Resolution = 100 nm

Experiment No. 2B

Coordinate Measuring Machine

Aim: To study the functioning of the CNC coordinate measuring machine and perform measurement using this machine.

Theory: The students are advised to read the principle of measurements using CMM from the given notes.

Results:

1) Draw the sketch of the given component.
2) List various dimensions that are measured.
3) Draw overall sketch of the machine indicating various movements.
4) Make a 3D model of the component using the measurements.

Conclusions: Give your conclusion on the observation of the machine features, measurement, capabilities and accuracy.

Limitations.

UNIT 8 COORDINATE MEASURING MACHINES (CMM)

Structure

8.1 INTRODUCTION

With the advent of numerically controlled machine tools, the demand has grown for some means to support these equipment. There has been growing need to have an apparatus that can do faster first piece inspection and many times, 100% dimensional inspection. The Coordinate Measuring Machine (CMM) plays a vital role in the mechanisation of the inspection process. Some of the CMMs can even be used as layout machines before machining and for checking feature locations after machining.

Coordinate measuring machines are relatively recent developments in measurement technology. Basically, they consist of a platform on which the workpiece being measured is placed and moved linearly or rotated. A probe attached to a head capable of lateral and vertical movements records all measurements. Coordinate measuring machines are also called measuring machines. They are versatile in their capability to record measurement of complex profiles with high sensitivity (0.25 μm) and speed. In this unit, we will discuss the principle and the working of a Coordinate Measuring Machine (CMM).

Objectives

After studying this unit, you should be able to

- familiarise yourself with parts of a CMM, and
- understand the principle and the working of a CMM.

8.2 DESCRIPTION OF PARTS

Co-ordinate Measuring Machines are built rigidly and are very precise. They are equipped with digital readout or can be linked to computers for online inspection of parts. These machines can be placed close to machine tools for efficient inspection and rapid feedback for correction of processing parameter before the next part is made. They are also made more rugged to resist environmental effects in manufacturing plants such as temperature variations, vibration and dirt. Important features of the CMMs are :

(i) To give maximum rigidity to machines without excessive weight, all the moving members, the bridge structure, *Z*-axis carriage, and *Z*-column are made of hollow box construction.

(ii) A map of systematic errors in machine is built up and fed into the computer system so that the error compensation is built up into the software.

(iii) All machines are provided with their own computers with interactive dialogue facility and friendly software.

(iv) Thermocouples are incorporated throughout the machine and interfaced with the computer to be used for compensation of temperature gradients and thus provide increased accuracy and repeatability.

A CMM consists of four main elements :

Main Structure

The machine incorporates the basic concept of three coordinate axes so that precise movement in x, y, and z directions is possible. Each axis is fitted with a linear measurement transducer. The transducers sense the direction of movement and gives digital display. Accordingly, there may be four types of arrangement :

Cantilever

The cantilever construction combines easy access and relatively small floor space requirements. It is typically limited to small and medium sized machines. Parts larger than the machine table can be inserted into the open side without inhibiting full machine travel. Figure 8.1 shows a cantilever structure.

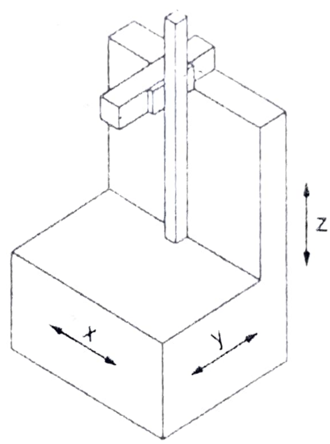


Figure 8.1 : Cantilever Structure

Bridge Type

The bridge arrangement over the table carries the quill (z-axis) along the x-axis and is sometimes referred to as a travelling bridge. It is claimed that the bridge construction provides better accuracy, although it may be offset by difficulty in making two members track in perfect alignment. This is by far the most popular CMM construction. Figure 8.2 shows a bridge structure.

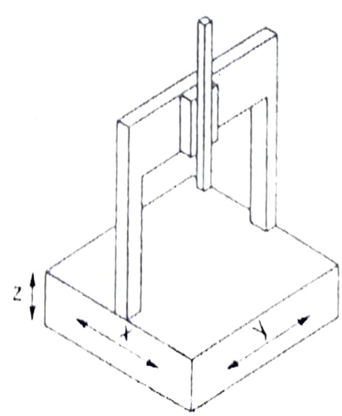


Figure 8.2 : Bridge Structure

Column Type

The column type machine is commonly referred to as a universal measuring machine rather than a CMM. These machines are usually considered gage room instruments rather than production floor machine. The direction of movements of the arms are as shown in Figure 8.3. The constructional difference in column type with the cantilever type is with x and y-axes movements.

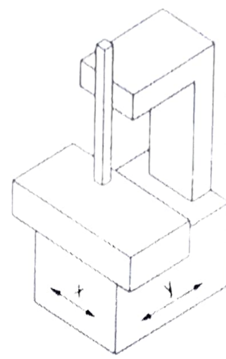


Figure 8.3 : Column Structure

Gantry

In a gantry type arrangement, arms are held by two fixed supports as shown in Figure 8.4. Other two arms are capable of sliding over the supports. Movements of the x, y and z-axes are also as shown in Figure 8.4. The gantry type construction is particularly suited for very large components and allows the operator to remain close to the area of inspection.

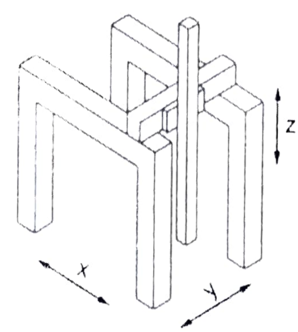


Figure 8.4 : Gantry Structure

Horizontal

Figure 8.5 shows the construction of a horizontal structure. The open structure of this arrangement provides optimum accessibility for large objects such as dies, models, and car bodies. Some horizontal arm machines are referred to as layout machines. There are some horizontal machines where the probe arm can rotate like a spindle to perform tramming operations. Tramming refers to accurate mechanical adjustment of instrument or machine with the help of tram.

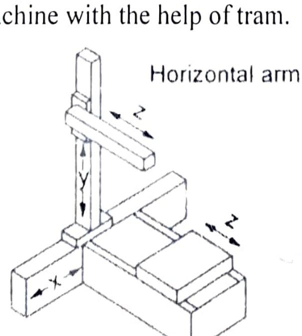


Figure 8.5 : Horizontal Structure

Probing System

It is the part of a CMM that sense the different parameters required for the calculation. Appropriate probes have to be selected and placed in the spindle of the CMM. Originally, the probes were solid or hard, such as tapered plugs for locating holes. These probes required manual manipulation to establish contact with the workpiece, at which time the digital display was read. Nowadays, transmission trigger-probes, optical transmission probes, multiple or cluster probes, and motorized probes are available. They are discussed in brief below:

Inductive and Optical Transmission Probes

Inductive and optical transmission probes have been developed for automatic tool changing. Power is transmitted using inductive linking between modules fitted to the machine structure and attached to the probe. Figure 8.6 shows a schematic of the inductive transmission probe. The hard-wired transmission probe shown is primarily for tool setting and is mounted in a fixed position on the machine structure.

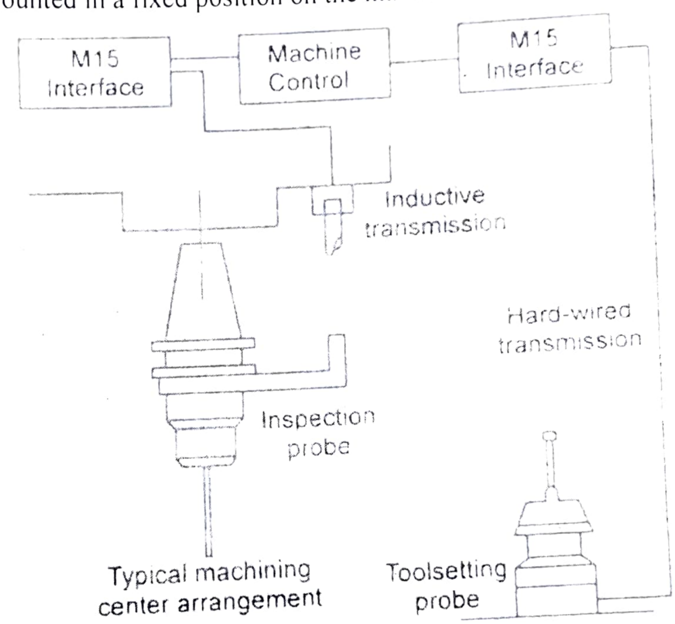


Figure 8.6 : Inductive Probe System and Automatic Probe Changing

The optical transmission probe shown in Figure 8.7 allows probe rotation between gaging moves, making it particularly useful for datuming the probe. The wide-angle system allows greater axial movement of the probe and is suitable for the majority of installation.

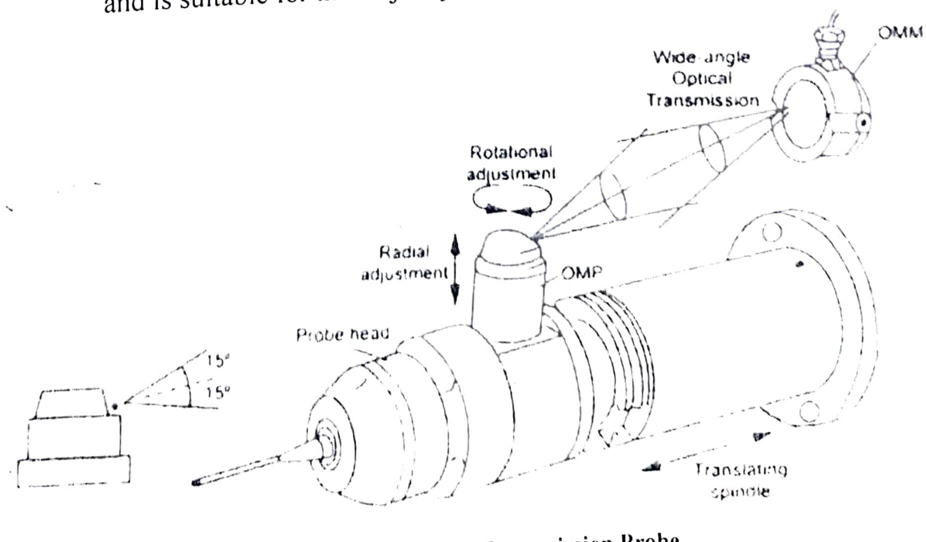
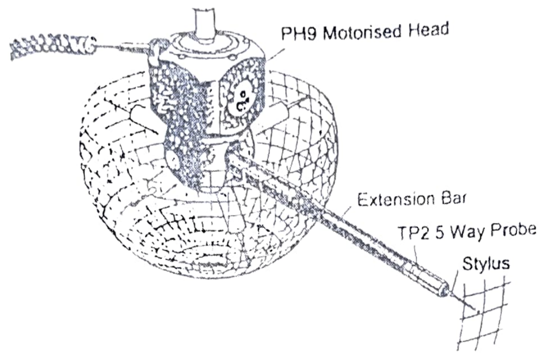


Figure 8.7 : Optical Transmission Probe

Motorized Probe

With the motorized probe, 48 positions in the horizontal axis, 15 in the vertical axis can be programmed for a total of 720 distinct probe orientations. Figure 8.8(b) shows some typical applications for motorized probe. It shows that with a range of light weight extensions, the head can reach into deep holes and recesses. The second diagram shows that head of the probe is sufficiently compact to be regarded as an extension of the machine quill. This enables the inspection of complex components that would otherwise be impossible or involve complex setups.



(a) Motorized Probe

(b) Typical Applications of Motorized Probe

Figure 8.8

Multiple Styluses Probe Heads

Wide ranges of styli have been developed to suit many different gaging applications. Some of the different styli available are shown mounted on a multiple gaging head in Figure 8.9. The selection of stylus is done based on the application for which the probe is to be used.

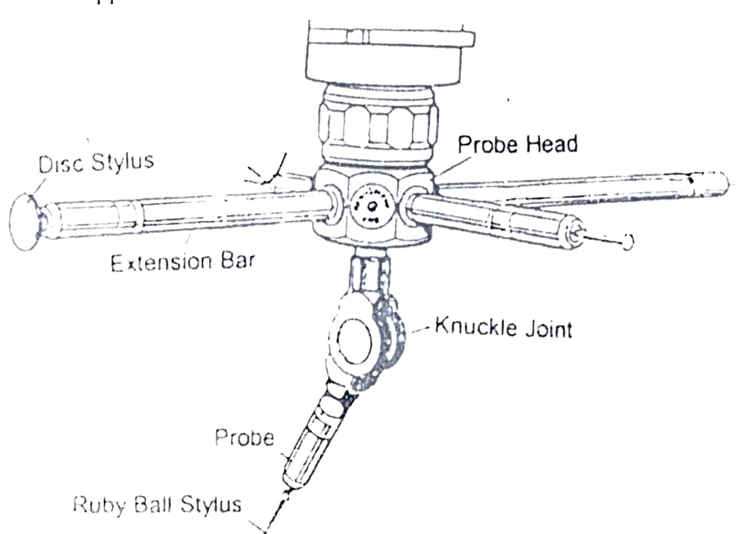


Figure 8.9 : Multiple Stylus Probe Head with Variety of Styli

Machine Control and Computer Hardware

The control unit allows manual measurement and self teach programming in addition to CNC operation. The control unit is microprocessor controlled. Usually a joystick is provided to activate the drive for manual measurement.

Software for Three-dimensional Geometry Analysis

In a CMM, the computer and the software are an inseparable part. They together represent one system. The efficiency and cost effectiveness of a CMM depend to a large extent on the software. The features that the CMM software should include :

- Measurement of diameter, center distances, lengths, geometrical and form errors in prismatic components, etc.
- Online statistics for statistical information in a batch.
- Parameter programming to minimize CNC programming time of similar parts.
- Measurement of plane and spatial curves.
- Data communications.
- Digital input and output commands for process integration.
- Program for the measurement of spur, helical, bevel and hypoid gears.
- Interface to CAD software.

SAQ 1

(a) What are the different structures that the body of a coordinate measuring machine can have? Describe them in brief.

(b) Describe the different parts of a coordinate measuring machine.

8.3 CMM IN COMPUTER AIDED MANUFACTURING

CMM is a very essential and useful tool in CAM. The old standards in communication in CAM were capable of only unidirectional communications, i.e. they translated data which were then converted into design form. But whether the design conforms to the specification could not be known from these standards. Dimensional Measurement Interface System (DMIS) is a new standard in communication used in CAM. It provides a bi-directional communication of inspection data between manufacturing systems and inspection equipment to see what has to be made and what has been made. CMMs enable DMIS bi-directional communication.

The data-collecting unit in a CMM is the probe. Therefore, selection of probe and its positioning is very crucial. Instructions must be given to CMM system for the speed for positioning the probe, the path to be followed by the probe, angle at which the probe approaches etc. After a part has been produced on the CNC machine, finished part would be checked on a CMM with its inspection program. Then, the data about the checked part is sent back to the computer, where the original part geometry is stored. The part geometry as designed is compared with the part produced and the resultant deviation could be identified. It helps in identifying problems in manufacturing. Figure 8.10 shows an interrelation among CNC machine tool, CAD system and a CMM.

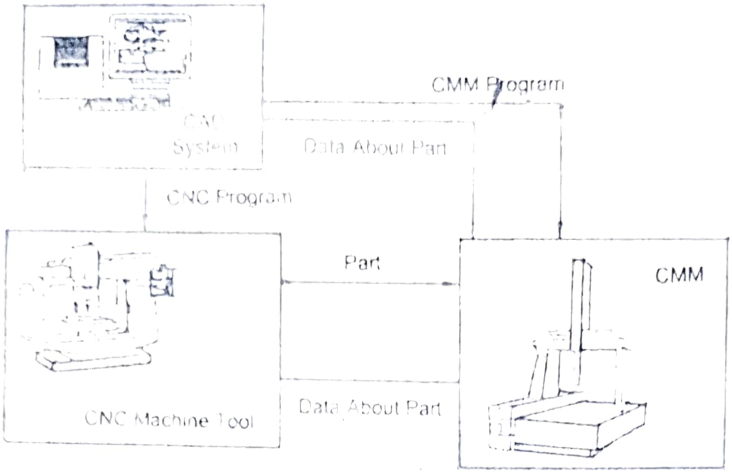


Figure 8.10 : CMM in CAM

8.4 ADVANTAGES OF CMM

CMM has got a number of advantages. The precision and accuracy given by a CMM is very high. It is because of the inherent characteristics of the measuring techniques used in CMM. Following are the main advantages that CMM can offer :

Flexibility

CMMs are essentially universal measuring machines and need not be dedicated to any particular task. They can measure almost any dimensional characteristic of a part configuration, including cams, gears and warped surfaces. No special fixtures or gages are required. Because probe contact is light, most parts can be inspected without being clamped to the table.

Reduced Setup Time

Part alignment and establishing appropriate reference points are very time consuming with conventional surface plate inspection techniques. Software allows the operator to define the orientation of the part on the CMM, and all subsequent data are corrected for misalignment between the parts-reference system and the machine coordinates.

Single Setup

Most parts can be inspected in a single setup, thus eliminating the need to reorient the parts for access to all features.

Improved Accuracy

All measurements in a CMM are taken from a common geometrically fixed measuring system, eliminating the introduction and the accumulation of errors that can result with hand-gage inspection methods and transfer techniques.

Reduced Operator Influence

The use of digital readouts eliminate the subjective interpretation of readings common with dial or vernier type measuring devices. Operator "feel" is virtually eliminated with modern touch-trigger probe systems, and most CMMs have routine measuring procedures for typical part features, such as bores or centre distances. In computer assisted systems; the operator is under the control of a program that eliminates operator choice. In addition, automatic data recording, available on most machines, prevents errors in transcribing readings to the inspection report. This adds upto the fact that less skilled operators can be easily instructed to perform relatively complex inspection procedures.

Improved Productivity

The above-mentioned advantages help make CMMs more productive than conventional inspection techniques. Furthermore, productivity is realized through the computational and analytical capabilities of associated data-handling systems, including calculators and all levels of computers.

SAQ 3

What are the advantages of a co-ordinate measuring machine?

8.5 SUMMARY

In this unit, coordinate measuring machines are discussed. The unit begins with a description of its part. Next to this, the principle of operation and the working of a coordinate measuring machine are discussed. Special consideration in case of coordinate measuring machines and the possible sources of errors in measurement are also noted down. The unit finishes with the discussion of the advantages of a coordinate measuring machine.

8.6 KEY WORDS

Tramming : Tramming refers to indicating a cylindrical surface of a part in such a manner as to centralise the surface with the spindle of the machine.

Stylus : A pointed instrument used as an input device in the probe of a CMM.

Axial Length Measuring Accuracy : It is defined as the absolute value of the difference between the reference lengths of gauges, aligned with a machine axis, and the corresponding measured results from the machine.

Length Measuring Accuracy : It is defined as the absolute value of the difference between the calibrated length of the gauge block and the actual measured value.

Probe : It is the sensory part of a CMM responsible for sensing different parameters required for the measurement.

DMIS : Dimensional Measurement Interface Specification is a new standard in communication being used in Computer Aided Manufacturing. It provides a bi-directional communication of inspection data between CAD system and inspection equipment so as to see what has to be made and what has been made.

8.7 ANSWERS TO SAQs

Please refer the preceding text for answers of all the SAQs.