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Design of Portable Coordinate Measuring Machine

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ABSTRACT

This paper describes the design of a non contact type of co ordinate measuring machine. The work volume of the machine is selected as 400x400x200 mm3. The investigations carried out describe the mechanical, electrical, electronic and software system design. This paper aims at presenting a design of a CMM which will be suitable to small and medium scale industries.

Keywords: Co ordinate measuring machine, inspection devices, quality control machines

INTRODUCTION

A coordinate measuring machine (CMM) is a device for measuring the physical geometrical characteristics of an object i.e. its dimensions. The machine may also be used to measure features, form, orientation, etc.

CMM may be classified in the following ways:

On the basis of the contact made by probe

Contact Type

The probe tip makes contact at the desired point and the coordinates of this point are documented.

They are most widely used due to less complexity in control and design.

They are more prone to errors and tip wear is common.

Non-Contact Scanning

The probe is one of the following types and does not make contact with the component surface.

e.g. High speed laser single point triangulation,

Laser line scanning.

On the Basis of Number of Axis

- 2 axes
  It consists of motion only in two directions, usually X and Y axis.
  The first CMM of this type was developed by the Ferranti Company of Scotland in the 1950s.
- 3-axis
  This is the most widely used type of CMM.
  It has motion in all three axis – X, Y and Z.

The first model of this type began appearing in the 1960s (DEA of Italy).

On Basis of Configurations of the CMM

The different types of configurations are explained next.

CONFIGURATIONS

The most popular CMM configurations include

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- Articulated arm.
- Moving Bridge Coordinate Measuring Machine.
- Fixed Bridge Coordinate Measuring Machine.
- Column coordinate measuring machine.
- Fixed Table Cantilever Coordinate Measuring Machine.
- L-shaped Bridge Coordinate Measuring Machine.
- Gantry.

COMPONENTS

The machine essentially consists of the following components

The Machine Itself

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

The Electrical System

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

The Control or Computing System

The control or the computing system reads the position of the probe from sensors and converts it to dimensional values and reports it to user.

DESIGN CONSIDERATIONS

Work Piece Size

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

X = 400 mm.

Y = 400 mm.

Z = 200 mm.

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.

- Provides better rigidity.
- Better accuracy.
- Ease of operation and programming.

CMM COMPONENTS

The CMM is divided into three sub systems. These are

- The CMM structure.
- The Electrical system.
- The Program.

MECHANICAL SUB ASSEMBLIES

The CMM structure is further divided into following sub assemblies.

- Frame sub-assembly.
- Y axis sub-assembly.
- X axis sub-assembly.
- 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.

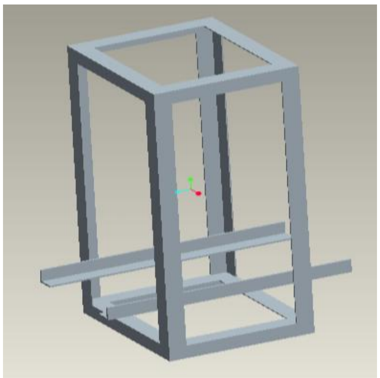

Fig1. *Frame sub assembly*

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.

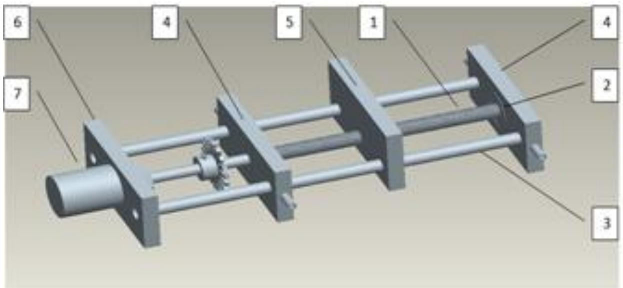

Fig2. *X axis sub assembly*

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

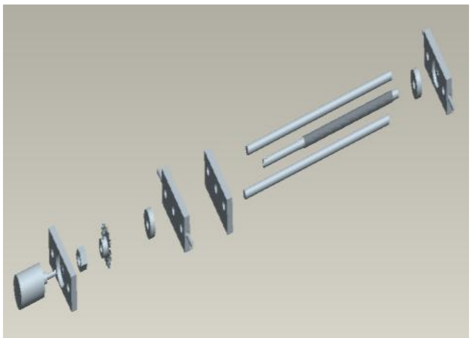

Fig3. *X axis sub assembly (Exploded view)*

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.

Z Axis Sub Assembly

The Z axis is also similar in construction to the X axis sub assembly. The mid plate has a 10mm diameter hole for attachment of the probe.

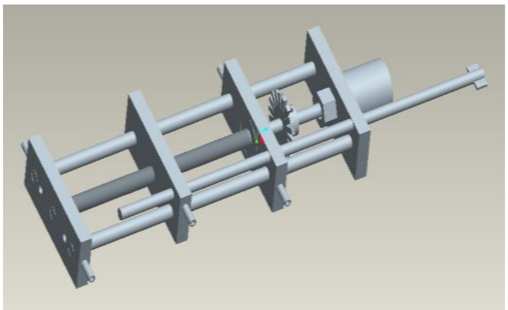

Fig4. *Z axis sub assembly*

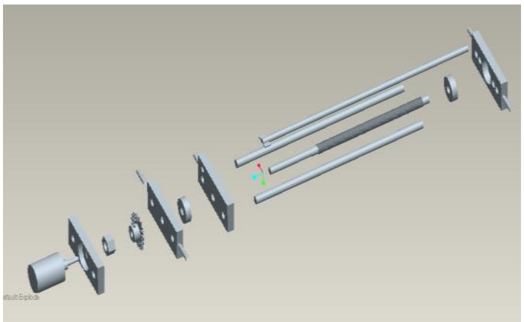

Fig5. *Z axis sub assembly (Exploded view)*

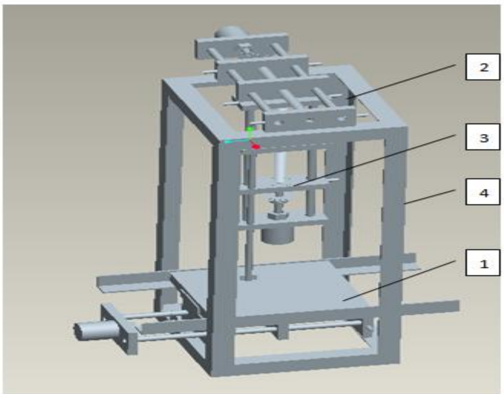

Fig6. *Final assembly*

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

DESIGN CALCULATIONS

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, d_o	= 10 mm
Mean diameter, d	= do- p/2
	= 10-1/2
	= 9.5 mm

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, d_o	= 10 mm
Mean diameter, d	= d_o- p/2
	= 9.5 mm

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, d_o	= 10 mm
Mean diameter, d	= d_o- 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, 0.0015

$$\tan = p/(\pi d)$$
$$= 1/ (\pi x10)$$
$$= 0.0318$$
$$\tan \Phi = \mu = 0.0015$$

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

External force, F_{ey} = m_y x g

=5 x 9.81

=49.05 N

Frictional force, F_{fy} = 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, N_Y

$N_Y = 30$ 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

Motor Selection

The power required to operate the CMM has been calculated in chapter 03. Assuming frictional losses and factor of safety, the following motor is selected

Type	-	Stepper motor
Speed	-	30 rpm
Current	-	1 Ampere
Voltage	-	12 Volt
Torque	-	2 kgf.cm

Three Motors are used, one for each axis

Power supply

Current of 1 ampere is supplied to each of the three motors using adapter whose input rating of 100 – 240V and 0.4 Ampere (max) while output rating is 12 volt and 1 Ampere

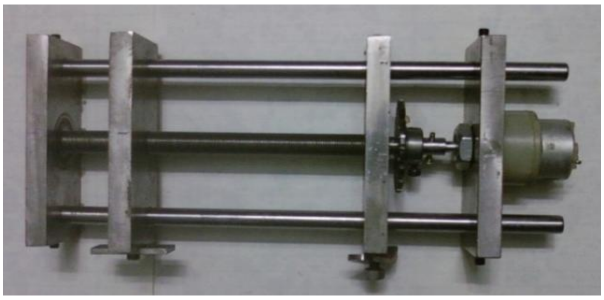

Fig7. *X axis sub assembly*

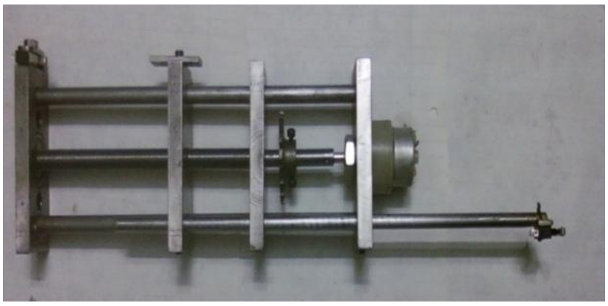

Fig8. *Z axis sub assembly*

Fig9. *Final assembly*

SOFTWARE SYSTEM

The working of the different buttons is explained next

Reset Axis Button

When the 'Reset axis' button is clicked

Motor for X axis starts to rotate in counter clockwise direction and starts to bring the axis to its home position.

The motor stops when the X axis proximity sensor is activated. This indicates that the home position has been reached by X axis.

The motor for Y and Z axis also perform similar function.

Get Z Coordinate

When the 'Get Z coordinate' button is clicked,

Motor for X axis starts to rotate in clockwise direction. The motor stops when the value indicated in the "X=" dialog box is reached.

Motor for Y axis also works in similar method.

Motor for Z axis starts to rotate in clockwise direction. The motor stops when the probe proximity sensor is activated. The corresponding Z coordinate is indicated in the 'The Z coordinate of the point is (mm)' box.

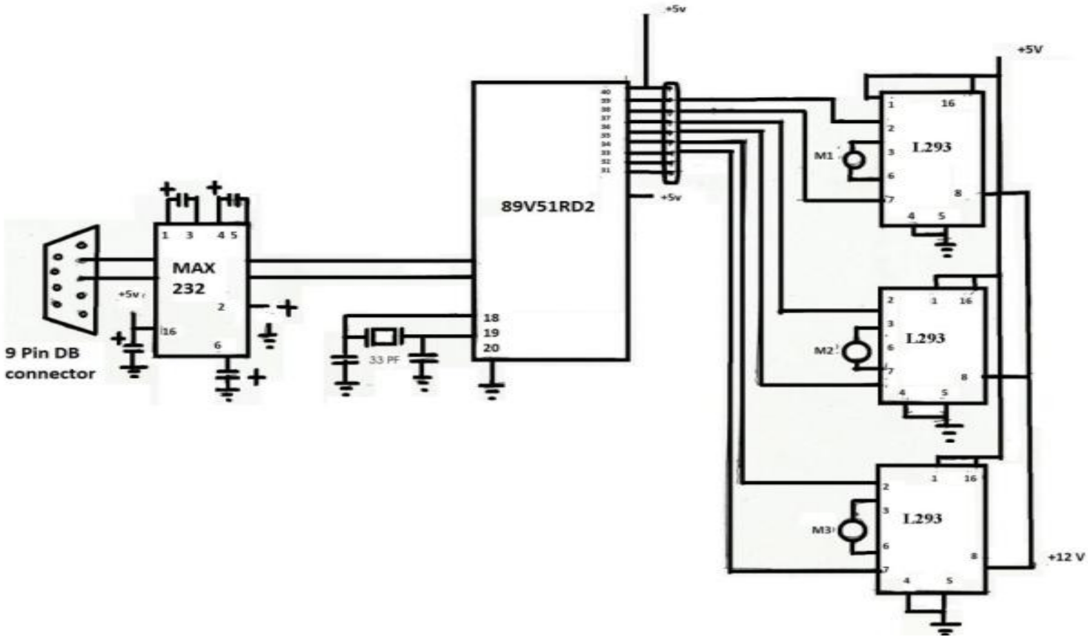

Fig10. *Circuit diagram*

OPERATING THE CMM

CMM Connections

The Block diagram of system is provided.

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

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

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

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.
Enter the desired values of X and Y in the box corresponding to the 'X=' and 'Y=' respectively.
Click 'Get z co ordinate' button.
When the probe proximity sensor is activated at probe is activated, the Z axis motor stops and the Z co ordinate of that point is displayed in the respective dialog box.

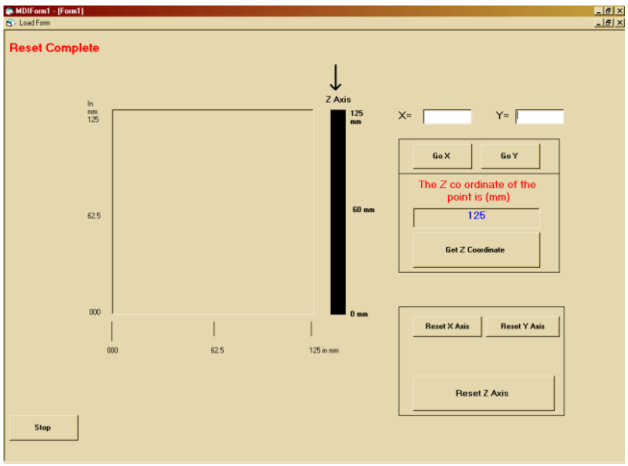

Fig11. *Program screen*

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