Coordinate Measuring Machine (CMM)

Overview

- Coordinate measuring machines (CMMs) are extremely powerful metrological instrument
- It is a device for measuring the physical geometrical characteristics of an object
- This machine may be manually controlled by an operator or it may be computer controlled.
- Measurements are defined by a probe attached to the third moving axis of this machine
- This probe touches the part of interest and allows collecting discrete points on the object's surface.

Measuring using CMM

THE ROLE OF COORDINATE MEASURING MACHINES

- CMMs play an important role in a large number of industries, including;
  - Aerospace
  - Automotive
  - Food processing
  - Health care
  - Paper
  - Pharmaceuticals
  - Plastics
  - Research and development
  - Semiconductor

THE ROLE OF COORDINATE MEASURING MACHINES

- CMMs are particularly suited for the following conditions:
  - Short runs
  - Multiple features
  - Flexibility
  - High unit cost
  - Production interruption

Short run

- We may be producing hundreds or even thousands of part, but the production run is not sufficient to justify the cost of production inspection tooling

Multiple features

- When we have a number of features- both dimensional and geometric- to control, CMM is the instrument that makes control easy and economical

Flexibility

- Because we can choose the application of the CMM system, we can also do short runs and measure multiple features

High unit cost

- Because reworking or scrapping is costly, CMM systems significantly increase the production of acceptable parts

Production interruption

- Whenever you have to inspect and pass one part before you can start machining on the next part, a machining center may actually be able to help a manufacturer save more money by reducing downtime than would be save by inspection

Comparison between conventional and coordinate measuring technology

CONVENTIONAL METROLOGY	COORDINATE METROLOGY
Manual, time consuming alignment of the test piece	Alignment of the test piece not necessary
Single purpose and multi-point measuring instruments making it hard to adapt to changing measuring task	Simple adaptation to the measuring test by software
Comparison of measurement with material measures, i.e., gauge block	Comparison of measurement with mathematical or numerical value
Separate determination of size, form, location and orientation with different machines	Determination of size, form, location and orientation in one setup using one reference system

Important features of the CMMs

1. 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.
2. 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.
3. All machines are provided with their own computers with interactive dialogue facility and friendly software.
4. Thermocouples are incorporated throughout the machine and interfaced with the computer to be used for compensation of temperature gradients and

Elements of CMM

1. Main Structure
2. Probing System
3. Machine Control and Computer Hardware
4. Software for Three-dimensional Geometry Analysis

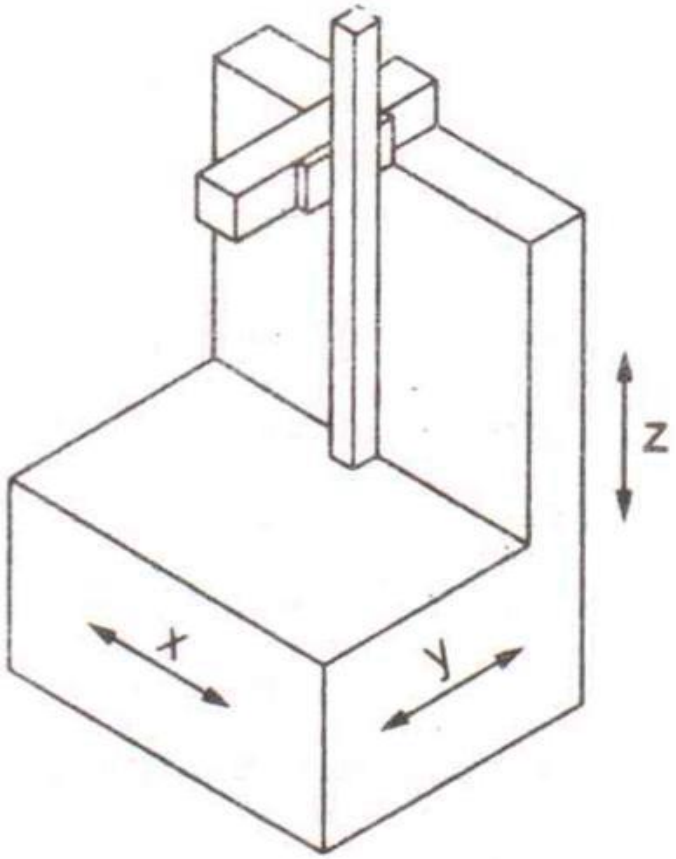
Main Structure

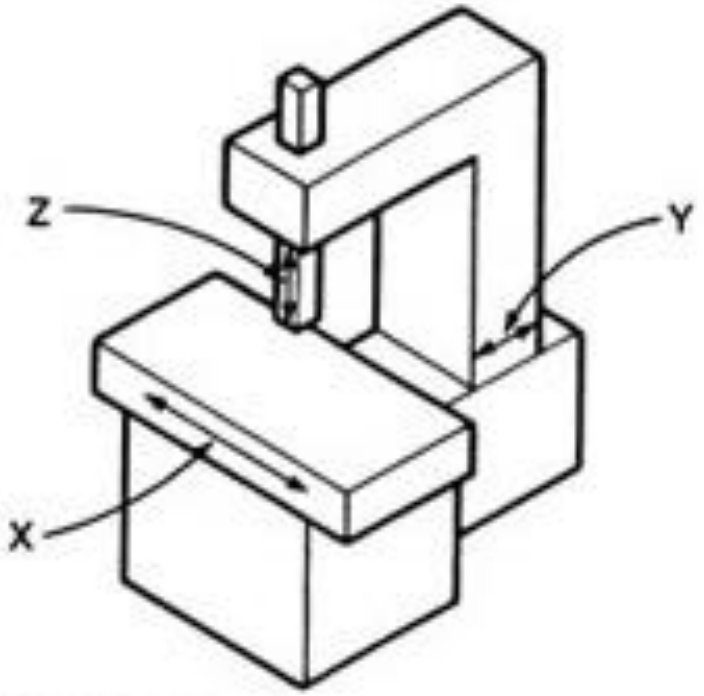
- The machine incorporates the basic concept of three coordinate axes so that precise movement in x, y, and z directions is possible.
- Each axis is fitted with a linear measurement transducer.
- The transducers sense the direction of movement and gives digital display.

TYPES OF CMMs

- The basic CMM has three perpendicular axis; x,y,z
- The physical configuration of CMMs vary widely, but they all provide a way to move a probe in three axes with respect to workpiece
- Five basic configurations that are used more frequently
  1. **Cantilever**
  2. **Bridge**
  3. **Column**
  4. **Horizontal arm**
  5. **Gantry**

Cantilever type





A. MOVING TABLE CANTILEVER ARM TYPE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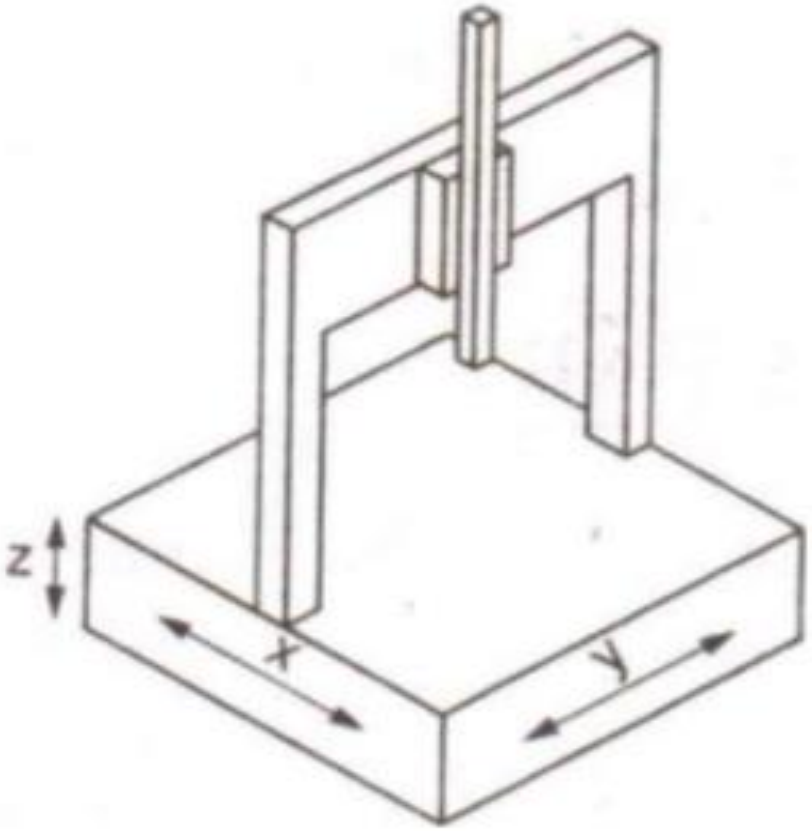
32 14 10

Cantilever type

- A vertical probe moves in the z-axis
- Carried by a cantilevered arm that moves in the y-axis
- This arm also moves laterally through the x-axis
- Advantage- a fixed table allows good accessibility to the workpiece
- Disadvantage- the bending caused by the cantilever design
- The cantilever design offers a long table with relatively small measuring ranges in the other two axis.
- Suitable for measuring long, thin part

Bridge type

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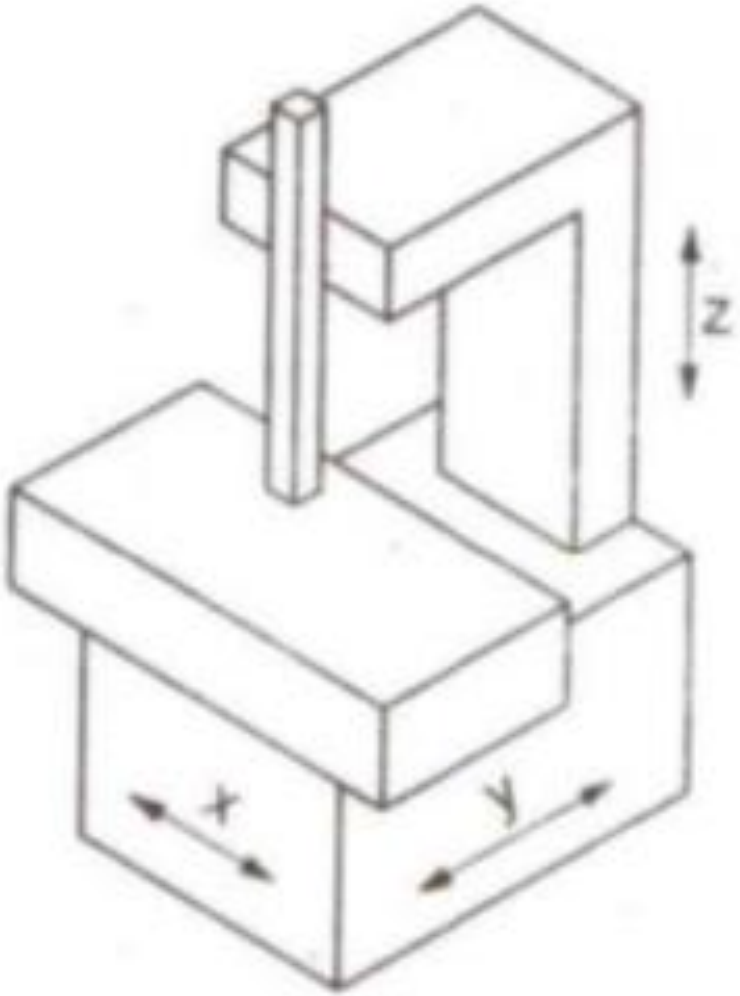
Moving bridge type

- Most widely used
- Has stationary table to support workpiece to be measured and a moving bridge
- The bridge arrangement over the table carries the quill (z-axis) along the x-axis and is sometimes referred to as a travelling bridge.
- Disadvantage- with this design, the phenomenon of yawing (sometimes called walking) can occur- affect the accuracy

Fixed bridge type

- 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

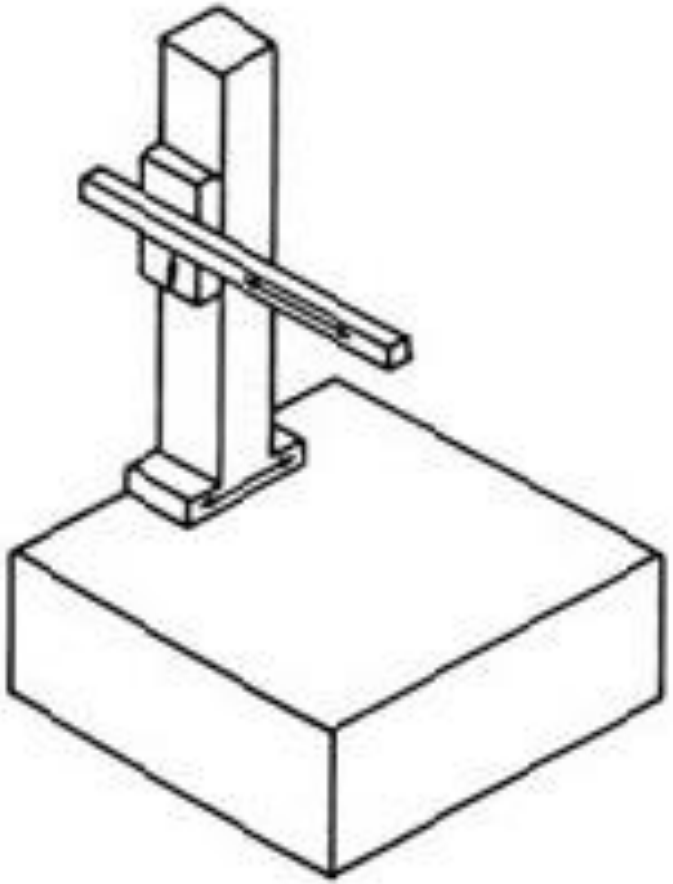
Column type



Column type

- Often referred to as universal measuring machine instead of CMM
- The column type CMM construction provides exceptional rigidity and accuracy
- These machines are usually reserved for gage rooms rather than inspection

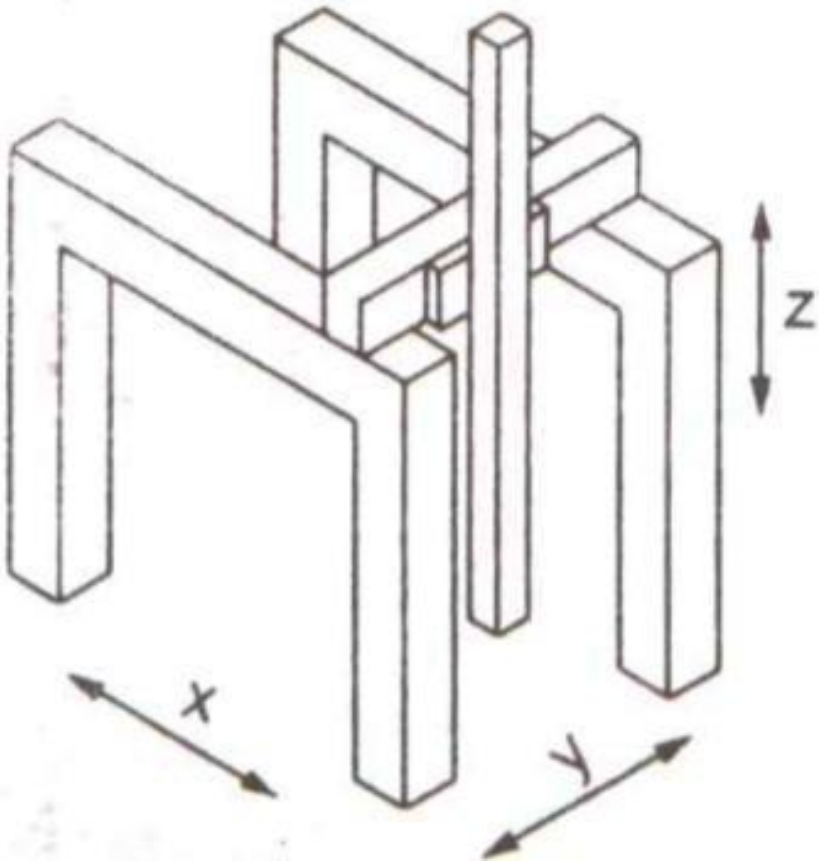
Horizontal arm type



Horizontal arm type

- Unlike the previous machines, the basic horizontal arm-type CMM
- Also referred to as layout machine
- Has a moving arm, and the probe is carried along the y-axis
- Advantage- provides a large area, unobstructed work area
- Ideal configuration for measurement of automobile parts

Gantry type

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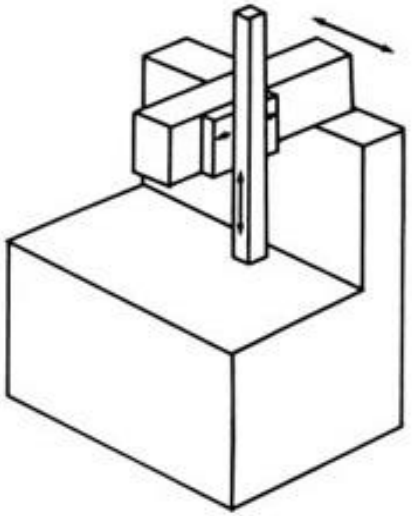
Gantry type

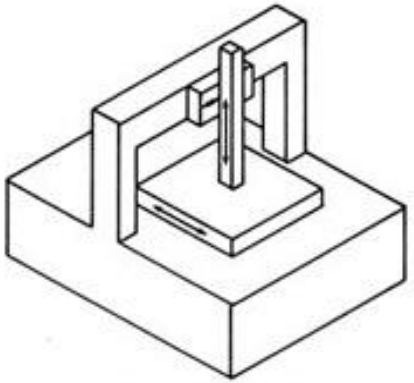
- The support of workpiece is independent of the x and y axes, both are overhead, supported by four vertical columns rising from the floor
- This setup allows you to walk along the workpiece with the probe, which is helpful for extremely large pieces

Gantry configuration with dual linear motor drives, laser scales an online compensation

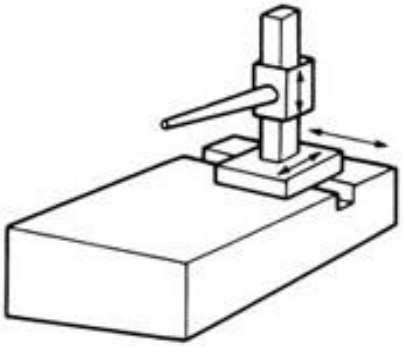
Other configuration



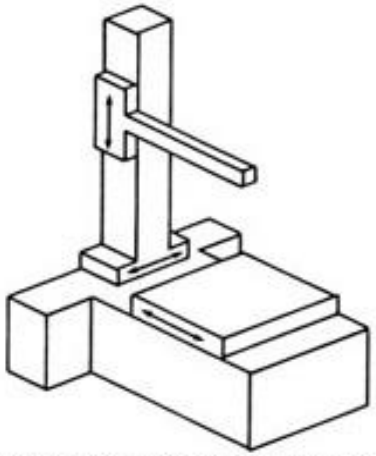
FIXED TABLE CANTILEVER TYPE



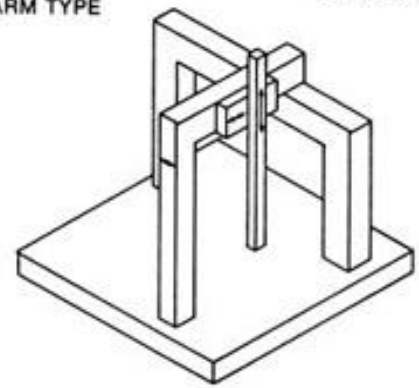
FIXED BRIDGE TYPE



FIXED TABLE HORIZONTAL ARM TYPE



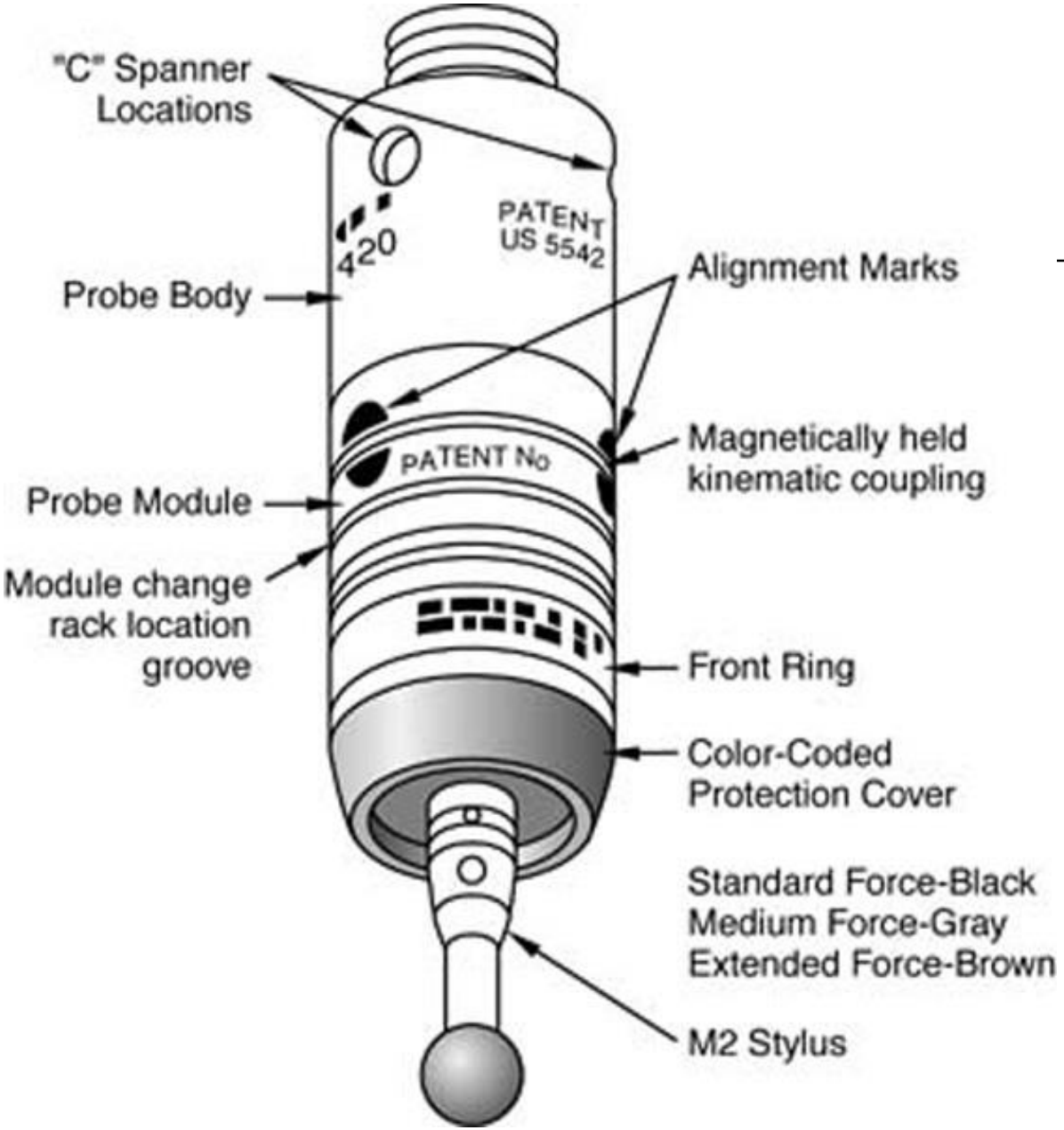
MOVING TABLE HORIZONTAL ARM TYPE



L-SHAPED BRIDGE TYPE

Probing System

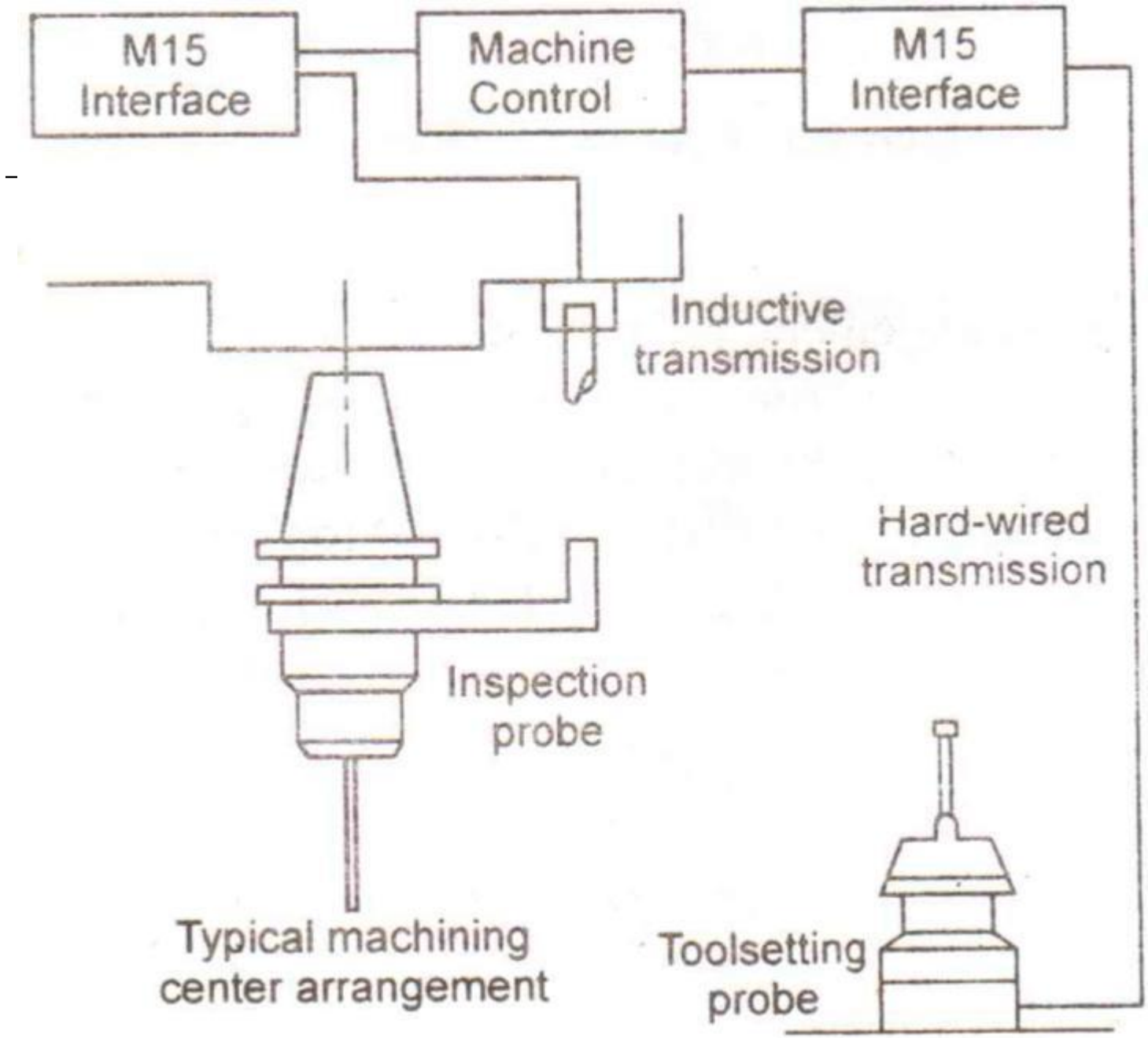
- It is the part of a CMM that sense the different parameters required for the calculation.
- Appropriate probes have to be selected and placed in the spindle of the CMM.
- Originally, the probes were solid or hard, such as tapered plugs for locating holes.
- These probes required manual manipulation 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.


"C" Spanner Locations
420
PATENT US 5542
Probe Body
Alignment Marks
PATENT No
Magnetically held kinematic coupling
Probe Module
Module change rack location groove
Front Ring
Color-Coded Protection Cover
Standard Force-Black
Medium Force-Gray
Extended Force-Brown
M2 Stylus

Inductive and Optical Transmission Probes

Inductive Transmission Probes

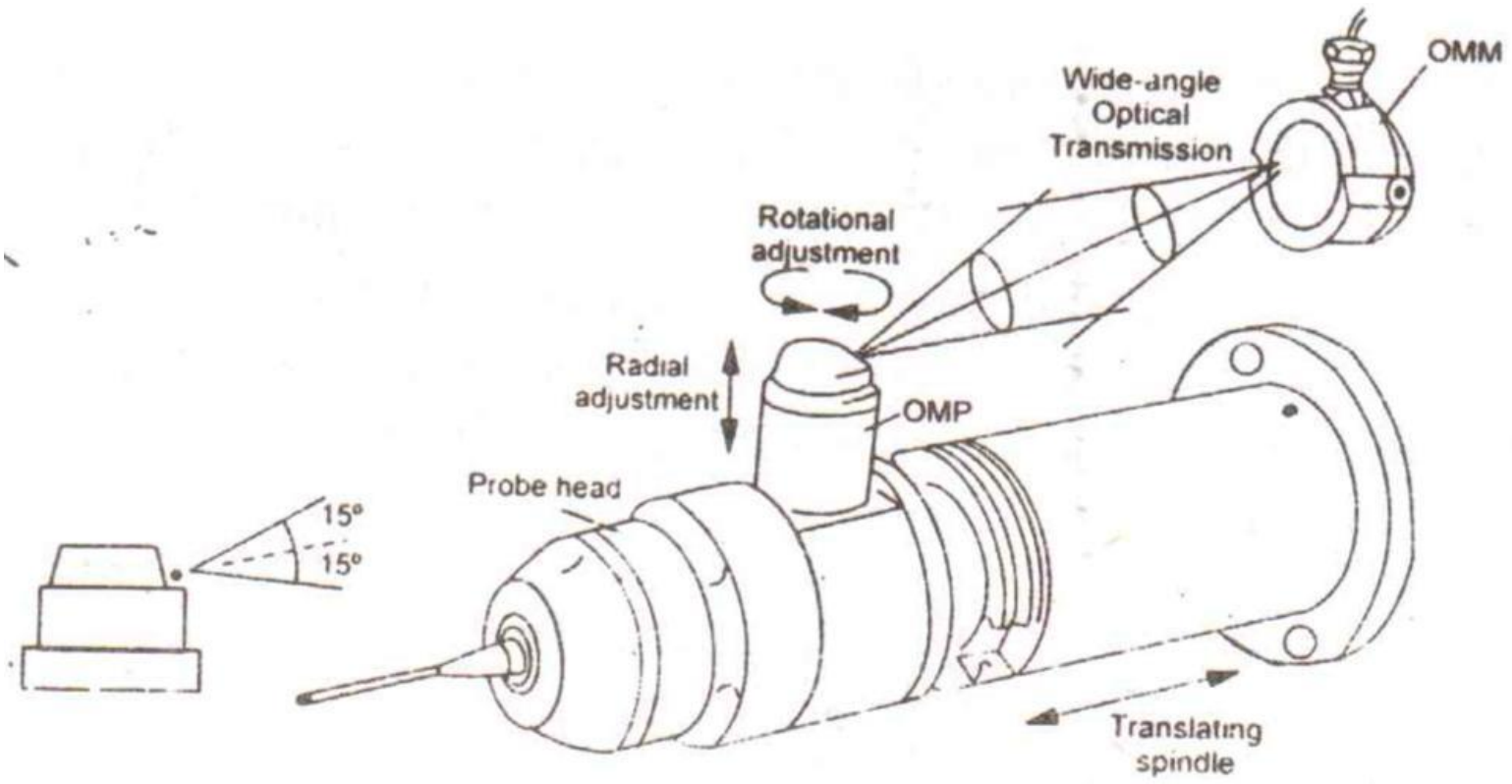
- Used for automatic tool changing.
- Power is transmitted using inductive linking between modules fitted to the machine structure and attached to the probe.


M15 Interface
Machine Control
M15 Interface
Inductive transmission
Hard-wired transmission
Inspection probe
Typical machining center arrangement
Toolsetting probe

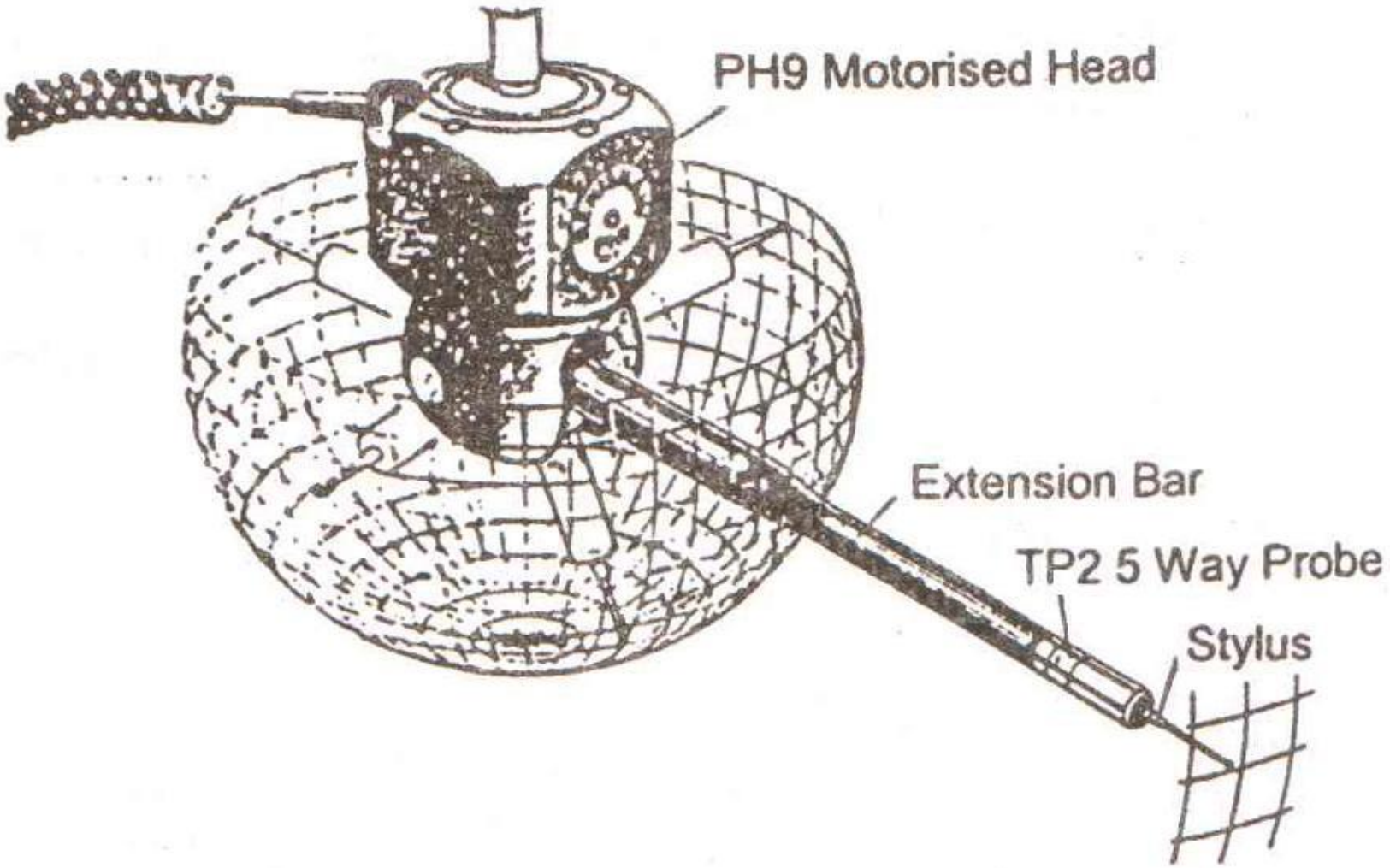
Optical Transmission Probes

- The optical transmission probe 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.

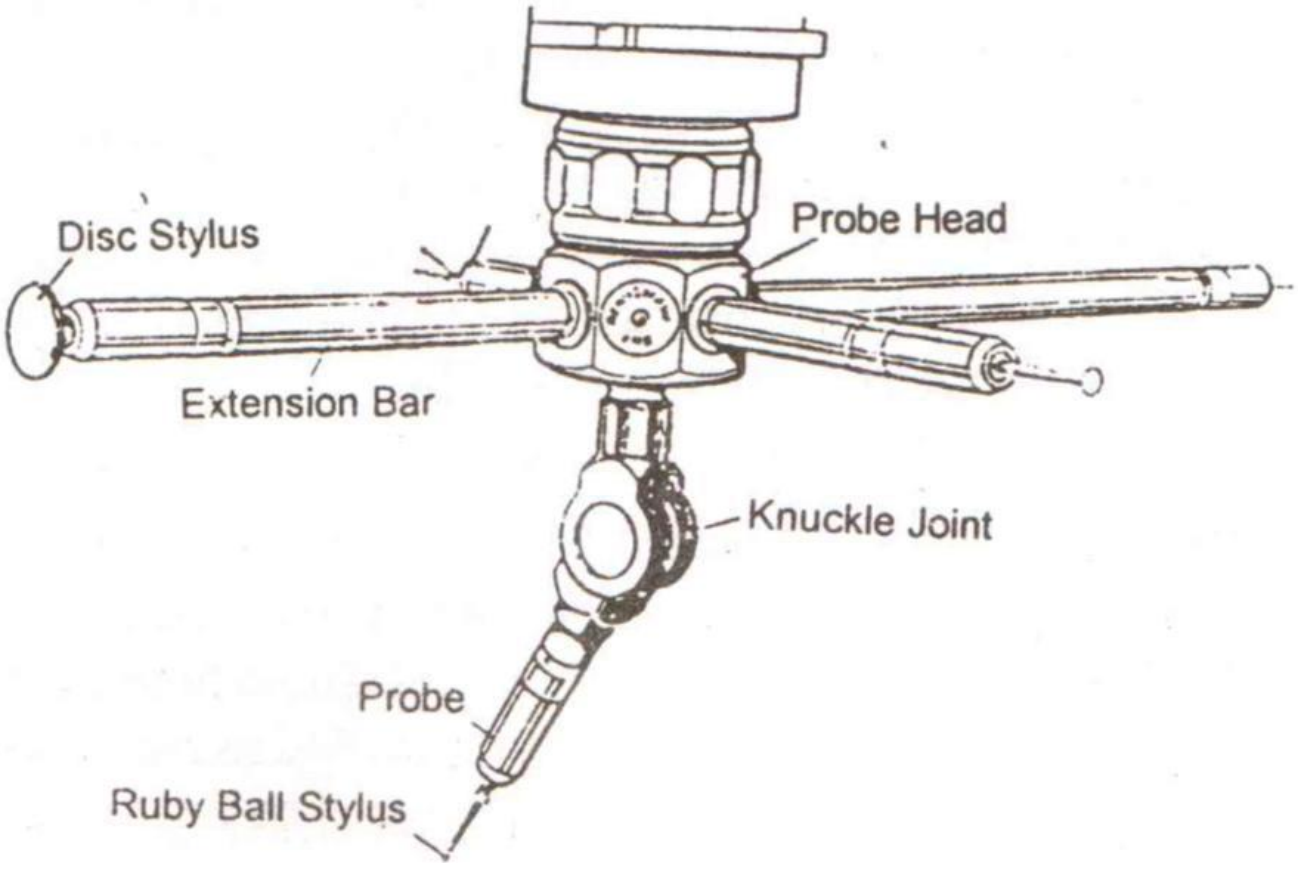
Optical Transmission Probes



Motorized Probe



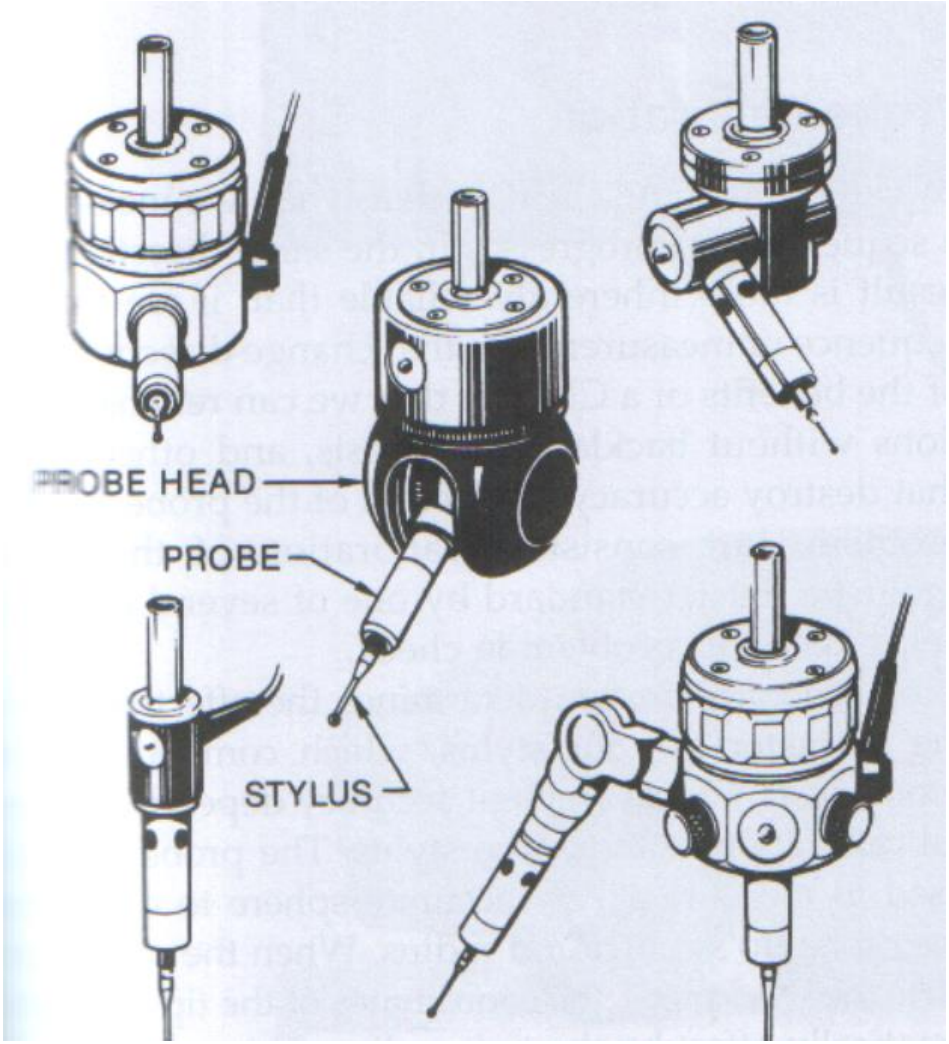
Multiple Styluses Probe Heads



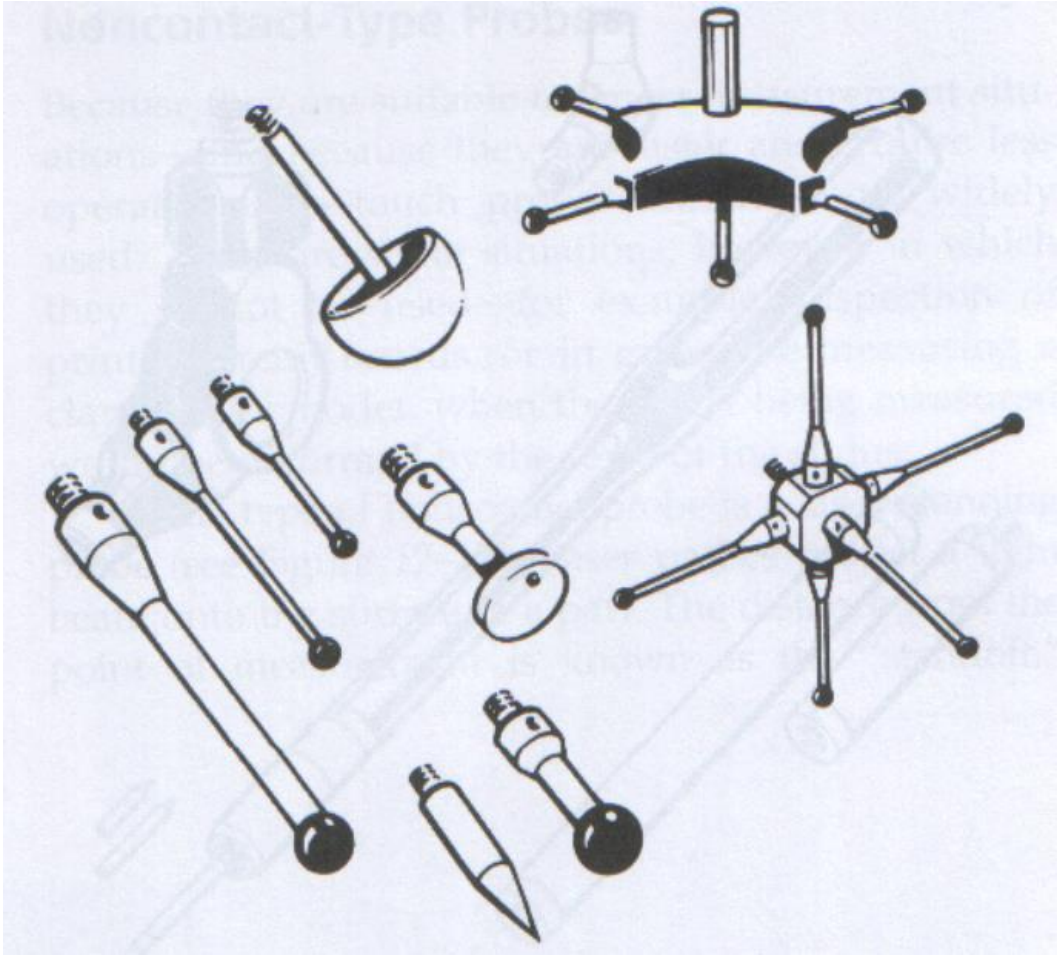
Non-contact probe

1. Laser scanning probe
   - Laser probes project a light beam onto the surface of a part
   - When the light beam is triggered, the position of beam is read by triangulation through a lens in the probe receptor
   - Laser tool have a high degree of speed and accuracy
2. Video probe
   - The feature are measured by computer ‘count’ of the pixels of the electronic image
   - The camera is capable of generating multitude of measurements points within a single video frame

Probe head, probes and stylus



Multiple shapes of sylus




Fowler


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.

Features that the CMM software

- 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,

MODES OF OPERATION

- Manual
- Manual computer assisted
- Motorized computer assisted
- Direct computer controlled

Manual

- CMM has a free floating probe that operator move along the machine’s three axes to establish contact with the part feature that accessing
- The differences among the contact positions are the measurements

Manual computer assisted

- Add electronic digital displays for these machines, making zero setting, changing sign, converting unit, and printing out data easy and practical
- Advantage- save time, minimize calculation, reduce error

Motorized computer assisted

- Uses a joystick to drive the machine axes
- The operator manipulates the joysticks to bring the probe sensor into contact with the workpiece

Direct computer controlled (DCC)

- Fully programmable
- Use CAD data to determine where the probe sensor contacts the workpiece, collecting measurement data
- The fully automated CMM allows operator to place the workpiece in a fixture/ worktable, run a stored program, collect the data points and generate the output report
- Measurement reports can be saved in the computer to compile a historical record for SPC.
- A program of DCC machine has three components:
  1. Movement commands – direct the probe to the data collection points
  2. Measurement command – compare the distance traveled with the standard built into the machine for that axis
  3. Formatting command- translate the data into a form for display or print out

CMM software

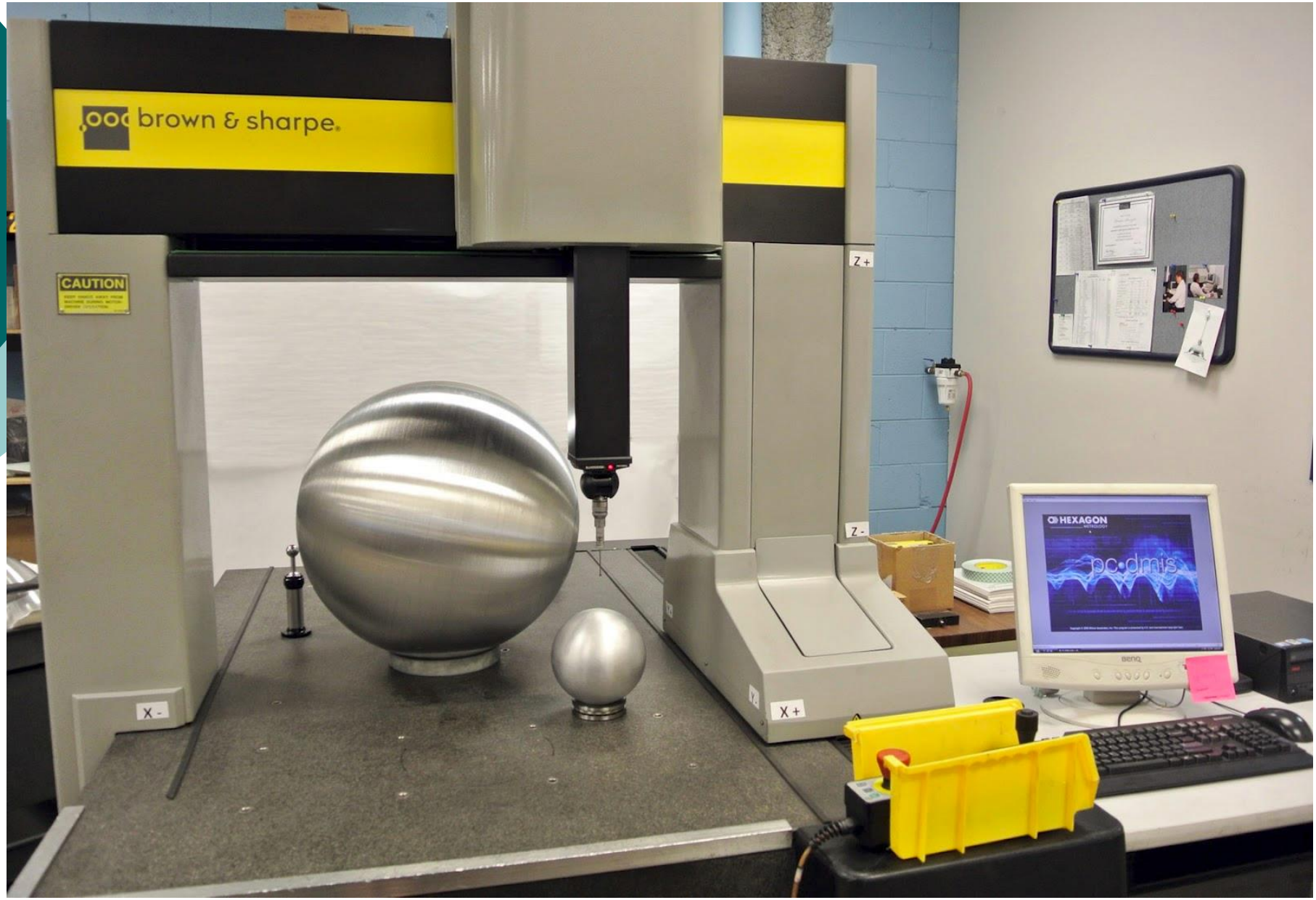
- The programming of the machine or the software of the system enables the CMM to reach its full potential for accuracy, precision and speed
- Contour programs allow the CMM to quickly define detailed, complex non-geometric shapes such as gear, cams, and injection molds
- These programs also can be used to compare the measurement data with a computer assisted drafting (CAD) model

CMM software (cont')

- Generally software packages contains some or all of the following capabilities:
  - Resolution selection
  - Conversion between SI and English (mm and inch)
  - Conversion of rectangular coordinates to polar coordinates
  - Axis scaling
  - Datum selection and reset
  - Circle center and diameter solution
  - Bolt-circle center and diameter
  - Save and recall previous datum
  - Nominal and tolerance entry
  - Out-of tolerance computation

Coordinate System

- A coordinate allows the CMM to locate features on a workpiece relative to other features
- The coordinate system is similar to a three-dimensional map, providing direction and location
- Each machine has a ‘home’ position (an origin) and x, y and z axes identify location that represents the machine coordinate system (MCS)
- A manufactured past can also have a part coordinate system (PCS)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CAUTION
Z+
Z-
X-
X+
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pc-dmis


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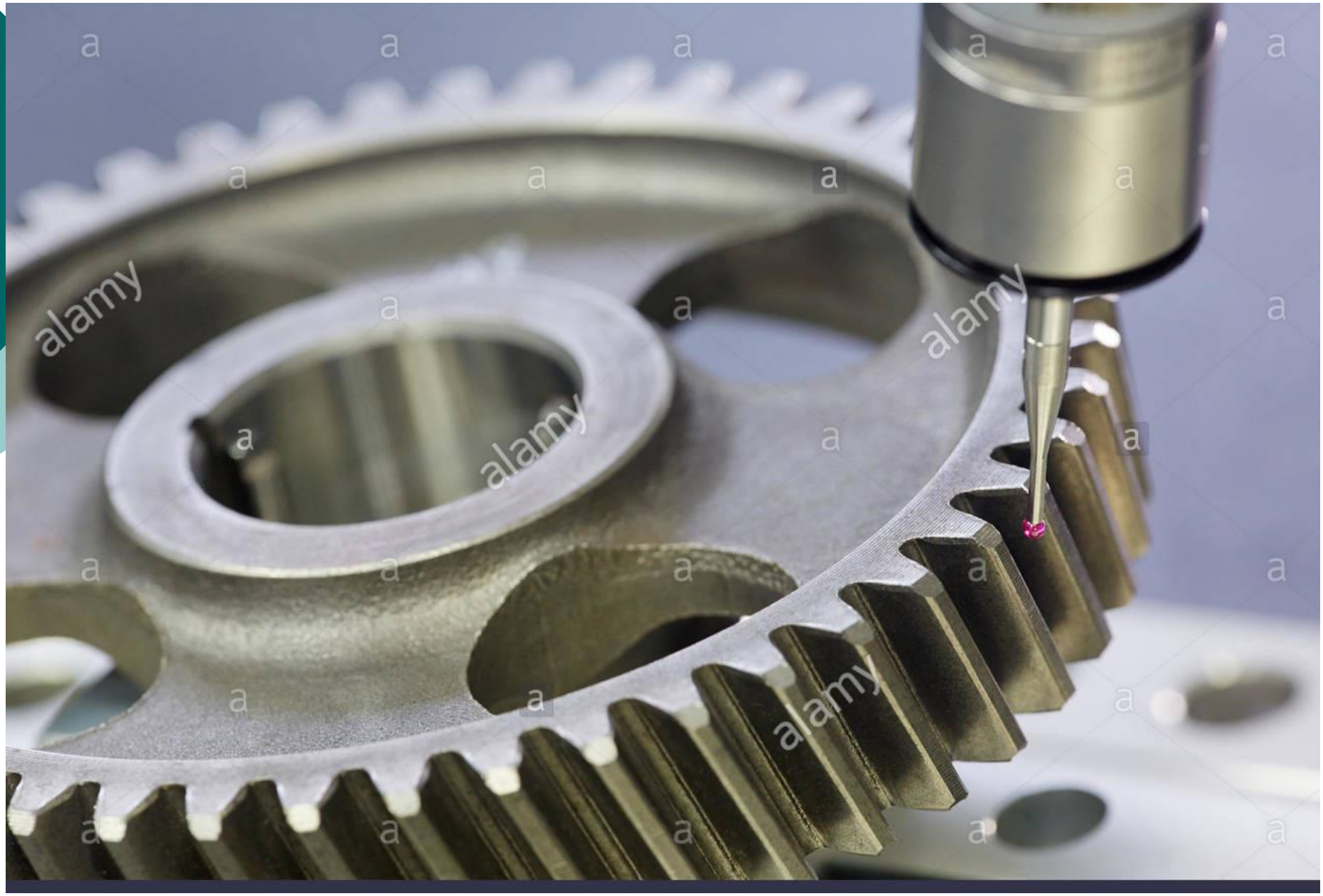

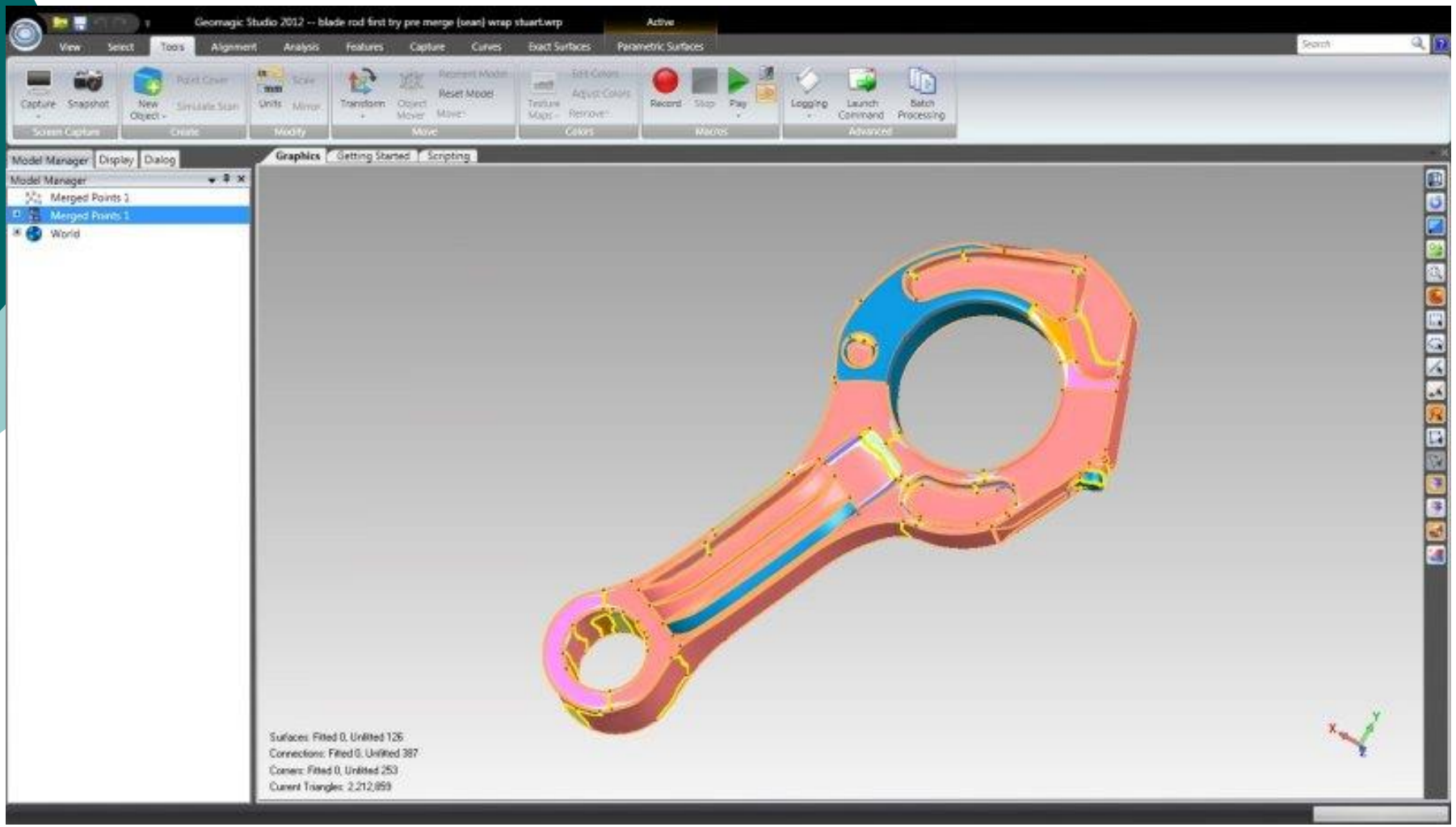
Geomagic Studio 2012 -- blade rod first try pre merge (sean) wrap stuart.wrp
Active
View
Select
Tools
Alignment
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Features
Capture
Curves
Exact Surfaces
Parametric Surfaces
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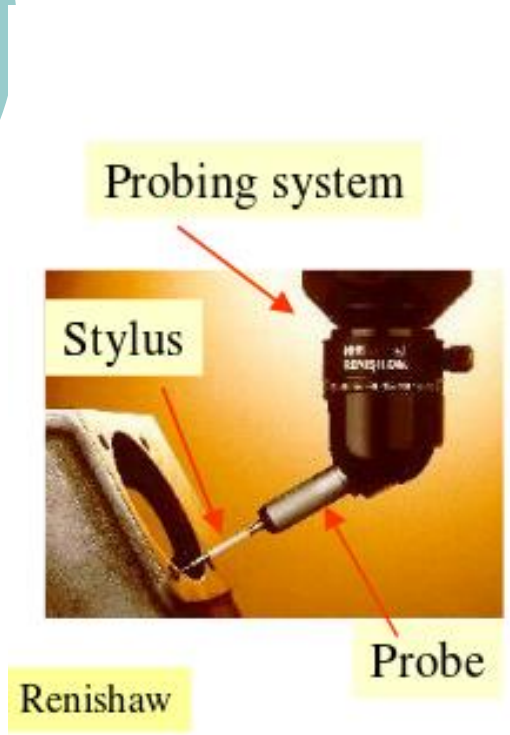
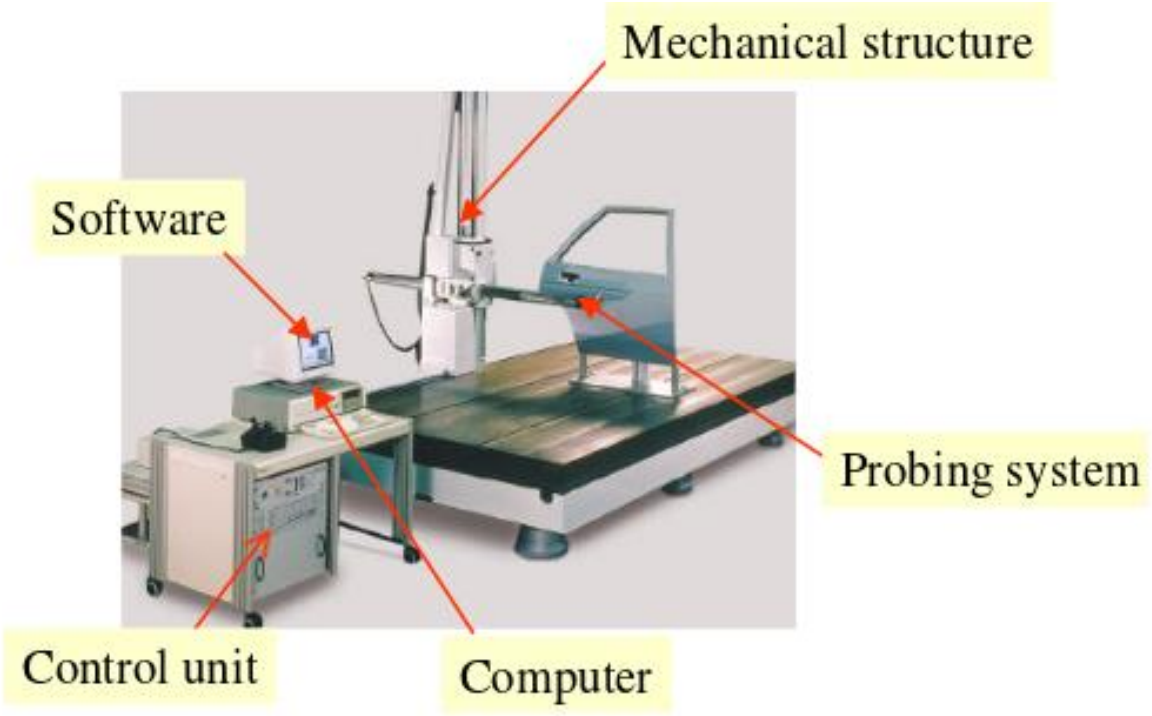
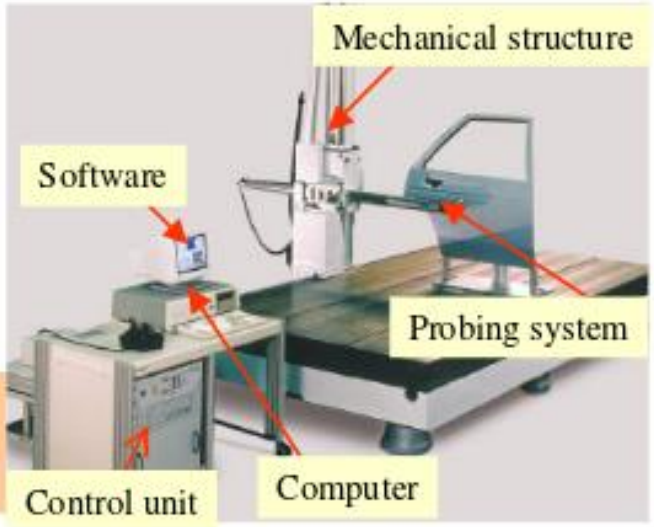
Snapshot
New Object
Point Cloud
Simulate Scan
Units
Scale
Mirror
Transform
Object Mover
Reorient Model
Reset Model
Move
Texture Maps
Edit Colors
Adjust Colors
Remove
Record
Stop
Play
Logging
Launch Command
Batch Processing
Screen Capture
Create
Modify
Move
Colors
Macros
Advanced
Model Manager
Display
Dialog
Model Manager
Merged Points 1
Merged Points 1
World
Graphics
Getting Started
Scripting
Surfaces: Fitted 0, Unfitted 126
Connections: Fitted 0, Unfitted 387
Corners: Fitted 0, Unfitted 253
Current Triangles: 2,212,859
X
Y
Z

CMM IN COMPUTER AIDED MANUFACTURING





Factors influencing the CMM development



New Probing Technologies (laser, video)

Manufacturing Automation

Design Data Transfer

Manufacturing Process Integration

CMM (Software)

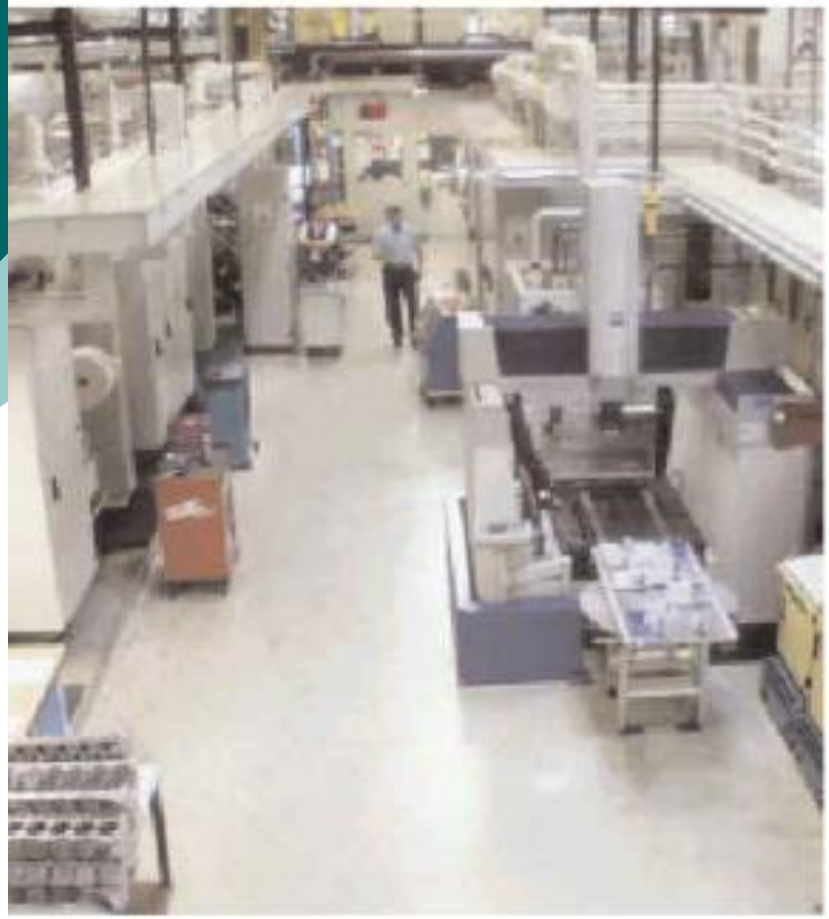
Computing Power

Standards Development (ANSI Y14.5, ISO 1101, DMIS)

Metrology Issues

Accuracy Requirements

CMMs in Industry

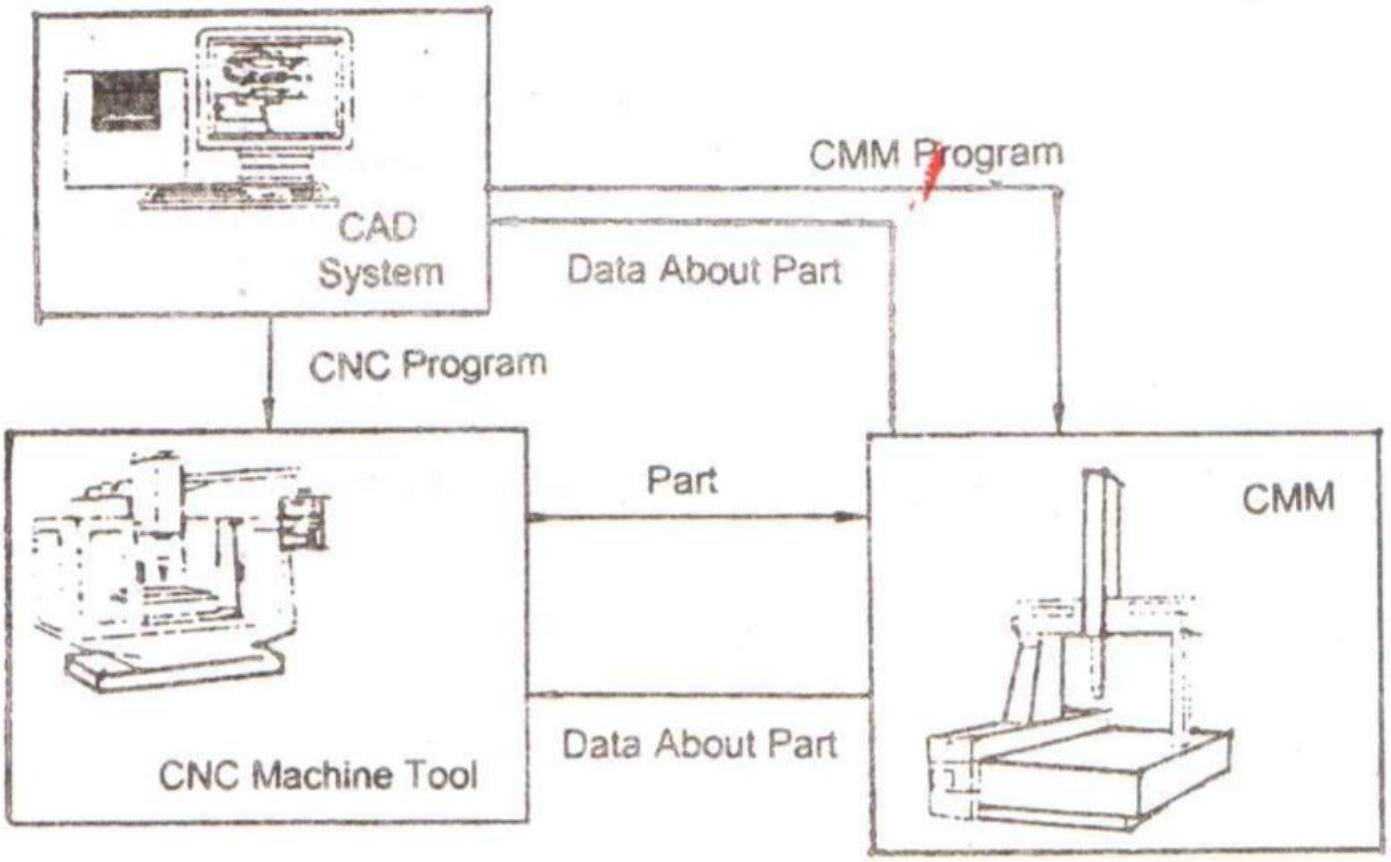


CMM IN COMPUTER AIDED MANUFACTURING

- 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

- 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.

Interrelation among CNC machine tool, CAD system and a CMM.



ADVANTAGES OF CMM

- **Flexibility:** 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:** Software allows the operator to define the orientation of the part on the CMM

- **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:** measurements in a CMM are taken from a common geometrically fixed measuring system, eliminating the introduction and the accumulation of errors

Reduced Operator Influence:

- use of digital readouts eliminate the subjective interpretation of readings common with dial or vernier type measuring devices.
- automatic data recording,available on most machines, prevents errors in transcribing readings to the inspection report.

- **Improved Productivity:** Productivity is realized through the computational and analytical capabilities of associated data-handling systems, including calculators and all levels of computers.