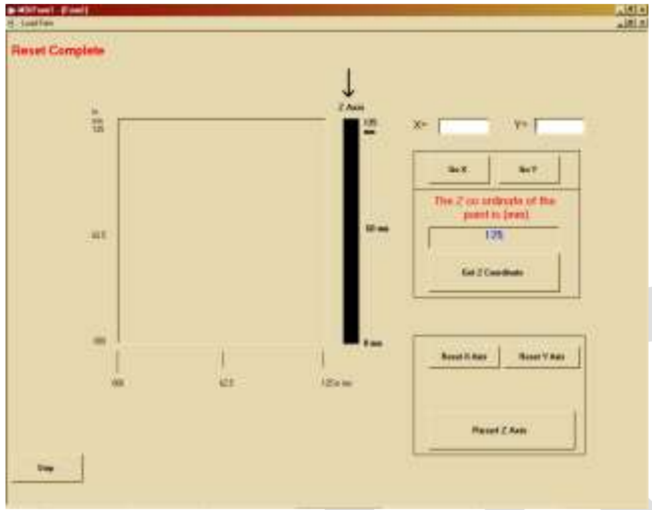

Fig.11 Program screen

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