UNIT-V

CO-ORDINATE MEASURING MACHINE

INTRODUCTION

- Measuring machines are used for measurement of length over the outer surfaces of a length bar or any other long member. The member may be either rounded or flat and parallel.
- It is more useful and advantageous than vernier calipers, micrometer, screw gauges etc. the measuring machines are generally universal character and can be used for works of varied nature.
- The co-ordinate measuring machine is used for contact inspection of parts. When used for computer-integrated manufacturing these machines are controlled by computer numerical control.
- A general software is provided for reverse engineering complex shaped objects. The component is digitized using CNC, CMM and it is then converted into a computer model which gives the two surface of the component.
- These advances include for automatic work part alignment on the table. Savings in inspection 5 to 10 percent of the time is required on a CMM compared to manual inspection methods.

TYPES OF MEASURING MACHINES

1. Length bar measuring machine.
2. Newall measuring machine.
3. Universal measuring machine.
4. Co-ordinate measuring machine.
5. Computer controlled co-ordinate measuring machine.

CONSTRUCTIONS OF CMM

- Co-ordinate measuring machines are very useful for three dimensional measurements. These machines have movements in X-Y-Z co-ordinate, controlled and measured easily by using touch probes
- These measurements can be made by positioning the probe by hand, or automatically in more expensive machines. Reasonable accuracies are 5 micro in. or 1 micrometer.
- The method these machines work on is measurement of the position of the probe using linear position sensors.
- These are based on moiré fringe patterns (also used in other systems). Transducer is provided in tilt directions for giving digital display and senses positive and negative direction.

Types of CMM:

(1) Cantilever type: -

- The cantilever type is very easy to load and unload, but mechanical error takes place because of sag or deflection in Y-axis.

(ii) Bridge type: -

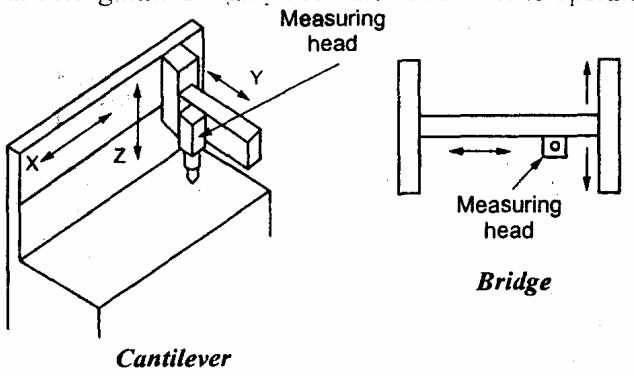
- Bridge type is more difficult to load but less sensitive to mechanical errors.

(iii) Horizontal boring Mill type: -

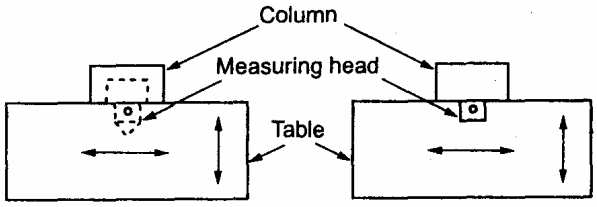
- This is best suited for large heavy work pieces.

(iv) Vertical boring mill type: -

Vertical boring mill is highly accurate but slower to operate.

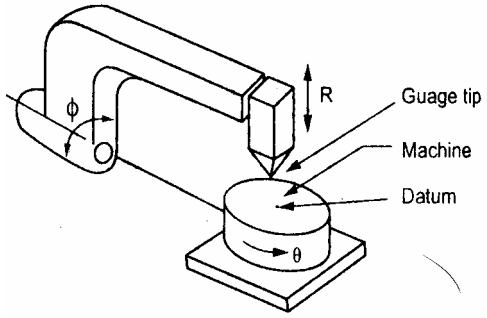


(Measuring head movement in plane perpendicular to paper)



Working Principle:

- CMM is used for measuring the distance between two holes.
- The work piece is clamped to the worktable and aligned for three measuring slides x, y and z.
- The measuring head provides a taper probe tip which is seated in first datum hole and the position of probe digital read out is set to zero.
- The probe is then moved to successive holes, the read out represent the co-ordinate part print hole location with respect to the datum hole.
- Automatic recording and data processing units are provided to carry out complex geometric and statistical analysis.
- Special co-ordinate measuring machines are provided both linear and rotary axes. This can measure various features of parts like cone, cylinder and hemisphere.



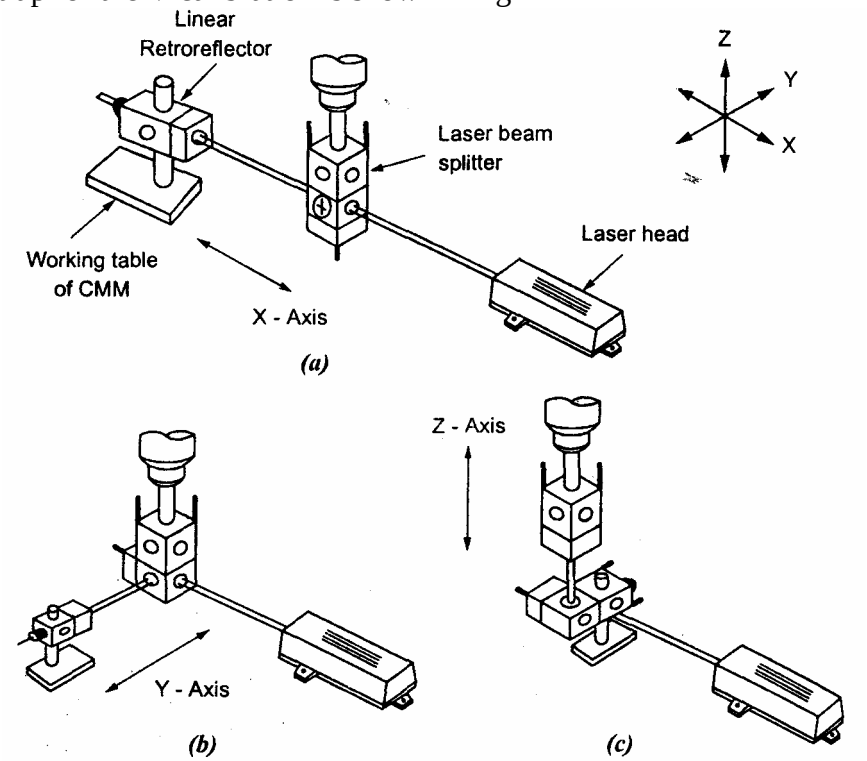
- The prime advantage of co-ordinate measuring machine is the quicker inspection and accurate measurements.

CAUSES OF ERRORS IN CMM

1) The table and probes are in imperfect alignment. The probes may have a degree of run out and move up and down in the Z-axis may occur perpendicularity errors. So CMM should be calibrated with master plates before using the machine.
2) Dimensional errors of a CMM is influenced by
    - v Straightness and perpendicularity of the guide ways.
    - v Scale division and adjustment.
    - v Probe length.
    - v Probe system calibration, repeatability, zero point setting and reversal error.
    - v Error due to digitization.
    - v Environment
3) Other errors can be controlled by the manufacture and minimized by the measuring software. The length of the probe should be minimum to reduce deflection.
4) The weight of the work piece may change the geometry of the guide ways and therefore, the work piece must not exceed maximum weight.
5) Variation in temperature of CMM, specimen and measuring lab influence the uncertainly of measurements.
6) Translation errors occur from error in the scale division and error in straightness perpendicular to the corresponding axis direction.
7) Perpendicularity error occurs if three axes are not orthogonal.

CALIBRATION OF THREE CO-ORDINATE MEASURING MACHINE

The optical set up for the V calibration is shown in fig



- v The laser head is mounted on the tripod stand and its height is adjusted corresponding to the working table of CMM.
- v The interferometer contains a polarized beam splitter which reflects F1 component of the laser beam and the F2 Component parts through.

- The retro reflector is a polished trihedral glass prism. It reflects the laser beam back along a line parallel to the original beam by twice the distance.
- For distance measurement the F1 and F2 beams that leave the laser head are aimed at the interferometer which splits F1 and F2 via polarizing beaming splitter. Component F1 becomes the fixed distance path and F2 is sent to a target which reflects it back to the interferometer.
- Relative motion between the interferometer and the remote retro reflector causes a Dopper shift in the returned frequency. Therefore the laser head sees a frequency difference given by F1-F2 ± ΔF2
- The F1-F2 ± ΔF2 signal that is returned from the external interferometer is compared in the measurement display unit to the reference signal. The difference ΔF2 is related to the velocity.
- The longitudinal micrometer microscope of CMM is set at zero and the laser display unit is also set at zero. The CMM microscope is then set at the following points and the display units are noted.1 to 10mm, every mm and 10 to 200mm, in steps of 10mm.
- The accuracy of linear measurements is affected by changes in air temperature. pressure and humidity.

PERFORMANCE OF CMM:

1) Geometrical accuracies such as positioning accuracy. Straightness and squareness.
2) Total measuring accuracy in terms of axial length measuring accuracy. Volumetric length measuring accuracy and length measuring repeatability. i.e., Coordinated measuring machine has to be tested as complete system.
3) Since environmental effects have great influence for the accuracy testing, including thermal parameters, vibrations and relative humidity are required.

APPLICATION, ADVANTAGES AND DISADVANTAGES OF CMM

APPLICATIONS:

1) Co-ordinate measuring machines find applications in automobile, machine tool, electronics, space and many other large companies.
2) These machines are best suited for the test and inspection of test equipment, gauges and tools.
3) For aircraft and space vehicles, hundred percent inspections is carried out by using CMM.
4) CMM can be used for determining dimensional accuracy of the components.
5) These are ideal for determination of shape and position, maximum metal condition, linkage of results etc. which cannot do in conventional machines.
6) CMM can also be used for sorting tasks to achieve optimum pairing of components within tolerance limits.
7) CMMs are also best for ensuring economic viability of NC machines by reducing their downtime for inspection results. They also help in reducing cost, rework cost at the appropriate time with a suitable CMM.

ADVANTAGES:

- The inspection rate is increased.
- Accuracy is more.
- Operators error can be minimized.
- Skill requirements of the operator is reduced.
- Reduced inspection fixturing and maintenance cost.

- Reduction in calculating and recording time.
- Reduction in set up time.
- No need of separate go / no go gauges for each feature.
- Reduction of scrap and good part rejection.
- Reduction in off line analysis time.
- Simplification of inspection procedures, possibility of reduction of total inspection time through use of statistical and data analysis techniques.

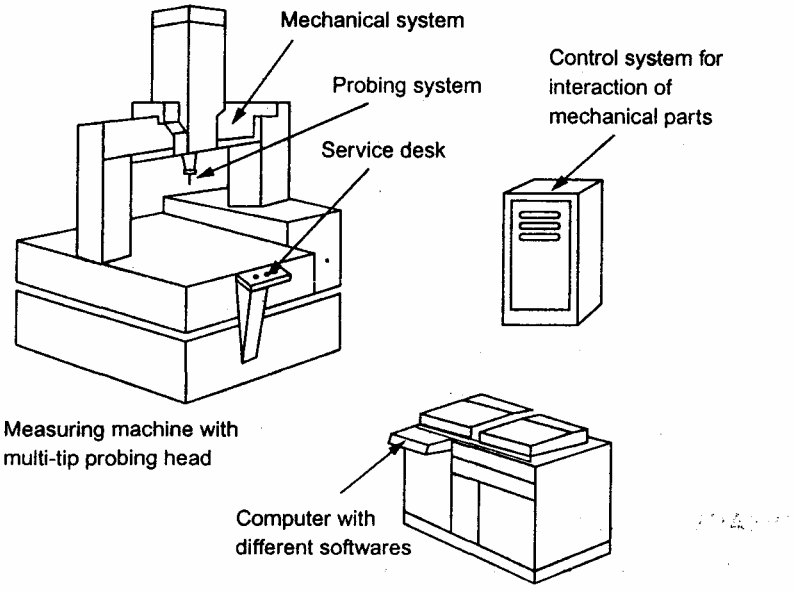
DISADVANTAGES:

1) The lable and probe may not be in perfect alignment.
2) The probe may have run out.
3) The probe moving in Z-axis may have some perpendicular errors.
4) Probe while moving in X and Y direction may not be square to each other.
5) There may be errors in digital system.

COMPUTER CONTROLLED CO-ORDINATE MEASURING MACHINE

- The measurements, inspection of parts for dimension form, surface characteristics and position of geometrical elements are done at the same time.
- Mechanical system can be divided into four basic types. The selection will be depends on the application.

1. Column type.
2. Bridge type.
3. Cantilever type.
4. Gantry type.



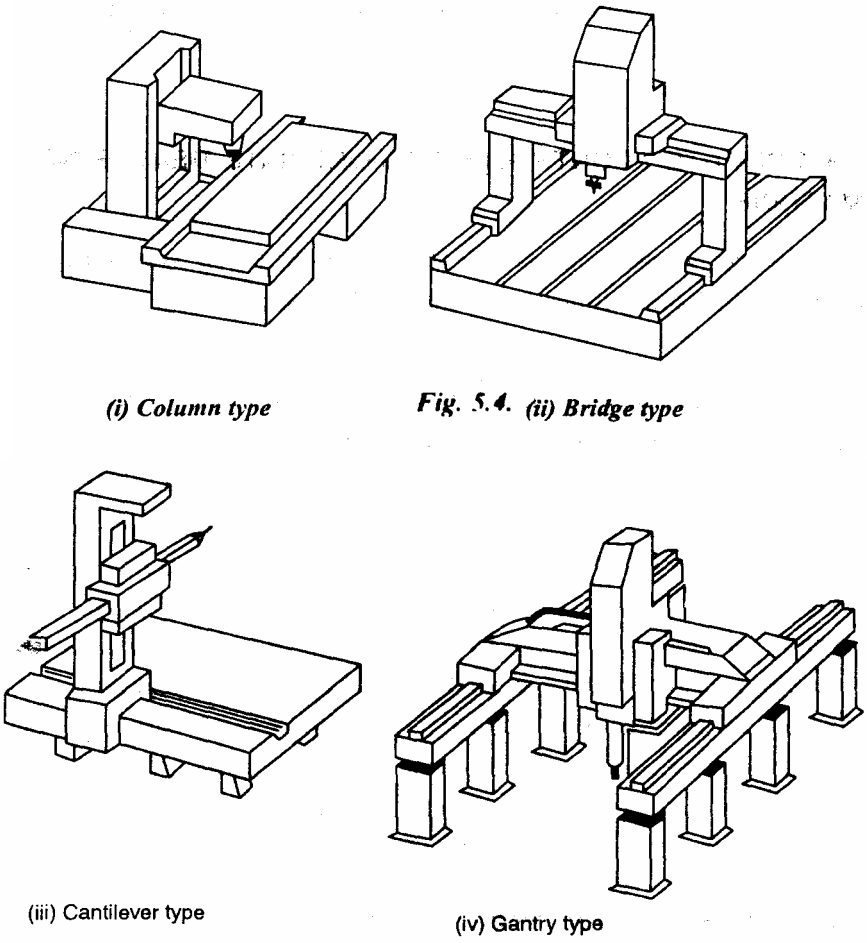
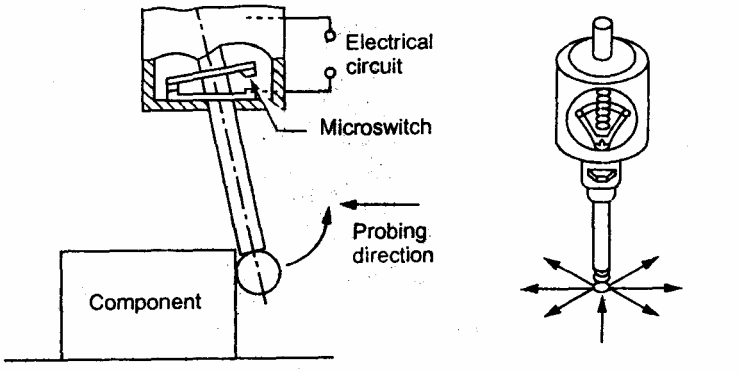


Fig. 5.4.

v All these machines use probes which may be trigger type or measuring type. This is connected to the spindle in Z direction. The main features of this system are shown in figure

Trigger type probe system



(a) Part section of Probe head *(b) Outline of Probe head*

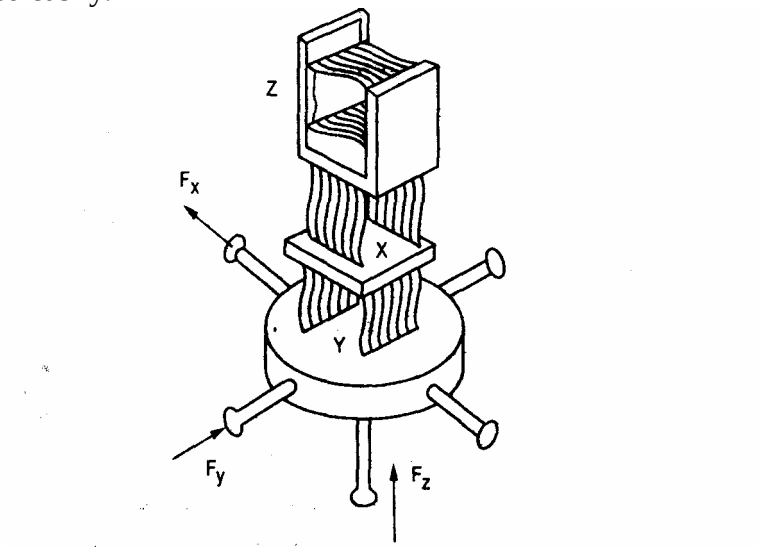
v The buckling mechanism is a three point hearing the contacts which are arranged at 1200 around the circumference. These contacts act as electrical micro switches.

v When being touched in any probing direction one or f contacts is lifted off and the current is broken, thus generating a pulse, when the circuit is opened, the co-ordinate positions are read and stored.

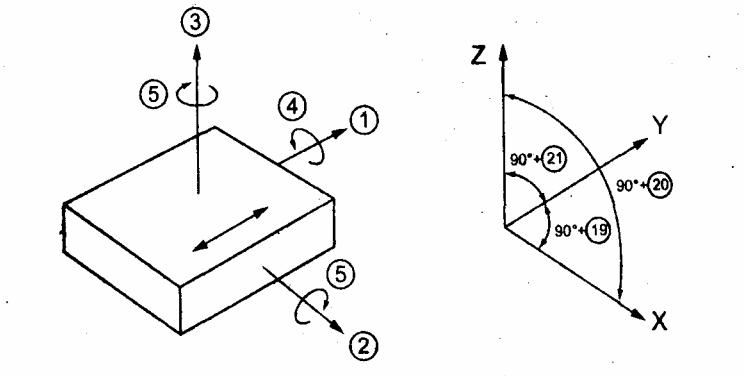
- After probing the spring ensures the perfect zero position of the three-point bearing. The probing force is determined by the pre stressed force of the spring with this probe system data acquisition is always dynamic and therefore the measuring time is shorter than in static principle..

Measuring type probe system

- It is a very small co-ordinate measuring machine in which the buckling mechanism consists of parallel guide ways when probing the spring parallelogram are deflected from their initial position.
- Since the entire system is free from, torsion, friction, the displacement can be measured easily.



- The mathematical model of the mechanical system is shown in figure If the components of the CMM are assumed as rigid bodies, the deviations of a carriage can be described by three displacement deviations.
- Parallel to the axes 1, 2 and 3 and by three rotational deviations about The axes 4, 5 and 6.Similarly deviations 7-12 occur for carriage and 13-18 occur for Z carriage and the three squareness deviations 19, 20 and 21 are to be measured and to be treated in the mathematical model.



- Moving the probe stylus in the Y direction the co-ordinate system L is not a straight line but a curved one due to errors in the guide.
- If moving on measure line L further corrections are required in X, Y and Z co-ordinates due to the offsets X and Z from curve L resulting from the pitch angle 5, the roll angle 4 and the yaw angle 6.

v Similarly the deviations of all three carriages and the squareness errors can be taken into account.

v The effect of error correction can be tested by means of calibrated step gauges. The following test items are carried out for CMM.

(i)Measurement accuracy

a. Axial length measuring accuracy

b.Volumetric length measuring accuracy

(ii)Axial motion accuracy

a. Linear displacement accuracy

b. Straightness

c. Perpendicularity

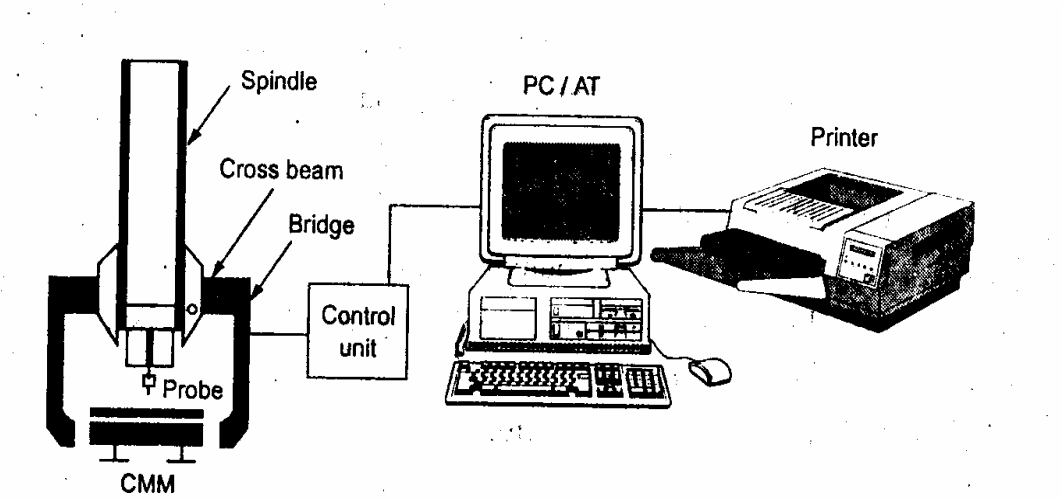
d. Pitch, Yaw and roll.

v The axial length measuring accuracy is tested at the lowest position of the Z-axis. The lengths tested are approximately 1/10, 1/5, 2/5, 3/5 and 4/5 of the measuring range of each axis of CMM. Tile test is repeated five times for each measuring length and results plotted and value of measuring accuracy is derived.

CNC-CMM

Construction:

The main features of CNC-CMM are shown in fig. has stationary granite measuring table, Length measuring system. Air bearings; control unit and software are the important parts of CNC & CMM.



Stationary granite measuring table:

v Granite table provides a stable reference plane for locating parts to be measured. It is provided with a grid of threaded holes defining clamping locations and facilitating part mounting.

v As the table has a high load carrying capacity and is accessible from three sides. It can be easily integrated into the material flow system of CIM.

Length measuring system:

v A 3- axis CMM is provided with digital incremental length measuring system for each axis.

Air Bearing:

v The Bridge cross beam and spindle of the CMM are supported on air bearings.

Control unit: -

- The control unit allows manual measurement and programme. It is microprocessor control.

Software: -

- The CMM, the computer and the software represent one system, the efficiency and cost effectiveness depend on the software.

Features of CMM Software:

(i) Measurement of diameter, center distance, length.
(ii) Measurement of plane and spatial carvers.
(iii) Minimum CNC programme.
(iv) Data communications.
(v) Digital input and output command.
(vi) Programme for the measurement of spur, helical, bevel' and hypoid gears.
(vii) Interface to CAD software.

- A new software for reverse engineering complex shaped objects. The component is digitized using CNC CMM.
- The digitized data is converted into a computer model which is the true surface of the component.
- Recent advances include the automatic work part alignment and to orient the co-ordinate system. .
- Savings in inspection time by using CMM is 5 to 10% compared to manual inspection method.

COMPUTER AIDED INSPECTION USING ROBOTS

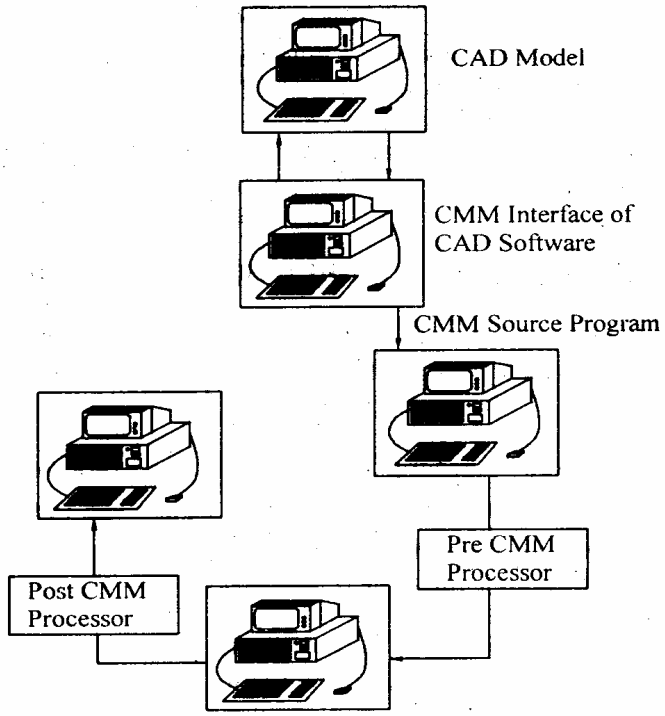
- Robots can be used to carry out inspection or testing operation for mechanical dimension physical characteristics and product performance.
- Checking robot, programmable robot, and co-ordinate robot are some of the types given to a multi axis measuring machines. These machines automatically perform all the basic routines of a CNC co ordinate measuring machine but at a faster rate than that of CMM.
- They are not as accurate as p as CMM but they can check up to accuracies of 5 micrometers. The co-ordinate robot can take successive readings at high speed and evaluate the results using a computer graphics based real time statistical analysis system.

INTEGRATION OF CAD/CAM WITH INSPECTION SYSTEM

- A product is designed, manufactured and inspected in one automatic process. One of the critical factors in manufacturing equality assurance. The co-ordinate measuring machine assists in the equality assurance function.
- The productivity can be improved by interfacing with CAD/CAM system. This eliminates the labour, reduces preparation time and increases availability of CMM for inspection.
- Generally the CAD/CAM-CMM interface consists of a number of modules as given

(1) CMM interface:

- This interface allows to interact with the CAD/CAM database to generate a source file that can be converted to a CMM control data file.



- During source file creation, CMM probe path motions are simulated and displayed on the CAD/CAM workstation for visual verification.
- A set of CMM command allow the CMM interface to take advantage of most of the CMM functional capabilities. .
- These command statement include set up, part datum control, feature construction, geometric relations, tolerance, output control and feature measurements like measurements of lines, points, arcs, circles, splines, conics, planes, analytic surfaces.

(ii) Pre- processor:

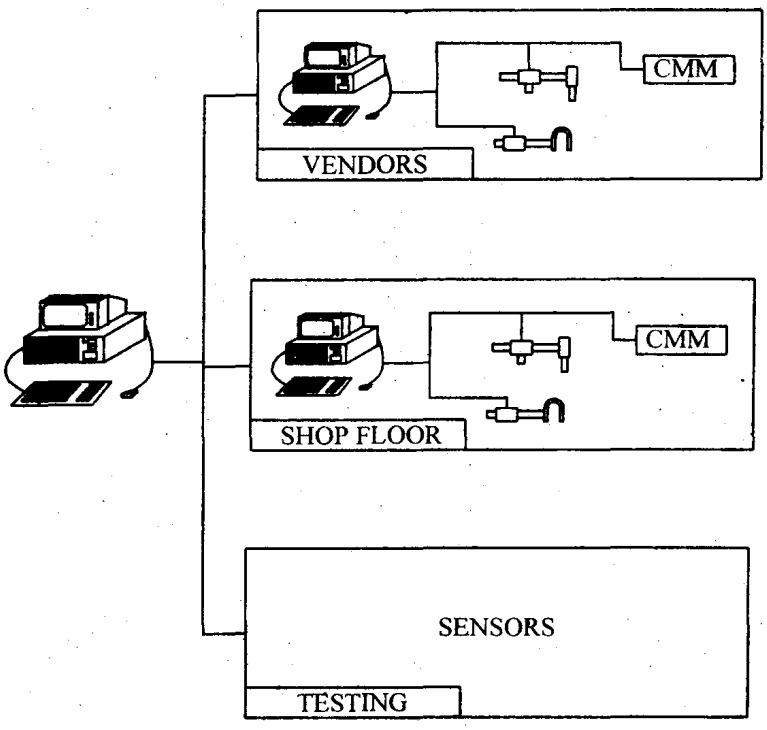
- The pre-CMM processor converts the language source file generated by CMM interface into the language of the specified co ordinate measuring machine.

(iii) Post-CMM processor:

- This creates wire frame surface model from the CMM-ASCII output file commands are inserted into the ASCJI-CMM output file to control the creation of CAD/CAM which include points, lines, arcs, circles, conics, splines and analytic surfaces.

FLEXIBLE INSPECTION SYSTEM

- The block diagram of flexible inspection system is shown in fig This system has been developed and the inspection done at several places in industry.
- This system helps product performance to improve inspection and increase productivity.
- Real time processor to handle part dimensional data and as a multi programming system to perform manufacturing process control.
- The input devices used with this system are CMMs, Microprocessor based gauges and other inspection devices.



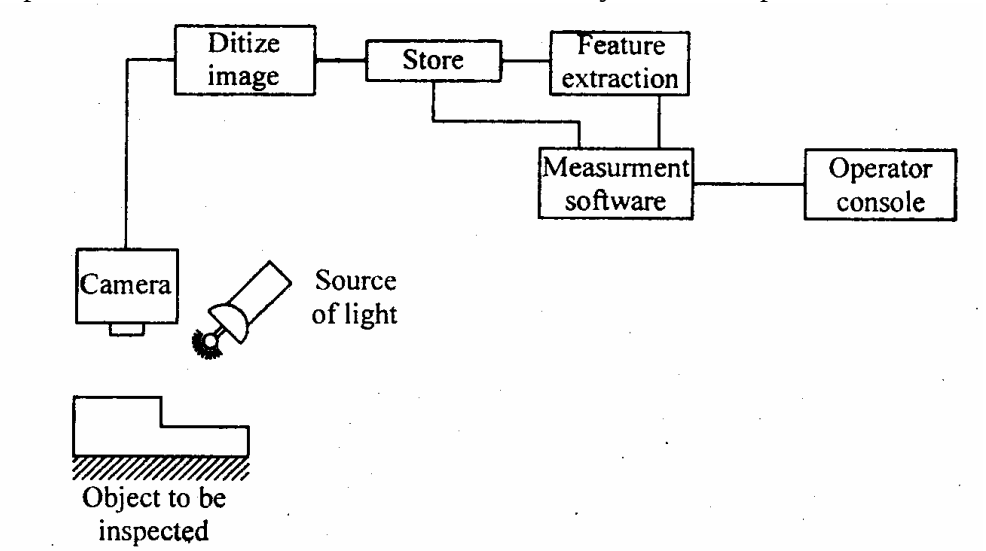
- The terminal provides interactive communication with personal computers where the programmes are stored.
- The data from CMMs and other terminals are fed into the main computer for analysis and feed back control. The equality control data and inspection data from each stations are fed through the terminals to the main computer. The data will be communicated through telephone lines.
- Flexible inspection system involves more than one inspection station.
- The objective of the flexible inspection system is to have off time multi station automated dimensional verification system to increase the production rate and less inspection time and to maintain the inspection accuracy and data processing integrity.

MACHINE VISION

- A Vision system can be defined as a system for automatic acquisition and analysis of images to obtain desired data for interpreting or controlling an activity.
- It is a technique which allows a sensor to view a scene and derive a numerical or logical decision without further human intervention.
- Machine vision can be defined as a means of simulating the image recognition and analysis capabilities of the human system with electronic and electro mechanical techniques.
- Machine vision system are now a days used to provide accurate and in expensive 100% inspection of work pieces. These are used for functions like gauging of dimensions, identification of shapes, measurement of distances, determining orientation of parts, quantifying motion-detecting surface shading etc.
- It is best suited for high production. These systems function without fatigue.
- This is suited for inspecting the masks used in the production of micro electronic devices. Stand off distance up to one meter is possible.

VISION SYSTEM

- The schematic diagram of a typical vision system is shown in fig This system involves image acquisition, image processing Acquisition requires appropriate lighting.
- The camera and store digital image processing involves manipulating the digital image to simplify and reduce number of data points..
- Measurements can be carried out at any angle along the three reference axes x y and z without contacting the part. The measured values are then compared with the specified tolerance which stores in the memory of the computer.



- The main advantage of vision system is reduction of tooling and fixture costs, elimination of need for precise part location for handling robots and integrated automation of dimensional verification and defect detection.

Principle:

Four types of machine vision system and the schematic arrangement is shown in fig

(i) Image formation.
(ii) Processing of image in a form suitable for analysis by computer.
(iii) Defining and analyzing the characteristic of image.
(iv) Interpretation of image and decision-making.

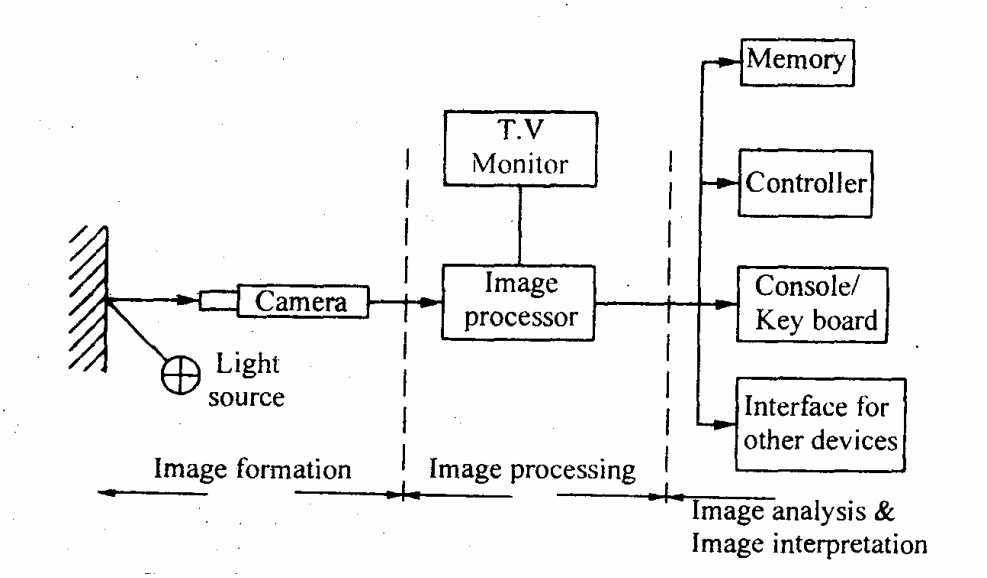
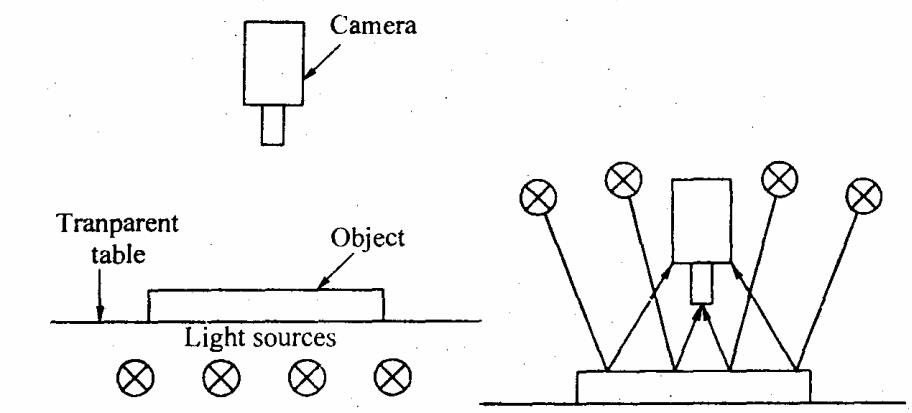


Image formation:



- For formation of image suitable light source is required. It consists of incandescent light, fluorescent tube, fiber optic bundle, and arc lamp.
- Laser beam is used for triangulation system for measuring distance. Ultraviolet light is used to reduce glare or increase contrast. Proper illumination back lighting, front lighting, structured light is required.
- Back lighting is used to obtain maximum image contrast. The surface of the object is to be inspected by using front lighting. For inspecting three-dimensional feature structured lighting is required.
- An image sensor vidicon camera, CCD camera is used to generate the electronic signal representing the image. The image sensor collects light from the scene through a lens, using photosensitive target, converts into electronic signal.

Vidicon camera:

- Image is formed by focusing the incoming light through a series of lenses onto the photoconductive faceplate of the vidicon tube.
- The electron beam scans the photoconductive surface and produces an analog voltage proportional to the variation in light intensity for each scan line of the original scene.

Solid-state camera:

- The image sensors change coupled device (CCD) contain matrix of small array, photosensitive elements accurately spaced and fabricated on silicon chips using integrated circuit technology.
- Each detector converts in to analog signal corresponding to light intensity through the camera lens.

Image processor:

- A camera may form an image 30 times per sec at 33 m sec intervals. At each time interval the entire image frozen for processing by an image processor.
- An analog to digital converter is used to convert analog voltage of each detector in to digital value.
- If voltage level for each pixel is given by either 0 or I depending on threshold value. It is called binary system on the other hand grey scale system assigns upto 256 different values depending on intensity to each pixel.
- Grey scale system requires higher degree of image refinement, huge storage processing capability. For analysis 256 x 256 pixels image array up to 256 different pixel values will require 65000-8 bit storage locations at a speed of 30 images per second.

- Techniques windowing and image restoration are involved.

Windowing:

- Processing is the desired area of interest and ignores non-interested part of image.

Image restoration:

- Preparation of image during the pre-processing by remove the degrade. Blurring of lines, poor contrast between images, presence of noise are the degrading

The quality may be improved

1) By improving the contrast by brightness addition.
2) By increasing the relative contrast between high and low intensity elements.
3) By Fourier domain processing.
4) Other techniques to reduce edge detection and run length encoding.

Image Analysis:

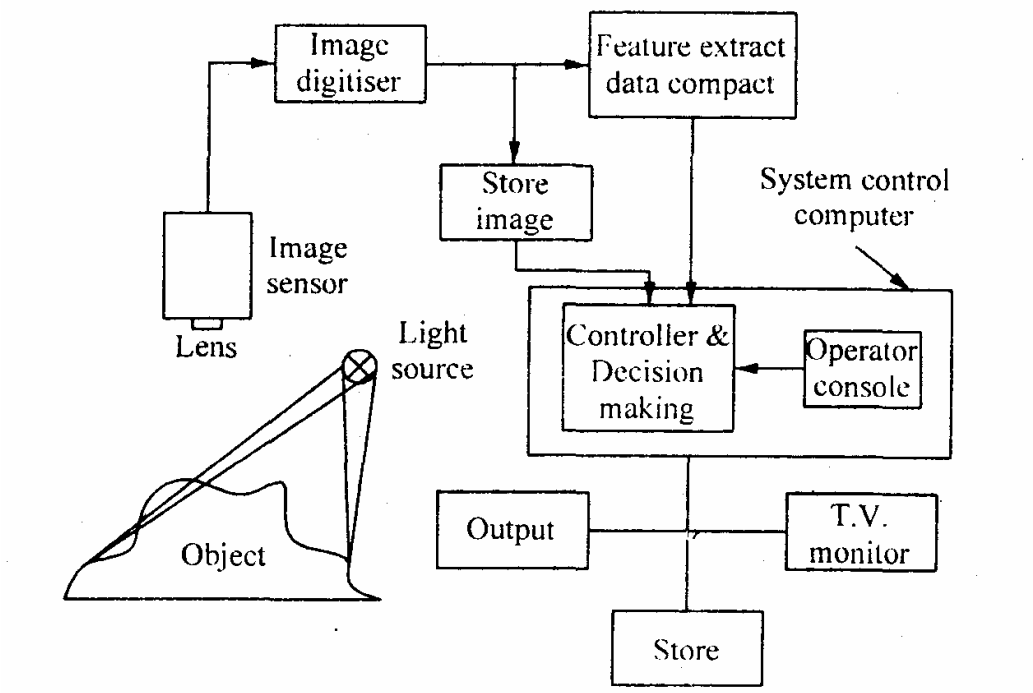
- Digital image of the object formed is analyzed in the central processing Unit of the system.
- Three important tasks performed by machine vision system are measuring the distance of an object from a vision system camera, determining object orientation and defining object position.
- The distance of an object from a vision system camera can be determined by **triangulation technique.** The object orientation can he determined by the methods of **equivalent ellipse**. The image can be interpreted by two-dimensional image.
- For complex three-dimensional objects boundary locations are determined and the image is segmented into distinct region.

Image Interpretation:

- This involves identification of on object. In binary system, the image is segmented on the basis of while and black pixels.
- The complex images can he interpreted by grey scale technique and algorithms. The must common image interpretation is template matching.

FUNCTION OF MACHINE VISION

- Lighting and presentation of object to evaluated.
- It has great compact on repeatability, reliability and accuracy.
- I.ighting source and projection should be chosen and give sharp contrast.
- Images sensor compressor TV camera may he vidicon or solid state.
- For simple processing, analog comparator and a computer controller to convert the video information to a binary image is used.
- Data compactor employs a high speed away processor to provide high speed processing of the input image data.
- System control computer communicates with the operator and make decision about the part being inspected.
- The out put and peripheral devices operate the control of the system. The output enables the vision system to either control a process or provide caution and orientation information two a robot, etc.
- These operate under the control of the system control of computer.



Applications:

- Machine vision can he used to replace human vision fur welding. machining and maintained relationship between tool and work piece. and assembly of parts to analyze the parts.
- This is frequently used for printed circuit board inspection to ensure minimum conduction width and spacing between conductors.
- These are used for weld seam tracking, robot guideness and control, inspection of microelectronic devices and tooling, on line inspection in machining operation, assemblies monitoring high-speed packaging equipment etc.
- It gives recognition of an object from its image. These are designed to have strong geometric feature interpretation capabilities and pa handling equipment.

PART-A

1. Define- CMM
2. What are the important features available in CMM software?
3. Define machine vision.
4. Name the four types of machine vision system.
5. Mention the advantages of CMM
6. Mention the disadvantages of CMM
7. Define –Position accuracy?
8. Name the types of CMM?
9. Define –CNC
10. Define –Machine Vision
11. Name the four types of machine vision system?
12. Define –Gray scale analysis?
13. Describe the features of a flexible inspection system?
14. State the constructions of CMM
15. Explain the principle of CMM

PART-B

1. Explain the method of part inspection using CMM.
2. Explain the constructions and principle of CMM.
3. Mention the advantages and disadvantages of CMM.
4. Explain briefly trigger type and measuring type probe system.
5. How is the post process metrology incorporated in CNC machine?
6. Describe about flexible inspection system in detail?
7. Discuss briefly the following
    a. Image formation.
    b. Image processing.
    c.Defining and analyzing the characteristic of image.
    d.Interpretation of image and decision-making.
8. Describe in details of the function and application of machine vision system.