

3.5 CO-ORDINATE MEASUREMENT MACHINES (CMM)

The term measuring machine generally refers to a single-axis measuring instrument. Such an instrument is capable of measuring one linear dimension at a time. The term coordinate measuring machine refers to the instrument/machine that is capable of measuring in all three orthogonal axes. Such a machine is popularly abbreviated as CMM.

A CMM enables the location of point coordinates in a three-dimensional (3D) space. It simultaneously captures both dimensions and orthogonal relationships. Another remarkable feature of a CMM is its integration with a computer. The computer provides additional power to generate 3D objects as well as to carry out complex mathematical calculations. Complex objects can be dimensionally evaluated with precision and speed.

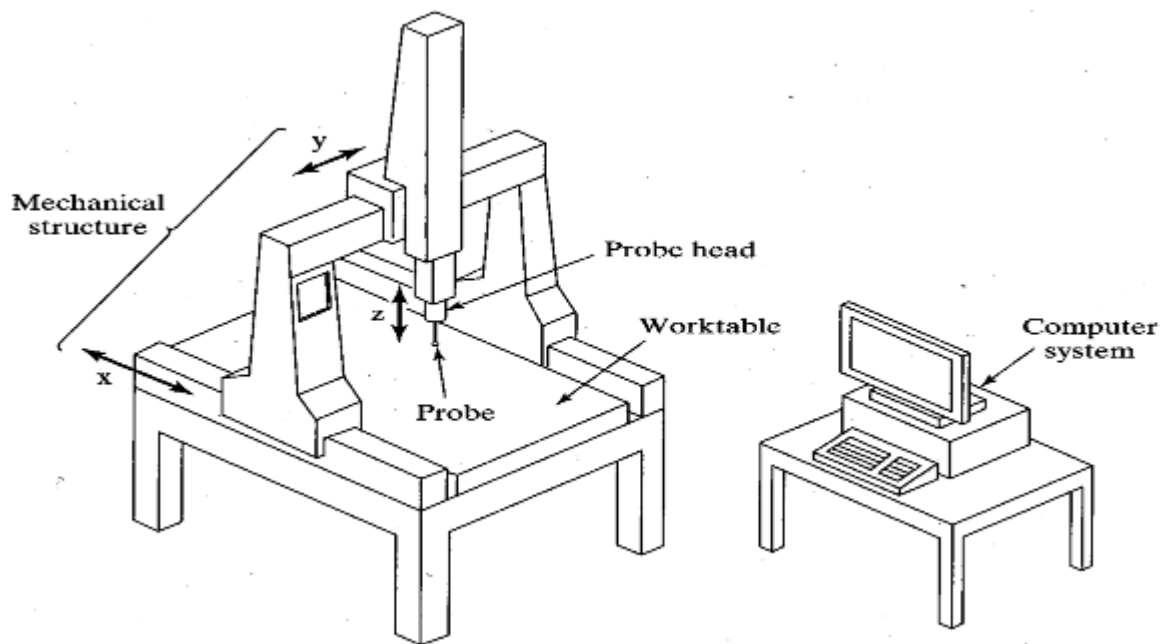


Fig. 3.31 CO-ORDINATE MEASUREMENT MACHINE

[source: https://www.slideshare.net/dharanimech/cmm-3?from_action=save]

The first batch of CMM prototypes appeared in the United States in the early 1960s. However, the modern version of CMM began appearing in the 1980s, thanks to the rapid developments in computer technology. The primary application of CMM is for inspection. Since its functions are driven by an on-board computer, it can easily be

integrated into a computer-integrated manufacturing (CIM) environment. Its potential as a sophisticated measuring machine can be exploited under the following conditions:

Multiple features The more the number of features (both dimensional and geometric) that are to be controlled, the greater the value of CMM.

Flexibility It offers flexibility in measurement, without the necessity to use accessories such as jigs and fixtures.

Automated inspection Whenever inspection needs to be carried out in a fully automated environment, CMM can meet the requirements quite easily.

High unit cost If rework or scrapping is costly, the reduced risk resulting from the use of a CMM becomes a significant factor.

3.5.1 Introduction

- Coordinate metrology is concerned with the measurement of the actual shape and dimensions of an object and comparing these with the desired shape and dimensions.
- In this connection, coordinate metrology consists of the evaluation of the location, orientation, dimensions, and geometry of the part or object.
- A Coordinate Measuring Machine (CMM) is an electromechanical system designed to perform coordinate metrology.

3.5.2 Types of Measuring Machines

- Length bar measuring machine.
- Newell measuring machine.
- Universal measuring machine.
- Co-ordinate measuring machine.
- Computer controlled co-ordinate measuring machine.

3.5.3 Structure

The basic version of a CMM has three axes, along three mutually perpendicular directions. Thus, the work volume is cuboidal. A carriage is provided for each axis, which

is driven by a separate motor. While the straight-line motion of the second axis is guided by the first axis, the third axis in turn is guided by the second axis. Each axis is fitted with a precision measuring system, which continuously records the displacement of the carriage from a fixed reference.

The third axis carries a probe. When the probe makes contact with the workpiece, the computer captures the displacement of all the three axes. Depending on the geometry of the workpiece being measured, the user can choose any one among the five popular physical configurations. Figure illustrates the five basic configuration types: cantilever, bridge, column, horizontal arm and gantry.

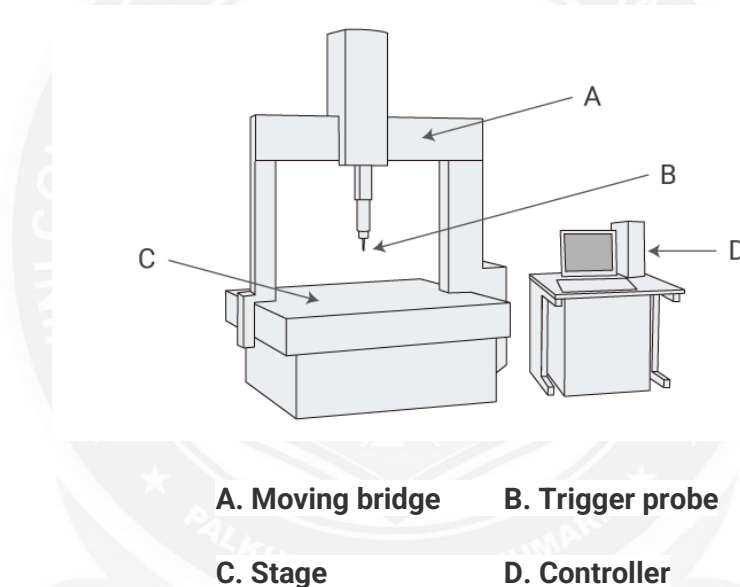


Fig. 3.32 Co-Ordinate Measurement Machines (CMM)

[source: <https://www.keyence.com/ss/products/measure-sys/measurement-selection/type/3d.jsp>]

3.5.4 TYPES OF CO-ORDINATE MEASUREMENT MACHINES (CMM)

3.5.4.1 Cantilever type CMM

The vertically positioned probe is carried by a cantilevered arm. The probe moves up and down along the Z-axis, whereas the cantilever arm moves in and out along the Y-axis (lateral movement). The longitudinal movement is provided by the X-axis, which is basically the work table. This configuration provides easy access to the workpiece and a relatively large work volume for a small floor space.

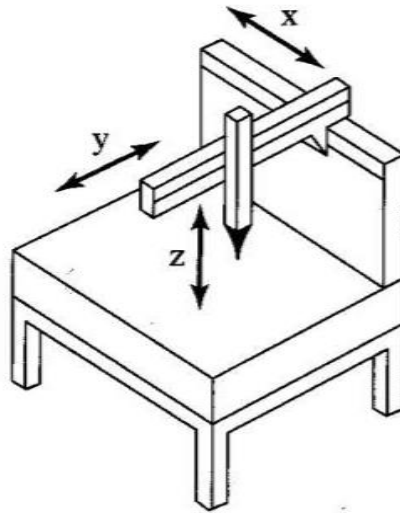


Fig. 3.33 Cantilever type CMM

[source: https://www.slideshare.net/dharanimech/cmm-3?from_action=save]

3.5.4.2 Bridge type CMM

A bridge-type configuration is a good choice if better rigidity in the structure is required. The probe unit is mounted on a horizontal moving bridge, whose supports rest on the machine table.

a) Moving Bridge type CMM

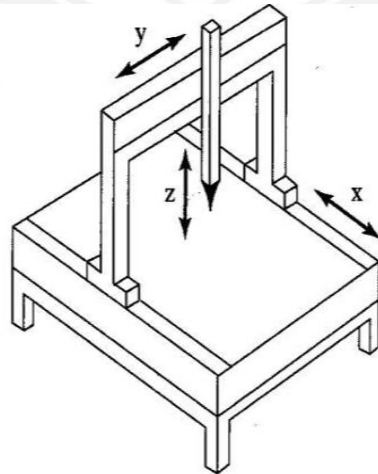


Fig. 3.33 Moving Bridge type CMM

[source: https://www.slideshare.net/dharanimech/cmm-3?from_action=save]

- Most widely used
- Has stationary table to support work piece to be measured and a moving bridge
- **Disadvantage-** with this design, the phenomenon of yawing (sometimes called walking) can occur- affect the accuracy
- **Advantage-** reduce bending effect

b) Fixed Bridge type CMM

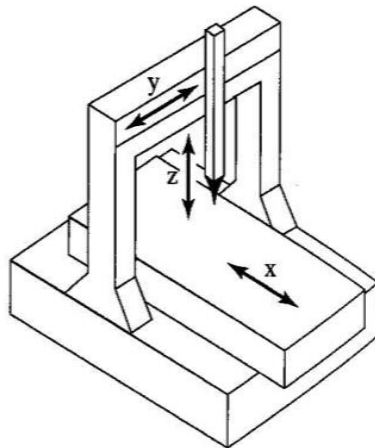


Fig. 3.34 Fixed Bridge type CMM

[source: https://www.slideshare.net/dharanimech/cmm-3?from_action=save]

- In the fixed bridge configuration, the bridge is rigidly attached to the machine bed
- This design eliminates the phenomenon of walking and provides high rigidity

3.5.4.3 Column type CMM

This configuration provides exceptional rigidity and accuracy. It is quite similar in construction to a jig boring machine. Machines with such a configuration are often referred to as universal measuring machines.

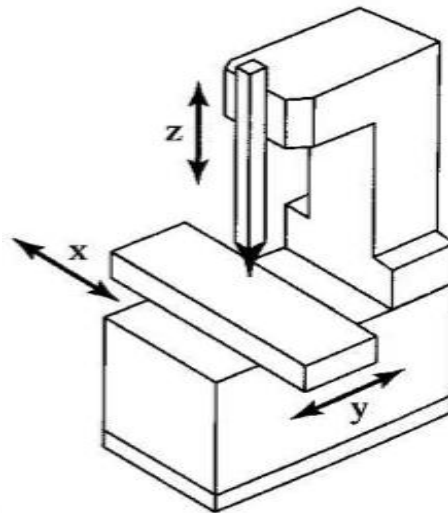


Fig. 3.35 Column type CMM

[source: https://www.slideshare.net/dharanimech/cmm-3?from_action=save]

3.5.4.4 Horizontal arm type CMM

In this type of configuration, the probe is carried by the horizontal axis. The probe assembly can also move up and down along a vertical axis. It can be used for gauging larger workpieces since it has a large work volume. It is often referred to as a layout.

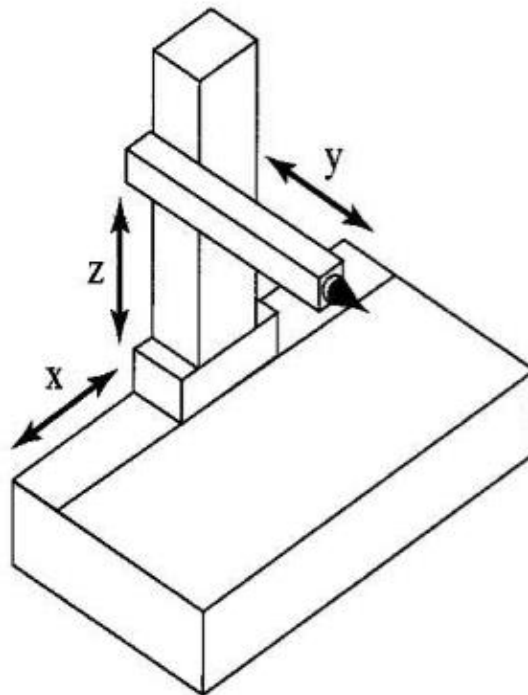


Fig. 3.36 Horizontal arm type CMM

[source: https://www.slideshare.net/dharanimech/cmm-3?from_action=save]

3.5.4.5 Gantry type CMM

In this configuration, the support of the workpiece is independent of the X- and Y-axis. Both these axes are overhead and supported by four vertical columns from the floor. The operator can walk along with the probe, which is desirable for large workpieces. Some of the machines may have rotary tables or probe spindles, which will enhance the versatility of the machines. The work space that is bounded by the limits of travel in all the axes is known as the work envelop. Laser interferometers are provided for each of the axes if a very precise measurement is necessary.

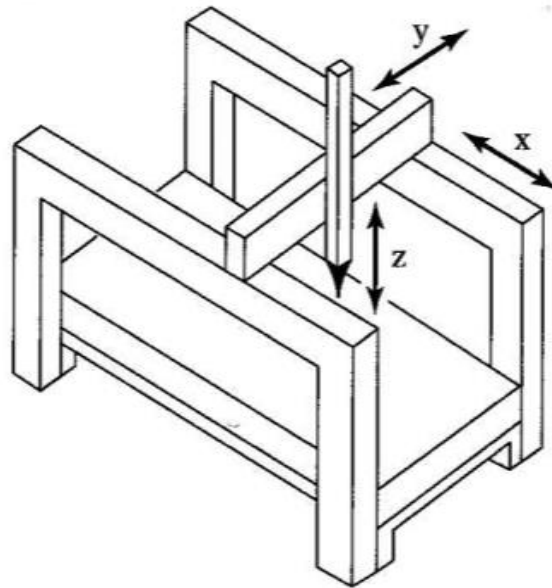


Fig. 3.37 Gantry type CMM

[source: https://www.slideshare.net/AUSTINMOSES/probing-systems-seminar?from_action=save]

3.5.5 Modes of Operation

Modes of operation are quite varied in terms of type of construction and degree of automation. Accordingly, CMMs can be classified into the following three types based on their modes of operation:

1. Manual
2. Semi-automated
3. Computer controlled

The manual CMM has a free-floating probe that the operator moves along the machine's three axes to establish contact with part features. The differences in the contact positions are the measurements. A semi-automatic machine is provided with an electronic digital display for measurement. Many functions such as setting the datum, change of sign, and conversion of dimensions from one unit to another are done electronically.

A computer-controlled CMM has an on-board computer, which increases versatility, convenience, and reliability. Such machines are quite similar to CNC machines in their control and operation. Computer assistance is utilized for three major functions. Firstly, a programming software directs the probe to the data collection points. Secondly, measurement commands enable comparison of the distance traversed to the standard built into the machine for that axis. Thirdly, computational capability enables processing of the data and generation of the required results.

3.5.6 CMM Operation and Programming

Positioning the probe relative to the part can be accomplished in several ways, ranging from manual operation to direct computer control.

Computer-controlled CMMs operate much like CNC machine tools, and these machines must be programmed.

3.5.6.1 CMM Operation

This section explains the operation or the measurement process using a CMM. Most modern CMMs invariably employ computer control. A computer offers a high degree of versatility, convenience, and reliability. A modern CMM is very similar in operation to a computer numerical control (CNC) machine, because both control and measurement cycles are under the control of the computer. A user-friendly software provides the required functional features. The software comprises the following three components:

1. Move commands, which direct the probe to the data collection points

2. Measurement commands, which result in the comparison of the distance traversed to the standard built into the machine for that axis
3. Formatting commands, which translate the data into the form desired for display or printout.

Machine Programming

Most measurement tasks can be carried out using readily available subroutines. The subroutines are designed based on the frequency with which certain measurement tasks recur in practice. An operator only needs to find the subroutine in a menu displayed by the computer. The operator then inputs the data collection points, and using simple keyboard commands the desired results can be obtained. The subroutines are stored in the memory and can be recalled whenever the need arises.

The program automatically calculates the centre point and the diameter of the best-fit circle. A cylinder is slightly more complex, requiring five points. The program determines the best-fit cylinder and calculates the diameter, a point on the axis, and a best-fit axis.

Situations concerning the relationship between planes are common. Very often, we come across planes that need to be perfectly parallel or perpendicular to each other. A situation where the perpendicularity between two planes is being inspected. Using a minimum of two points on each line, the program calculates the angle between the two lines. Perpendicularity is defined as the tangent of this angle. In order to assess the parallelism between two planes, the program calculates the angle between the two planes. Parallelism is defined as the tangent of this angle.

In addition to subroutines, a CMM needs to offer a number of utilities to the user, especially mathematical operations. Most CMMs have a measurement function library. The following are some typical library programs:

1. Conversion from SI (or metric) to British system

2. Switching of coordinate systems, from Cartesian to polar and vice versa
3. Axis scaling
4. Datum selection and resetting
5. Nominal and tolerance entry
6. Bolt-circle centre and diameter
7. Statistical tools

3.5.7 CMM Controls

The methods of operating and controlling a CMM can be classified into four main categories:

1. Manual drive,
 2. Manual drive with computer-assisted data processing,
 3. Motor drive with computer-assisted data processing, and
 4. Direct Computer Control with computer-assisted data processing
1. In **Manual drive CMM**, the human operator physically moves the probe along the machine's axes to make contact with the part and record the measurements.
 - The measurements are provided by a digital readout, which the operator can record either manually or with paper print out.
 - Any calculations on the data must be made by the operator.
 2. A CMM with **Manual drive and computer-assisted data processing** provides some data processing and computational capability for performing the calculations required to evaluate a give part feature.
 - The types of data processing and computations range from simple conversions between units to more complicated geometry calculations, such as determining the angle between two planes.

3. A **Motor-driven CMM with computer-assisted data processing** uses electric motors to drive the probe along the machine axes under operator control.
 - A joystick or similar device is used as the means of controlling the motion.
 - Motor-driven CMMs are generally equipped with data processing to accomplish the geometric computations required in feature assessment.
4. A CMM with **Direct computer control (DCC)** operates like a CNC machine tool. It is motorized and the movements of the coordinate axes are controlled by a dedicated computer under program control.
 - The computer also performs the various data processing and calculation functions.
 - As with a CNC machine tool, the DCC CMM requires part programming.

3.5.8 DCC CMM Programming

There are two principle methods of programming a DCC measuring machine:

1. Manual lead through method.
2. Off-line programming.
 1. In the **Manual Lead through method**, the operator leads the CMM probe through the various motions required in the inspection sequence, indicating the points and surfaces that are to be measured and recording these into the control memory.
 - During regular operation, the CMM controller plays back the program to execute the inspection procedure.
 2. **Off-line Programming** is accomplished in the manner of computer-assisted NC part programming; The program is prepared off-line based on the part drawing and then downloaded to the CMM controller for execution.