UNIT V LASER AND ADVANCES IN METROLOGY 10 hrs.

Precision instruments based on laser principles- laser interferometer-application in linear and angular measurements and machine tool metrology – Coordinate measuring machine (CMM) – Constructional features- types, applications-digital devices-computer aided inspection.

TECHNICAL TERMS

- **Interferometer**

Interferometer is optical instruments used for measuring flatness and determining the lengths of slip gauges by direct reference to the wavelength of light.

- **Machine Vision**

Machine vision can be defined as a means of simulating the image recognition and analysis capabilities of the human system with electronic and electromechanical techniques.

- **Inspection**

It is the ability of an automated vision system to recognize well-defined pattern and if these pattern match these stored in the system makes machine vision ideal for inspection of raw materials, parts, assemblies etc.

- **CMM**

It is a three dimensional measurements for various components. These machines have precise movement is x,y,z coordinates which can be easily controlled and measured. Each slide in three directions is equipped with a precision linear measurement transducer which gives digital display and senses positive and negative direction.

- **Axial Length Measuring Accuracy**

It is defined as difference between the reference length of gauges aligned with a machine axis and the corresponding measurement results from the machine.

PRECISION INSTRUMENT BASED ON LASER

Laser stands for **Light Amplification by Stimulated Emission of Radiation.** Laser instrument is a device to produce powerful, monochromatic, collimated beam of light in which the **waves are coherent**. Laser development is for production of clear coherent light. The advantage of coherent light is that whole of the energy appears to be emanating from a very small point. The beam can be focused easily into either a parallel beam or onto a very small point by use of lenses A major impact on optical measurement has been made by development in elector optics, providing automation, greater acuity of setting and faster response time. Radiation sources have developed in a number of areas; the most important developments are light emitting diodes and lasers. The laser is used extensively for interferometry particularly the He- Ne gas type. The laser distance measuring interferometer has become an industry standard. This produces 1 to 2mm diameter beam of red light power of 1MW and focused at a point of very high intensity. The beam begins to expand at a rate of 1mm/m. The laser beam is visible and it can be observed easily. This is used for very accurate measurements of the order of 0.lμm are 100m.

Laser Metrology

Metrology lasers are low power instruments. Most are helium-neon type. Wave output laser that emit visible or infrared light. He-Ne lasers produce light at a wavelength of 0.6µm that is in phase, coherent and a thousand times more intense than any other monochromatic source. Laser systems have wide dynamic range, low optical cross talk and high contrast. Laser fined application in dimensional measurements and surface inspection because of the properties of laser light. These are useful where precision, accuracy, rapid non-contact gauging of soft, delicate or hot moving points.

Use of Laser

- **Laser Telemetric system**

Laser telemetric system is a non-contact gauge that measures with a collimated laser beam. It measures at the rate of 150 scans per second. It basically consists of three components, a transmitter, a receiver and processor electronics. The transmitter module produces a collimated parallel scanning laser beam moving at a high constant, linear speed. The scanning beam appears a red line. The receiver module collects and photoelically senses the laser light transmitted past the object being measured. The processor electronics takes the received signals to convert them 10 a convenient form and displays the dimension being gauged. The transmitter contains a low power helium-neon gas laser and its power supply, a specially designed collimating lens, a synchronous motor, a multi faceted reflector prism, a synchronous pulse photo detector and a protective replaceable window. The high speed of scanning permits on line gauging and thus it is possible to detect changes in dimensions when components are moving on a continuous product such as in rolling process moving at very high speed. There is no need of waiting or product to cool for taking measurements. This system can also be applied on production machines and control then with closed feedback loops. Since the output of this system is available in digital form, it can run a process controller limit alarms can be provided and output can be taken on digital printer.

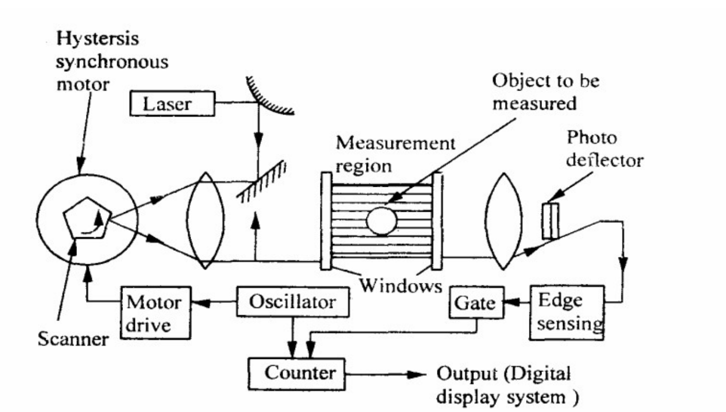
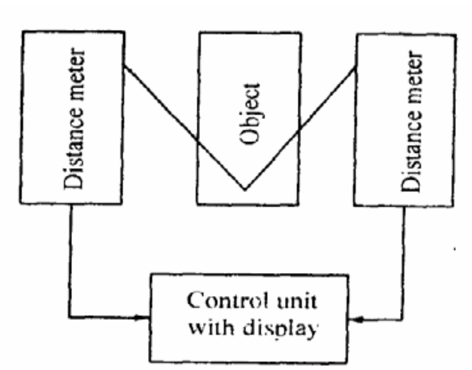


Fig Laser Telemetric System

- **Laser and LED based distance measuring instruments**

These can measure distances from I to 2in with accuracy of the order of 0. 1 to 1% of the measuring range When the light emitted by laser or LED hits an object, scatter and some of this scattered light is seen by a position sensitive detector or diode array. If the distance between the measuring head and the object changes. The angle at which the light enters the detector will also change. The angle of deviation is calibrated in terms of distance and output is provided as 0-2OmA.

Such instruments are very reliable because there are no moving parts their response time is milliseconds. The measuring system uses two distance meters placed at equal distance on either side of the object and a control unit to measure the thickness of an object. The distance meter is focused at the centre of the object.



- **Scanning Laser gauge**

Fig shows a schematic diagram of a scanning laser gauge. It consist of transmitter, receives and processor electronics. A thin band of scanning laser light is made to pass through a linear scanner lens to render it parallel beam. 'The object placed in a parallel beam, casts a time dependent shadow. Signal from the light entering the photocell (receiver) arc proc by a microprocessor to provide display of the dimension represented by the time difference between the shadow edges. It can provide results to an accuracy of0.25 for 10—50mm diameter objects. It can be used for objects 0.05mm to 450mm diameter; and offers repeatability of 0.1µm

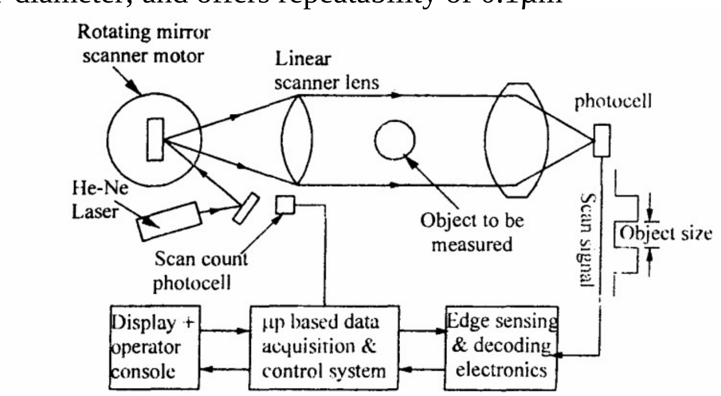


Fig Scanning Laser Gauge

- **Photo diode away imaging**

The system comprises of laser source, imaging optics. Photo-diode array. Signal processor and display unit. For large parts, two arrays in which one for each edge are used. Accuracies as high as 0.05 µm have been achieved.

- **Diffraction pattern technique**

These are used to measure small gaps and small diameter parts. A parallel coherent laser beam is diffracted by a small part and a lens on a linear diode array focuses the resultant pattern. Its use is restricted to small wires. The measurement accuracy is more for smaller parts. The distance between the alternating light and dark hands in the diffraction pattern is a (tired function of the wile diameter, wavelength of laser beam and the focal length of the lens.

- **Two- frequency laser interferometer**

Fig. shows schematic arrangement. This consists of two frequency laser head, beam directing and splitting optics, measurement optics, receivers, and wavelength compensators and electronics. It is ideally suited for measuring linear positioning straightness in two planes, pitch and yaw.

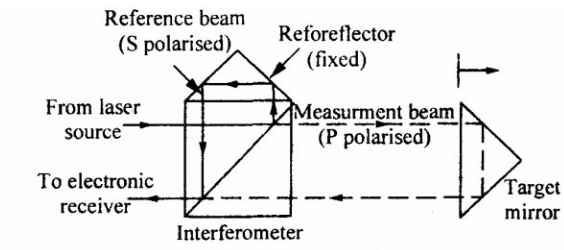


Fig Two-frequency laser interferometer

The two-frequency laser head provides one frequency with P-polarization and another frequency with S-polarization. The laser beam is split at the polarizing beam splitter into its two separate frequencies. The measuring beam is directed through the interferometer to reflect off a target mirror or retro reflector attached to the object to be measured. The reference beam is reflected from fixed retro reflector. The measurement beam on its return path recombines with the reference beam and is directed to the electronic receiver.

- **Gauging wide diameter from the diffraction pattern formed in a laser**

Figure shows a method of measuring the diameter of thin wire using the interference fringes resulting from diffraction of the light by the wire in the laser beam. A measure of the diameter can be obtained by moving the photo detector until the output is restored to its original value. Variation in wire diameter as small as 0.2% over wire diameter from 0.005 to 0.2mm can be measured.

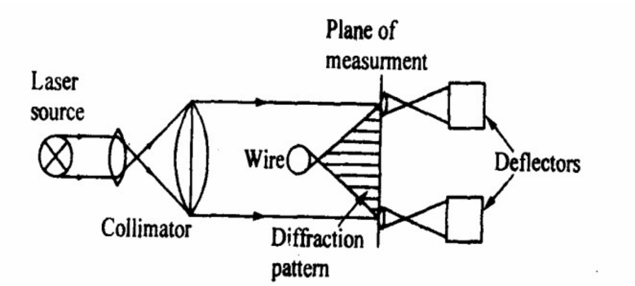


Fig. Diffraction Pattern

Figure shows the length measurement by fringe counting. The laser output, which may be incoherent illumines three slits at a time in the first plane which form interference fringes. The movement can be determined by a detector. The total number of slits in the first plane is governed by the length over which measurement is required

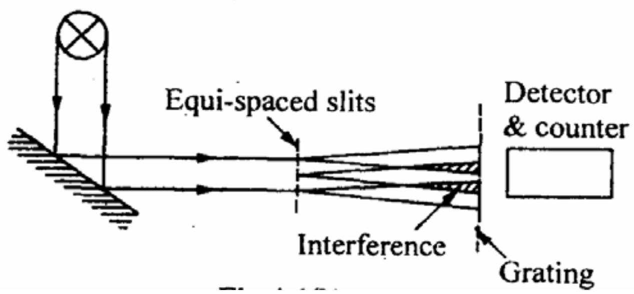


Fig Fringe counting

The spacing between the slits and distance of the slit to the plane of the grating depend on the wavelength of the light used.

Principle of Laser

The photon emitted during stimulated emission has the same energy, phase and frequency as the incident photon. This principle states that the photon comes in contact with another atom or molecule in the higher energy level E2 then it will cause the atom to return to ground state energy level E1 by releasing another photon. The sequence of triggered identical photon from stimulated atom is known as stimulated emission. This multiplication of photon through stimulated emission leads to coherent, powerful, monochromatic, collimated beam of light emission. This light emission is called laser.

LASER INTERFEROMETRY

Brief Description of components

(i) Two frequency Laser source

It is generally He-Ne type that generates stable coherent light beam of two frequencies, one polarized vertically and another horizontally relative to the plane of the mounting feet. Laser oscillates at two slightly different frequencies by a cylindrical permanent magnet around the cavity. The two components of frequencies are distinguishable by their opposite circular polarization. Beam containing both frequencies passes through a quarter wave and half wave plates which change the circular polarizations to linear perpendicular polarizations, one vertical and other horizontal. Thus the laser can be rotated by 90°about the beam axis without affecting transducer performance. If the laser source is deviated from one of the four optimum positions, the photo receiver will decrease. At 45° deviation the signal will decrease to zero.

(ii) Optical elements

a) Beam splitter

Sketch shows the beam splitters to divide laser output along different axes. These divide the laser beam into separate beams. To avoid attenuation it is essential that the beam splitters must be oriented so that the reflected beam forms a right angle with the transmitted beam. So that these two beams: are coplanar with one of the polarisation vectors of the input form.

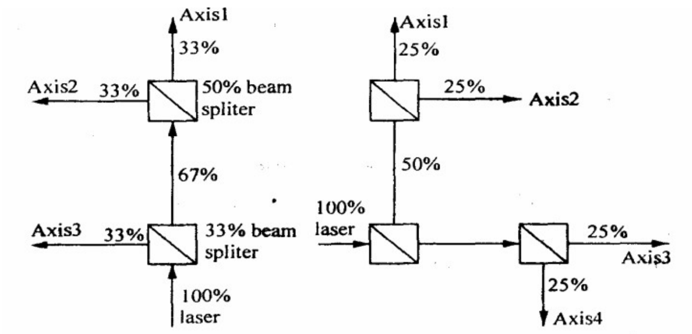


Fig. Beam Splitter

b) Beam benders

These are used to deflect the light beam around corners on its path from the laser to each axis. These are actually just flat mirrors but having absolutely flat and very high reflectivity. Normally these are restricted to 90° beam deflections to avoid disturbing the polarizing vectors.

c) Retro reflectors

These can be plane mirrors, roof prism or cube corners. Cube corners are three mutually perpendicular plane mirrors and the reflected beam is always parallel to the incidental beam. Each ACLI transducers need two retro reflectors. All ACLI measurements are made by sensing differential motion between two retro reflectors relative to an interferometer. Plane mirror used as retro reflectors with the plane mirror interferometer must be flat to within 0.06 micron per cm.

(iii) Laser head's measurement receiver

During a measurement the laser beam is directed through optics in the measurement path and then returned to the laser head is measurement receiver which will detect part of the returning beam and a doppler shifted frequency component.

(iv) Measurement display

It contains a microcomputer to compute and display results. The signals from receiver and measurement receiver located in the laser head are counted in two separate pulse converter and subtracted. Calculations are made and the computed value is displayed. Other input signals for correction are temperature, co-efficient of expansion, air velocity etc., which can be displayed.

(v) Various version of ACLI

a) Standard Interferometer

- Least expensive.
- Retro reflector for this instrument is a cube corner.
- Displacement is measured between the interferometer and cube corner.

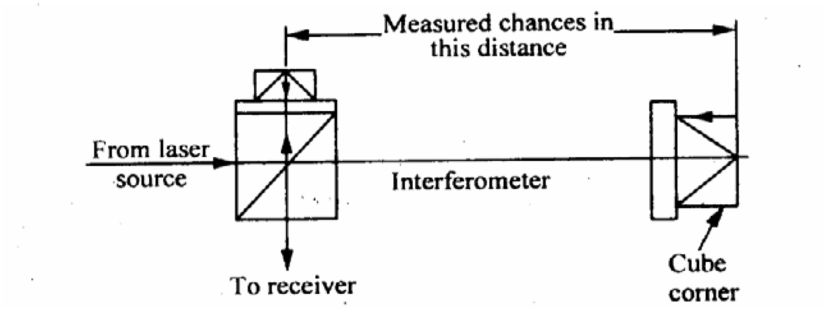


Fig Standard Interferometer

b) Signal beams Interferometer

- Beam traveling between the interferometer and the retro reflector.
- Its operation same as standard interferometer.
- The interferometer and retro reflector for this system are smaller than the standard system.
- Long range optical path
- Wear and tear.

LASER INTERFEROMETER

It is possible to maintain the quality of interference fringes over longer distance when lamp is replaced by a laser source. Laser interferometer uses AC laser as the light source and the measurements to be made over longer distance. Laser is a monochromatic optical energy, which can be collimated into a directional beam AC. Laser interferometer (ACLI) has the following advantages.

- High repeatability
- High accuracy
- Long range optical path
- Easy installations
- Wear and tear

Schematic arrangement of laser interferometer is shown in fig. Two-frequency zeeman laser generates light of two slightly different frequencies with opposite circular polarisation. These beams get split up by beam splitter B One part travels towards B and from there to external cube corner here the displacement is to the measured.

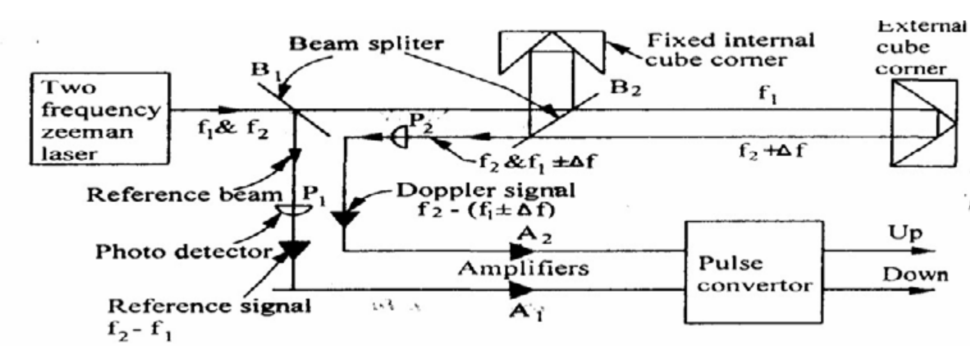


Fig Laser Interferometer

This interferometer uses cube corner reflectors which reflect light parallel to its angle of incidence. Beam splitter B2 optically separates the frequency J which alone is sent to the movable cube corner reflector. The second frequency from B2 is sent to a fixed reflector which then rejoins f1 at the beam splitter B2 to produce alternate light and dark interference flicker at about 2 Mega cycles per second. Now if the movable reflector moves, then the returning beam frequency Doppler-shifted slightly up or down by Δf. Thus the light beams moving towards photo detector P2 have frequencies f2 and (f1 $\pm$ Δf1) and P2 changes these frequencies into electrical signal. Photo detector P2 receive signal from beam splitter B2 and changes the reference beam frequencies f1 and f2 into electrical signal. An AC amplifier A separates frequency. Difference signal f2 – f1 and A2 separates frequency difference signal. The pulse converter extracts i. one cycle per half wavelength of motion. The up-down pulses are counted electronically and displayed in analog or digital form.

Michelson Interferometer

Michelson interferometer consists of a monochromatic light source a beam splitter and two mirrors. The schematic arrangement of Michelson interferometer is shown in fig. The monochromatic light falls on a beam splitter, which splits the light into two rays of equal intensity at right angles. One ray is transmitted to mirror M1 and other is reflected through beam splitter to mirror M2,. From both these mirrors, the rays are reflected back and these return at the semireflecting surface from where they are transmitted to the eye. Mirror M2 is fixed and mirror M1 is movable. If both the mirrors are at same distance from beam splitter, then light will arrive in phase and observer will see bright spot due to constructive interference. If movable mirror shifts by quarter wavelength, then beam will return to observer 1800 out of phase and darkness will be observed due to destructive interference

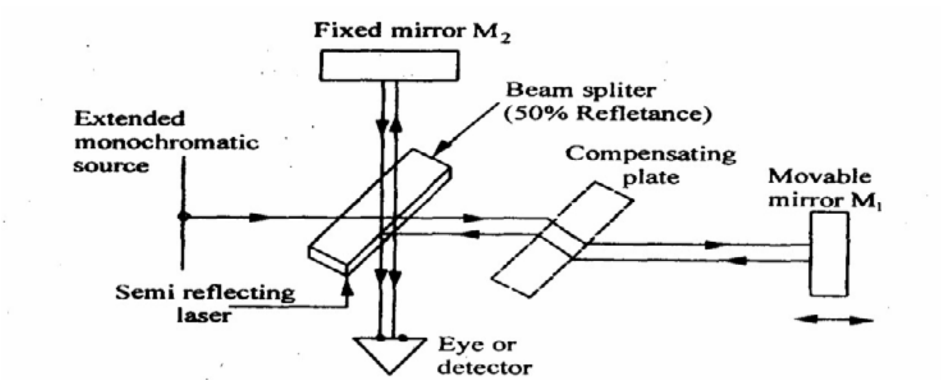


Fig Michelson Interferometer

Each half-wave length of mirror travel produces a change in the measured optical path of one wavelength and the reflected beam from the moving mirror shifts through 360° phase change. When the reference beam reflected from the fixed mirror and the beam reflected from the moving mirror rejoin at the beam splitter, they alternately reinforce and cancel each other as the mirror moves. Each cycle of intensity at the eye represents l/2 of mirror travel. When white light source is used then a compensator plate is introduced in each of the path of mirror M1 So that exactly the same amount of glass is introduced in each of the path.

To improve the Michelson interferometer

(i) Use of laser the measurements can be made over longer distances and highly accurate measurements when compared to other monochromatic sources.

(ii) Mirrors are replaced by cube-corner reflector which reflects light parallel to its angle of incidence.

(iii) Photocells are employed which convert light intensity variation in voltage pulses to give the amount and direction of position change.

Dual Frequency Laser Interferometer

This instrument is used to measure displacement, high-precision measurements of length, angle, speeds and refractive indices as well as derived static and dynamic quantities. This system can be used for both incremental displacement and angle measurements. Due to large counting range it is possible to attain a resolution of 2mm in 10m measuring range. Means are also provided to compensate for the influence of ambient temperature, material temperature, atmospheric pressure and humidity fluctuation

Twyman-Green Interferometer

The Twyman-Green interferometer is used as a polarizing interferometer with variable amplitude balancing between sample and reference waves. For an exact measurement of the test surface, the instrument error can be determined by an absolute measurement. This error is compensated by storing the same in microprocessor system and subtracting from the measurement of the test surface. It has following advantages

- It permits testing of surface with wide varying reflectivity.
- It avoids undesirable feedback of light reflected of the tested surface and the instrument optics.
- It enables utilization of the maximum available energy.
- Polarization permits phase variation to be effected with the necessary precision.

Laser Viewers

The profile of complex components like turbine blades can be checked by the use of optical techniques. It is based on use of laser and CCTV. A section of the blade, around its edge is delineated by two flat beam of laser light. This part of the edge is viewed at a narrow angle by the TV camera or beam splitter

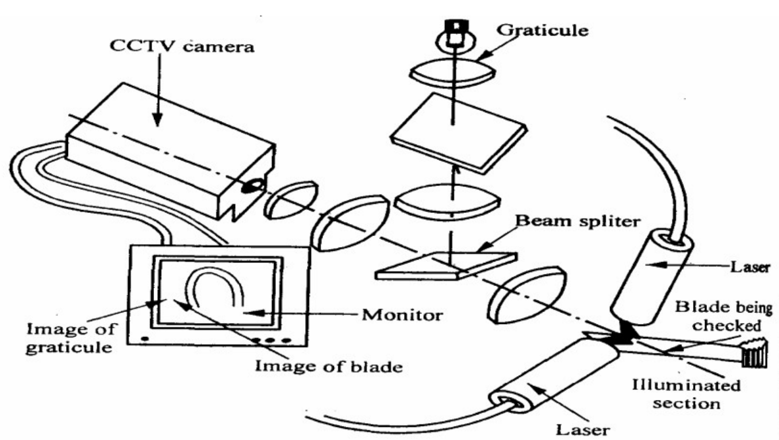


Fig Laser Viewers

Both blade and graticule are displayed as magnified images on the monitor, the graticule position being adjustable so that its image can be superimposed on the profile image. The graticule is effectively viewed at the same angle as the blade. So, distortion due to viewing angle affects both blade and graticule. This means that the graticule images are direct 1:1.

INTERFEROMETRIC MEASUREMENT OF ANGLE

With laser interferometer it is possible to measure length to accuracy of 1 part in 106 on a routine basis. With the help of two retro reflectors placed at a fixed distance and a length measuring laser interferometer the change in angle can be measured to an accuracy of 0.1 second. The device uses sine Principle. The line joining the poles the retro-reflectors makes the hypotenuse of the right triangle. The change in the path difference of the reflected beam represents the side of the triangle opposite to the angle being measured. Such laser interferometer can be used to measure an angle up to ± 10 degrees with a resolution of 0. 1 second. The principle of operation is shown in fig.

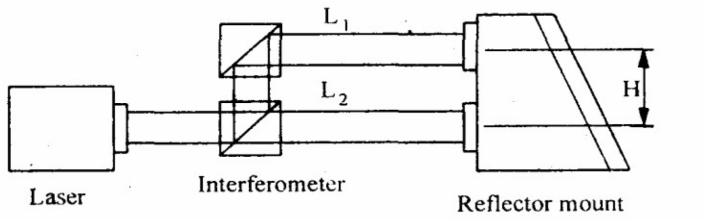


Fig Interferometric Angle Measurement

Laser Equipment for Alignment Testing

This testing is particularly suitable in aircraft production, shipbuilding etc. Where a number of components, spaced long distance apart, have to be checked to a predetermine straight line. Other uses of laser equipment are testing of flatness of machined surfaces, checking square ness with the help of optical square etc. These consist of laser tube will produces a cylindrical beam of laser about 10mm diameter and an auto reflector with a high degree of accuracy. Laser tube consists of helium-neon plasma tube in a heat aluminum cylindrical housing. The laser beam comes out of the housing from its centre and parallel to the housing within 10" of arc and alignment stability is the order of 0.2" of arc per hour. Auto reflector consists of detector head and read out unit. Number of photocell are arranged to compare laser beam in each half horizontally and vertically. This is housed on a shard which has two adjustments to translate the detector in its two orthogonal measuring directions perpendicular to the laser beam. The devices detect the alignment of flat surfaces perpendicular to a reference line of sight.

MACHINE TOOL TESTING

The accuracy of manufactured parts depends on the accuracy of machine tools. The quality of work piece depends on Rigidity and stiffness of machine tool and its components. Alignment of various components in relation to one another Quality and accuracy of driving mechanism and control devices.

It can be classified into

- Static tests
- Dynamic tests.
- **Static tests**

If the alignment of the components of the machine tool are checked under static conditions then the test are called static test.

- **Dynamic tests**

If the alignment tests are carried out under dynamic loading condition. The accuracy of machine tools which cut metal by removing chips is tested by two types of test namely.

  - Geometrical tests
  - Practical tests

- **Geometrical tests**

In this test, dimensions of components, position of components and displacement of component relative to one another is checked.

- **Practical tests**

In these test, test pieces are machined in the machines. The test pieces must be appropriate to the fundamental purpose for which the machine has been designed.

Purpose of Machine Tool Testing

The dimensions of any work piece, its surface finishes and geometry depends on the accuracy of machine tool for its manufacture. In mass production the various components produced should be of high accuracy to be assembled on a non-sensitive basis. The increasing demand for accurately machined components has led to improvement of geometric accuracy of machine tools. For this purpose various checks on different components of the machine tool are carried out.

Type of Geometrical Checks on Machine Tools.

Different types of geometrical tests conducted on machine tools are as follows:

1. Straightness.
2. Flatness.
3. Parallelism, equi-distance and coincidence.
4. Rectilinear movements or squareness of straight line and plane.
5. Rotations.

Main spindle is to be tested for

1) Out of round.
2) Eccentricity
3) Radial-throw of an axis.
4) Run out
5) Periodical axial slip
6) Camming

Various tests conducted on any Machine Tools

- Test for level of installation of machine tool in horizontal and vertical planes.
- Test for flatness of machine bed and for straightness and parallelism of bed ways on bearing surface.
- Test for perpendicularity of guide ways to other guide ways.
- Test for true running of the main spindle and its axial movements.

Test for parallelism of spindle axis to guide ways or bearing surfaces.

- Test for line of movement of various members like spindle and table cross slides etc.

Use of Laser for Alignment Testing

- The alignment tests can be carried out over greater distances and to a greater degree of accuracy using laser equipment.
- Laser equipment produces real straight line, whereas an alignment telescope provides an imaginary line that cannot be seen in space.
- This is important when it is necessary to check number of components to a predetermined straight line. Particularly if they are spaced relatively long distances apart, as in aircraft production and in shipbuilding.
- Laser equipment can also be used for checking flatness of machined surface by direct displacement. By using are optical square in conjunction with laser equipment squareness can be checked with reference to the laser base line.

CO-ORDINATE MEASURING MACHINES

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. 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

(i) 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.

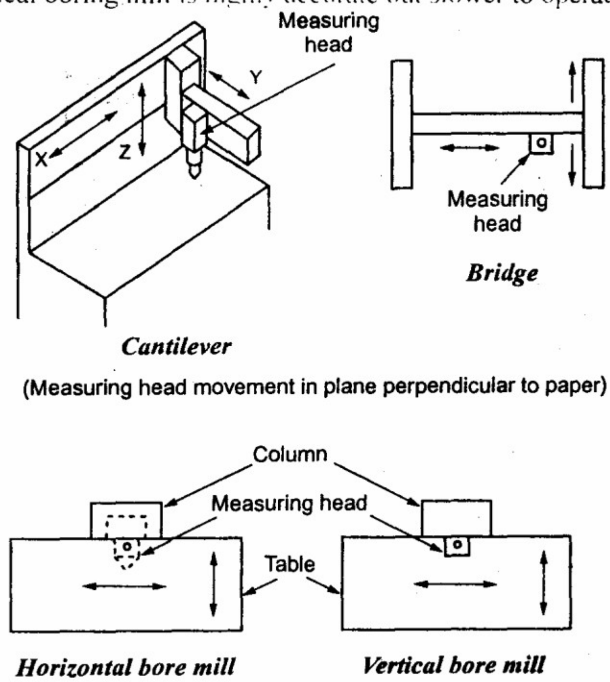


Fig Types of CMM

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.

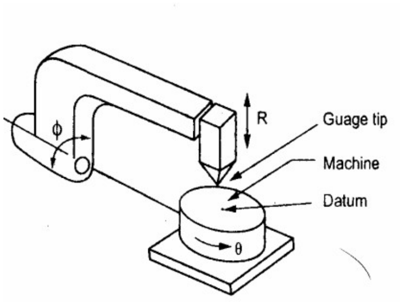


Fig Schematic Diagram

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 cause perpendicularity errors. So CMM should be calibrated with master plates before using the machine.

2) Dimensional errors of a CMM is influenced by

- Straightness and perpendicularity of the guide ways.
- Scale division and adjustment.
- Probe length.
- Probe system calibration, repeatability, zero point setting and reversal error.
- Error due to digitization.
- 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.

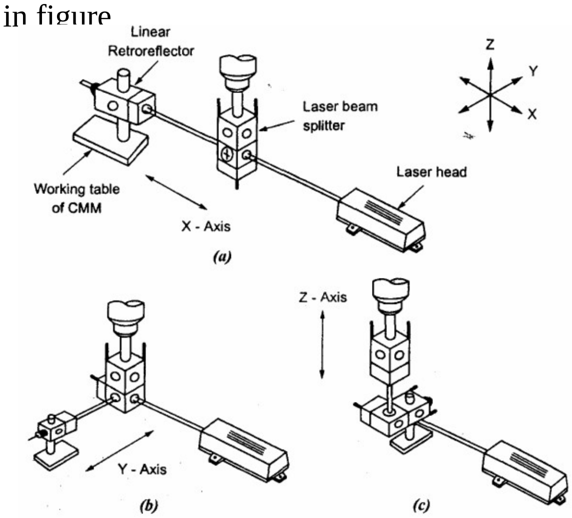
5) Variation in temperature of CMM, specimen and measuring lab influence the uncertainly of measurements.

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 figure



The laser head is mounted on the tripod stand and its height is adjusted corresponding to the working table of CMM. 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 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

Geometrical accuracies such as positioning accuracy, Straightness and Squareness.

- Total measuring accuracy in terms of axial length measuring accuracy. Volumetric length measuring accuracy and length measuring repeatability. i.e., Coordinate measuring machine has to be tested as complete system.
- Since environmental effects have great influence for the accuracy testing, including thermal parameters, vibrations and relative humidity are required.

APPLICATIONS

- Co-ordinate measuring machines find applications in automobile, machine tool, electronics, space and many other large companies.
- These machines are best suited for the test and inspection of test equipment, gauges and tools.
- For aircraft and space vehicles, hundred percent inspections is carried out by using CMM.
- CMM can be used for determining dimensional accuracy of the components.
- These are ideal for determination of shape and position, maximum metal condition, linkage of results etc. which cannot do in conventional machines.
- CMM can also be used for sorting tasks to achieve optimum pairing of components within tolerance limits.
- 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

- The lable and probe may not be in perfect alignment.
- The probe may have run out.
- The probe moving in Z-axis may have some perpendicular errors.
- Probe while moving in X and Y direction may not be square to each other.
- 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.

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

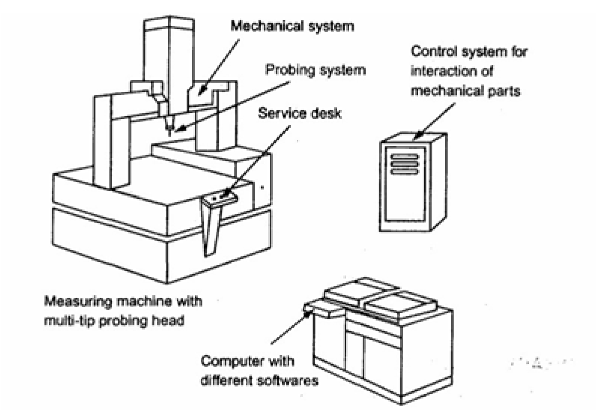


Fig.: **Column Type**

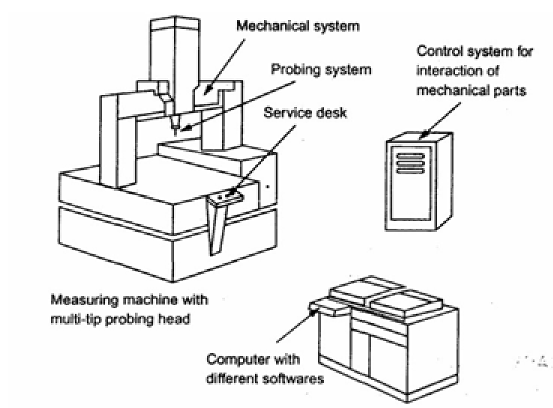
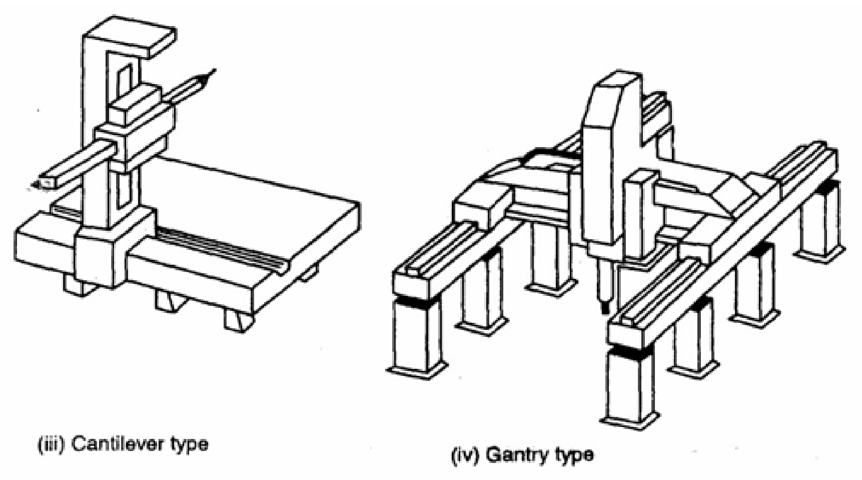


Fig.: Bridge Type



Trigger type probe system

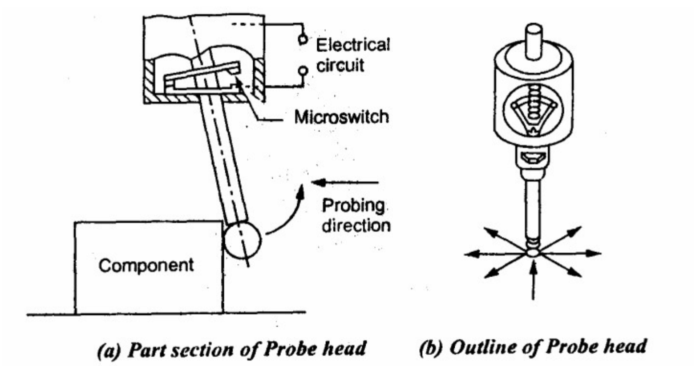


Fig 4.17 Trigger Type Probe System

- 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.
- 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

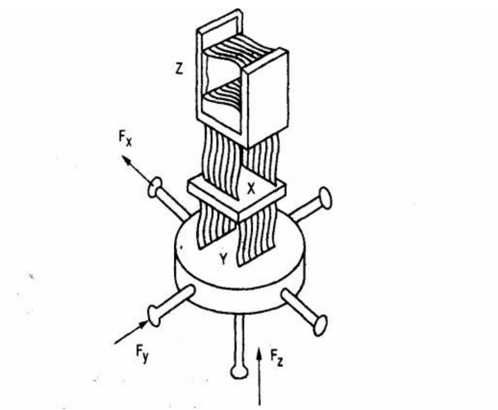
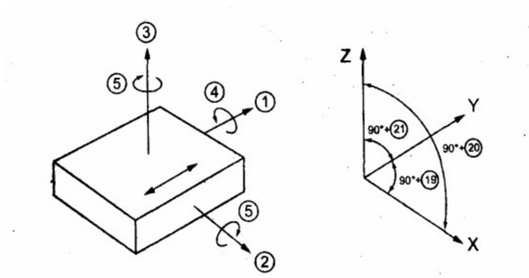


Fig Buckling Mechanism

- 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 coordinates 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.
  - Similarly the deviations of all three carriages and the squareness errors can be taken into account.
  - 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. b.Volumetric length measuring accuracy

(ii) Axial motion accuracy

a. Linear displacement accuracy

b. Straightness
c. Perpendicularity
d. Pitch, Yaw and roll.

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 figure has stationary granite measuring table, Length measuring system. Air bearings; control unit and software are the important parts of CNC & CMM.

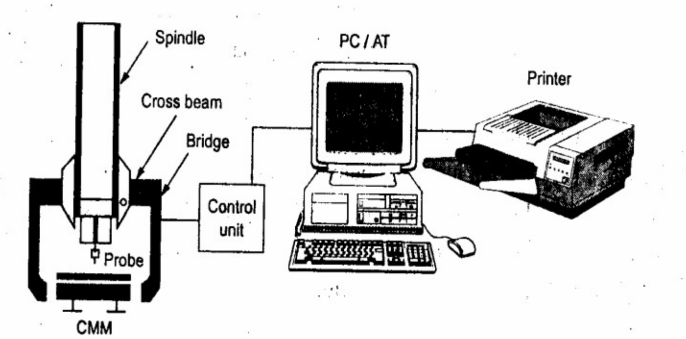


Fig CNC - CMM

Stationary granite measuring table

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. 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**

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

- **Air Bearing**

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 a 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 coordinate 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 5micrometers. 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 is 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

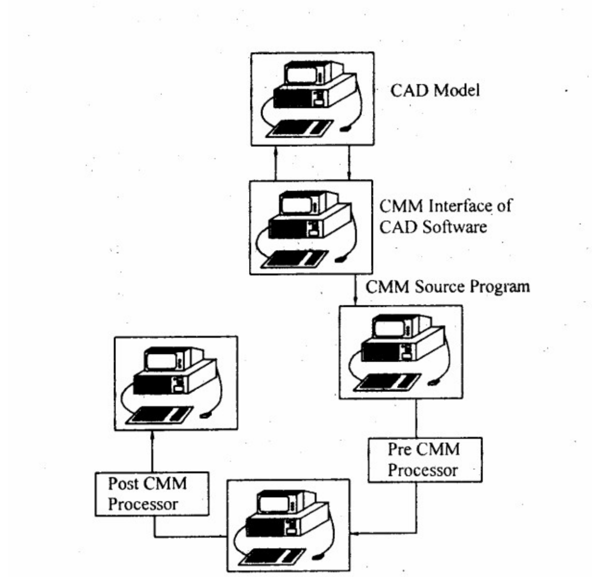


Fig CMM Interface

control, feature construction, geometric relations, tolerance, output control and feature measurements like measurements of lines, points, arcs, circles, splines, conics, planes, analytic surfaces.

(2) 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.

(3) 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 figure. 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. FIS is the 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 CMM's;

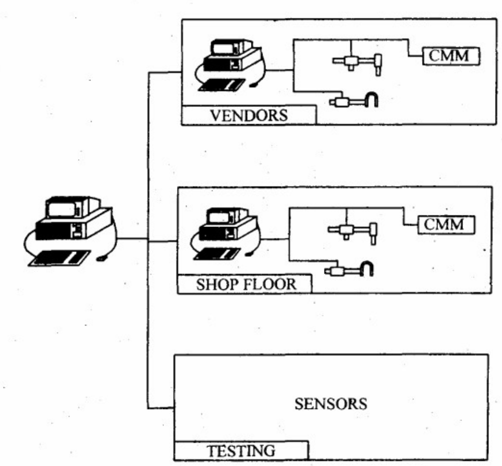


Fig Flexible Inspection System

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 feedback control. The equality control data and inspection data from each station 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. Standoff distance up to one meter is possible.

Vision System

The schematic diagram of a typical vision system is shown. 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.

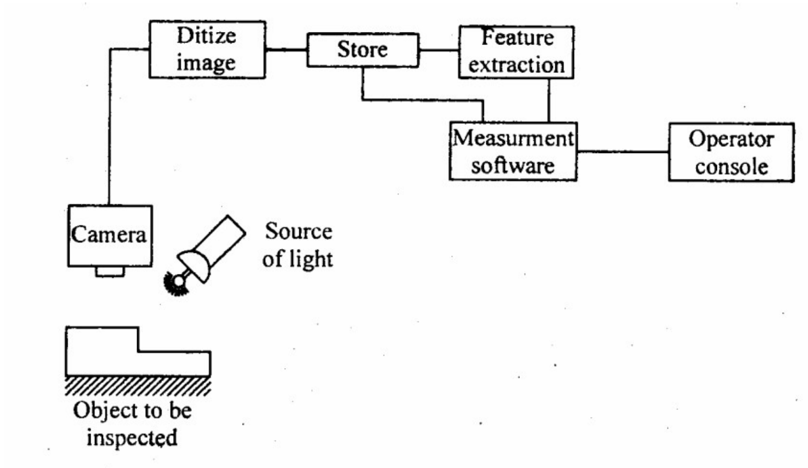


Fig Machine Vision

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

(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.

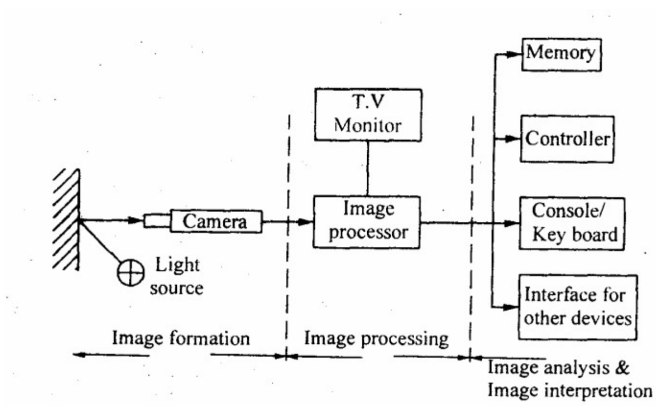


Fig Schematic arrangement of Machine Vision

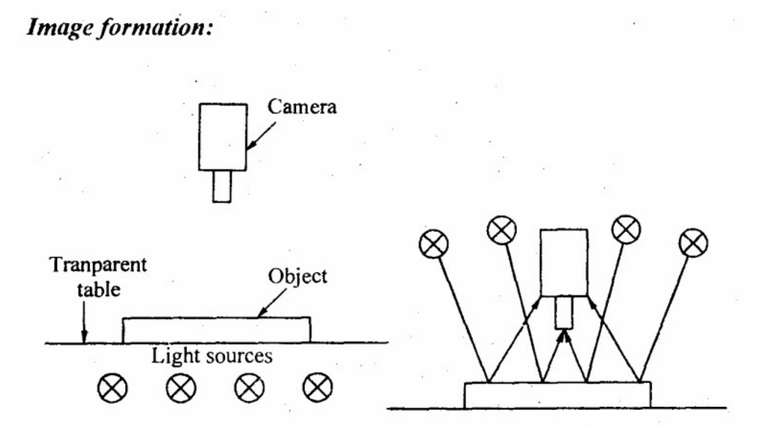


Fig Image Formation

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 by an image processor for processing. 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 removing the degrade. Blurring of lines, poor contrast between images and 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.

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 white and black pixels. The complex images can he interpreted by grey scale technique and algorithms. The most 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 output 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.

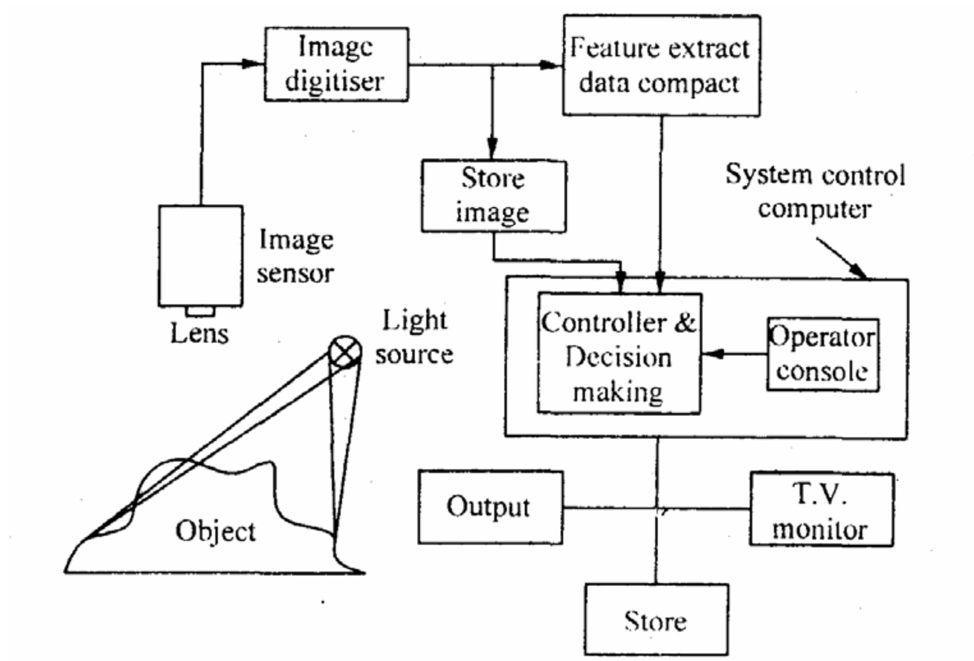


Fig. Functions of Machine Vision

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