Unit-1

Basics of Metrology :-

Introduction to metrology :-

Metrology is a "science of measurement". The most important parameter in metrology is the length. Metrology is divided into industrial metrology and medical metrology under consideration of its application and it may be divided into metrology of length and metrology of time under consideration of its quality.

Metrology is mainly concerned with the following elements.

* Unit of measurement and their standards
* Errors of measurement
* changing units in the form of standards
* Ensuring the uniformity of measurement.
* Developing new methods of measurement
* Analyzing the new methods and their accuracy.

* Establishing uncertainty of measurement

* Gauges design, manufacturing and testing

Introduction to measurement :-

Measurement is a comparison of a given unknown quantity with one of its predetermined standard values adopted as a unit. measurement provides us with means of describing various phenomena in quantiative terms. it plays an important role in all branches of engineering and science. There are two important requirements of the measurement.

* The standards used for comparison must be accurate and internationally accepted.

* The apparatus or instrument and process used for comparison must be provable

* The word measurand is used to designate the particular physical parameter being observed i.e, unknown quantity which is to be measured.

Some of the significance or applications of measurement are described below.

* Measurement provides the fundamental basis for research and development activities. In research activity, the experimental part is based on the types of measurement.

* Measurement is also the basis for commercial activities such as production, pricing, sales and purchase.

* Verification of physical phenomenon and theories require extensive experimentation of the measurement.

* Measurement is used to monitor data in the interest of health and safety, e.g. forecasting weather and predicting the onset of earthquakes.

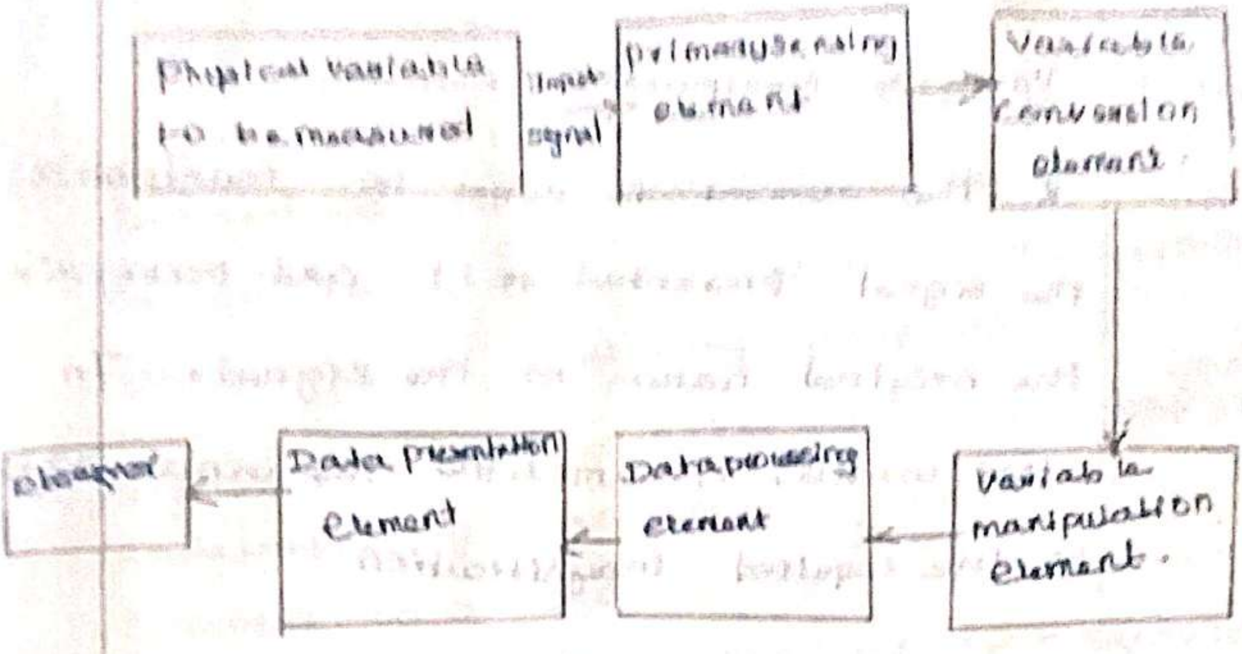
Need for Measurement :-

* To determine the true dimensions of a part.
* To increase our knowledge and understandi of the world.
* To ensure the public health and human safety.
* To convert physical parameters into meaningful numbers
* To test whether the elements which Constitu the system function as per the design.

Element of measurement system :-

A generalized measuring System consits of the following Common elements :-

(i) primary sensing element.
(ii) Variable conversion element.
(iii) Variable manipulation element
(iv) Data transmission element
(v) Data processing element
(vi) Data presentation element.



Primary sensing Element :-

* It is the first element which receives energy from the measured medium and it produces an output corresponding to the measurand. This output is then converted into an analogous electrical signal by a transducer.

Variable conversion Element :-

* It converts the output electrical signal of the primary sensing element (which may be a voltage, frequency or some other electrical parameter) into a more suitable form signal without changing the information containing in the input signal.

Variable manipulation Element:-

* This element is used to manipulate the signal presented to it and preserving the original nature of the signal. In other words, it amplifies the input signal to the required magnification.

Data Transmission Element:-

It transmits the data from one element to the other. It may be as simple as shaft and gear assembly system or as complicated as a telemetry system which is used to transmit the signal from one place to another.

Data processing Element:-

* To convert the data into useful form

* To seperate the signal hidden in noise

* It may provide corrections to the measured physical variables to compensate for zero offset, temperature error, scaling etc.

Data presentation element :-

* These are the elements that they finally communicate the information of measured variable to a human observer for monitoring controlling or analysing purposes.

* The value of measured variables may be indicated by an anolog indicator (pointer and a scale), digital indicator (ammeter, voltmeter, etc) or by a recorder (magnetic taps, camera, T.V equipment and storage type CRT).

Work piece :-

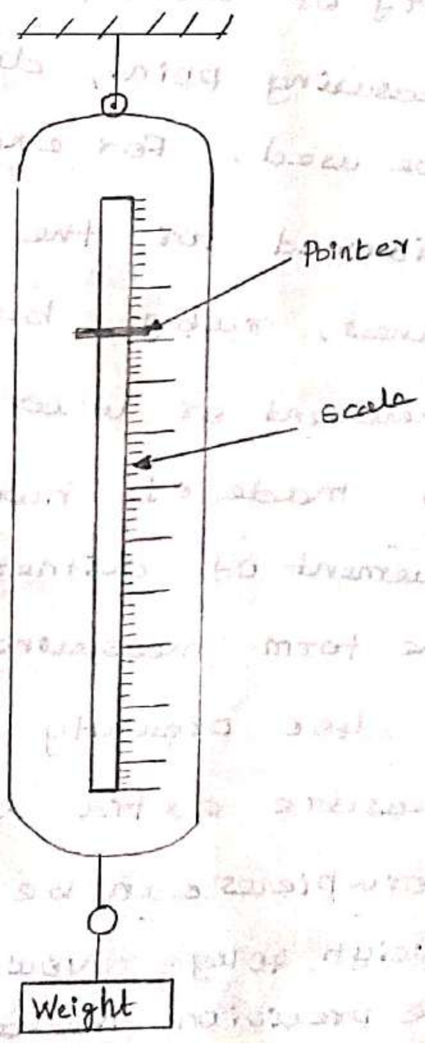
*. Depending on the measuring task, the geometry of work piece and the accessibility of measuring point, different probe systems can be used. For example, probes made of diamond for the measurement of roughness, ruby balls for the form measurement or wear and dirt resistant probes made of hard metal for the measurement of dimensions.

* The form measuring station MarForm MMQ 400 presently offer the possibility to measure extra long workpiece. The workpieces can be up to 900mm long and weigh 40kg. Now, production plants in the precision mechanics industry use long workpieces,

Measuring Instruments:-

Large number and Variety of Variables are involved in the Measurement system in practice. These Variables may be Constant with time or time varying. Measurement of the weight of an object is the example of time constant measurement. The measurement of pressure inside an IC engine is an example of time varying measurement.

Deflection and Null Type Instruments:-



* In a deflection type instrument, the measurement quantity generates some effect which can be ultimately related by the deflection of a pointer or displayed as a number to its magnitude. consider a simple example of measuring the weight of an object by a simple spring balance shown in figure.

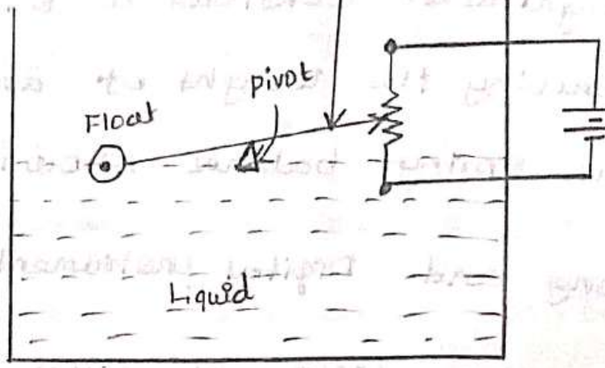
Analong and Digital instruments :-

* The analog instrument gives the output which varies in a continuous manner as the quantity being measured changes and it can take infinite values in a given range. An ordinary D' Arsonval type voltmeter and a pressure gauge indicate the voltage and pressure respectively in the analog form.

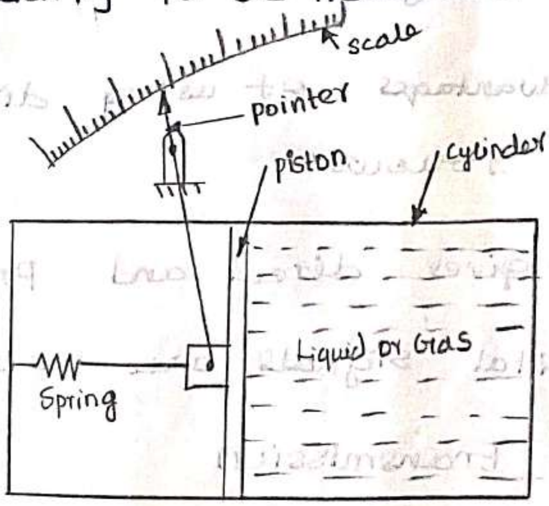
The advantages of using digital instruments are as follows:-

* It gives direct and Precise readings
* Digital signals are noise resistance during transmission
* Digital circuits operate on relatively low Voltage and they are particularly Suitable for digital computer processing.

Active and passive type instruments:-



In active instruments, the quantity being measured just activates the magnitude of some external power input source which in turn produces the measurement. In this type of instrument, another external energy input source is present apart from the quantity to be measured.



* In passive type instruments, the output is produced entirely by the quantity being measured. The example of such a system is shown in figure. The resolution

of the passive instrument is less and cannot be increased very easily.

Automatic and Manually operated instruments:-

* Manually operated instruments require the services of a human operator. If some auxilary devices are incorporated in the instrument to dispense with the human operator,

* It is termed as automatic instruments, For example, a null balance type instrument in which the null balance is achieved manually termed as manually operated instruments.

Absolute and Secondary instruments:-

Galvanometer,

* Absolute instruments are those which give the value of the electrical quantity to be measured in terms of constant of the instruments and their deflection only.

* Secondary instruments are those which have been precalibrated by Comparison with an absolute instrument. The value of the electrical quantity to be measurement in these instruments can be determined from the deflection of instruments.

Contacting and Non-contacting instruments:

* The instrument in which some parts of the instrument are in contact with the measuring medium is called contacting type instrument. Few example of contacting type instruments are thermometer (mercury-in-glass type). Bourdon type pressure gauge and voltmeter. These instruments are placed in an electrical circuit.

Intelligent Instrument:

* In conventional instrument, the basic functional element are present whereas the intelligent instrument incorporates a microprocessor.

* Time constants may be selected.

* Non-linear output can be linearis

* Suitable for various ranges of input signal strengths.

* Fault detection can be diagnostic

* Remote can be used to operate the instrument.

Persons :-

* Man is the measure of all "things" stated by Protagoras (Greek sophist 485-411 BC). Measurement consists of rules for assigning numbers to attributes of objects based upon rules.

* In science, the observer effect refers to changes that the act of observation will make on a phenomenon being observed. A common place checking the pressure in an automobile tire is difficult to do without letting out some of the air thereby changing the pressure.

Environment :-

* The measurement system is influenced by the environment also. For example, the Vernier Scale division (VSD) of vernier caliper always changes when the measurement process is carried for 'N' number of times for the same dimension. It is due to the one of the reasons of change in ambient temperature.

* The environment is indirectly related to temperature, humidity, conditioning and pre conditioning.

Range of Accuracy :-

* Accuracy may be defined as the ability of an instrument to respond to a true value of a measured variable under the reference conditions. It refers how closely the measured value agrees with the true value. The accuracy of an instrument can be specified in the following ways.

Accuracy as "percentage of full scale Reading"

This type of measuring accuracy is applicable in case of instruments having uniform scale. It can be expressed by.

$$\text{Percentage of full scale reading} = \frac{\text{Measured Value} - \text{True Value}}{\text{Maximum scale value}}$$

For example, if the accuracy of an instrument having full scale reading of 50 units is expressed as ±0.1% of full scale reading, then there will be error of 0.05 units.

Accuracy as "Percentage of True value"

This is the best way of specifying the accuracy. It is to be specified in terms of the true value of quantity being measured. It can be expressed by

$$\text{Percentage of true value} = \frac{\text{Measured value} - \text{True value}}{\text{True value}}$$

For example, a pressure gauge of range 0 - 100 kN/m². If it has an error of ± 1% of true value, the pressure of 100 kN/m² could be read from 99 to 101 kN/m²

Accuracy as "percentage of Scale span"

For an instrument, if q_{max} is the maximum point for which scale is calibrated and q_{min} is the minimum reading on scale, then ($q_{max} - q_{min}$).

* For example, if an instrument has a range from 10 to 150 units, the accuracy is specified as ± 0.1 % of the span, then the instrument will have $\pm \frac{0.1(150-10)}{100} = \pm 0.14$ units error in any measurement within this span.

Precision:-

* Precision is defined as the degree of exactness for which an instrument is designed or intended to perform. It refer the repeatability or consistency of measurement when the measurements are carried out under identical conditions at a short interval of time.

* It can also be defined as the ability of the instrument to reproduce a group of measurements of the same measured quantity under the same conditions.

The precision is composed of two characteristics

(i) conformity

(ii) significant figures.

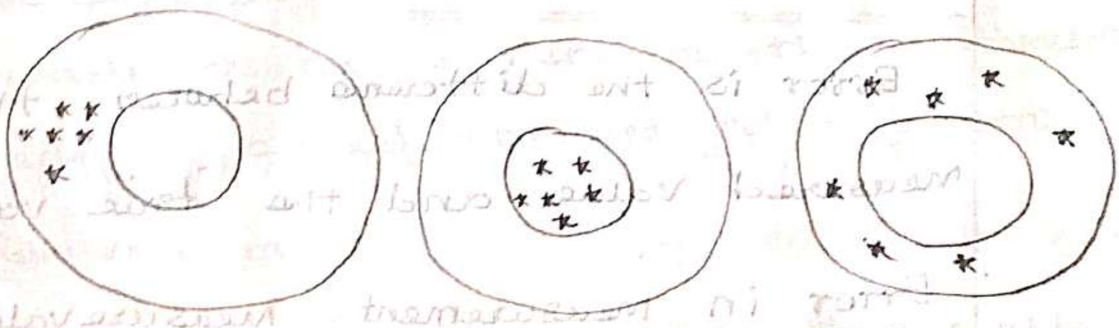
Conformity :-

* consider a resistor whose true value of resistance is 2834267 Ω and measured by an multimeter which consistently and repeatedly indicates 2.8 MΩ estimated by the reader from the available scale.

Significand figure :-

* Significand figure conveys the actual information regarding the magnitude and the measurement precision of a quantity. The precision of the instrument depends on the number of significand figure in which the reading is expressed.

* The more is significand figure, the greater will be the precision of measurement significand figure is the number of digits for measuring output.



High precision Poor accuracy

High precision High accuracy

Poor Precision Good average accuracy.

* Many times, the terms precision and accuracy are used interchangeably. But actually, there is a difference between these two terms.

* This difference can be clearly explained with the following example. The difference between accuracy and precision can be explained in another method also.

* Consider the measurement of a known pressure of 100 MPa with a pressure gauge. Six readings are taken and the indicated value are 103, 104, 102, 103, 102, 104 MPa. The averages of the indicated value is 103 MPa.

Errors in Measurements:-

Error is the difference between the Measured value and the true value.

Error in measurement = Measure value − True value.

The errors in measurement can be expressed either as an absolute error or relative error.

Absolute error :-

The absolute error is classified into two types :-

1. True absolute error
2. Apparent absolute error.

(i) True absolute error :-

Algebraic difference between the results of measurement and the true value of the quantity measured is called true absolute error.

(ii) Apparent absolute error :-

While taking the series of measurement the algebraic difference between on of the results of measurement to the arithmetic mean is called apparent absolute error.

Relative Error :-

Relative error is defined as the results of the absolute error and the value of comparison used for the calculation of absolute error. The comparison may be true value or conventional true value or arithmetic mean for series of measurement.

Types of Errors :-

1. Static errors

(i) Characteristic error

(ii) Reading error

(iii) Environmental error

2. Loading error

3. Dynamic error

Static Error :-

* It causes due to the physical nature of various components of the measuring system.

* The static errors due to environment effect and the other properties which influence the apparatus are also reasons for static errors.

(i) Characteristics error :-

* The deviation of the output of the measuring system from the nominal performance specifications is called characteristics error.

* The linearity, repeatability, hysteresis and resolution are part of the characteristic

(ii) Reading error:-

* It is exclusively applied to the read out device. The reading error describes the factors parallax error and interpolation error. The use of mirror behind the readout indicator, eliminates the occurrence of parallax error

(iii) Environmental error:-

* Every instrument is manufactured and calibrated at one place and it is used in some other place where the environmental conditions such as temperature, pressure, and humidity change.

(1) Monitoring the atmospheric conditions.

(2) By calibration of Instrument at the place of use

(3) Automatic devices are used to compensate the effects.

2. Loading error:-

* Loading means the measuring instrument always taking the input from the signal source. Due to this, the signal source will always be altered by the act of measurement known loading.

(3) Dynamic Error :-

* It is due to time variation in the measurand. The dynamic errors are caused by inertia, friction and clamping action. The dynamic errors are mainly classified into the following types :-

a) Systematic errors
b) Random error

a) Systematic error :-

* The systematic are constant and similar in form. These are controllable in both their sense and magnitude. The systematic errors are easily determined and reduced.

b) Random error :-

* These types of errors occur randomly and reason for this type of errors cannot be specified.

Control of Error :-

* The error can be controlled by using some mathamatical modeling. For error analysis, statistical analysis may be a more appropriate tool to solve large data which is obtained from measurement. The variance should be minimised to control error within the limit. Control charts are powerful tools for monitoring manufacturing processes by $\bar{x}$ and R control charts.

Standards :-

* Standard is a physical representation of a unit of measurement. A known accurate measure of physical quantity is termed as standard. These standards are used to determine the values of physical quantities.

* Different standards have been developed for various units including fundamental as well as derived units. All these standards are preserved at the international Bureau of weight and measures at Severs, paris.

Types of Standards :-

Standards of measurement are classified as follows :-

(i) International Standards
(ii) primary Standards
(iii) Secondary Standards.
(iv) Working Standards.

(i) International Standards :-

* International Standards are defined by international agreement. They are periodically evaluated and checked by absolute measurements in terms of fundamental units of physics.

* They represent certain units of measurement to closest possible accuracy attainable by the science and technology of measurement.

(ii) primary Standards :-

* The main function of primary Standard is the calibration and verification of Secondary Standards. Primary Standards are maintained at the National Standard Laboratories in different countries.

(iii) Secondary Standards:-

* Secondary standards are the basic reference standards used by the measurement and calibration laboratories in industries.

* These secondary standards are maintained by the particular industry to which they belong

* After comparison and calibration, the National Standards Laboratory returns the secondary standards to the particular industrial laboratory with a certification of measuring accuracy in terms of primary standards.

(iv) Working Standards:-

* Working standards are the main tools of a measuring laboratory. These standards are used to check and calibrate laboratory instrument for accuracy and performance.

* For example, manufacturing of mechanical components such as shaft, bearing gears etc, use a standard called working standard.

Unit- 2

Linear and Angular Measurements :-

EVOLUTION TO MEASUREMENTS :-

* Measurement is always very much important since man settled from his nomadic lifestyle and started using materials.

* For example, to occupy the land and trade with his neighbours, they need some Measurement.

(i) Length :-

The oldest unit of length was cubit which was the length of arm from the tip of the finger to the elbow. It was subdivided to shorter units such as foot, hand or finger.

(ii) weight :-

Weight is related with some degree of accuracy in terms of a number of grains. The measures of any heavy items is referred by weight.

(iii) Volume:-

Volume indirectly refers the quantity. For example, the volume of fluid is in a vessel. The nature provides some rough average such as goatskins.

(iv) Time:-

* Time parameter is a central theme in modern life for most of the human history

* Other parameters such as pressure, temperature, velocity are measurable which play a major role in day to day life.

CLASSIFICATION OF LINEAR MEASURING INSTRUMENTS

* A very common measurement of a dimension is length, width or height of an object.

* Depending on the quality of measurement required, the dimension measuring instruments are divided into the following types.

TYPES OF LINEAR MEASURING INSTRUMENTS:-

* The linear measurement includes the measurement of length, diameter, height and thickness. The basic principle of linear measurement. is the comparison of measured dimensions with standard dimensions on a suitably engraved instrument or device.

(i) Vernier calipers

(ii) Micrometers

(iii) Slip gauge or gauge blocks

(iv) comparators.

(i) vernier caliper:-

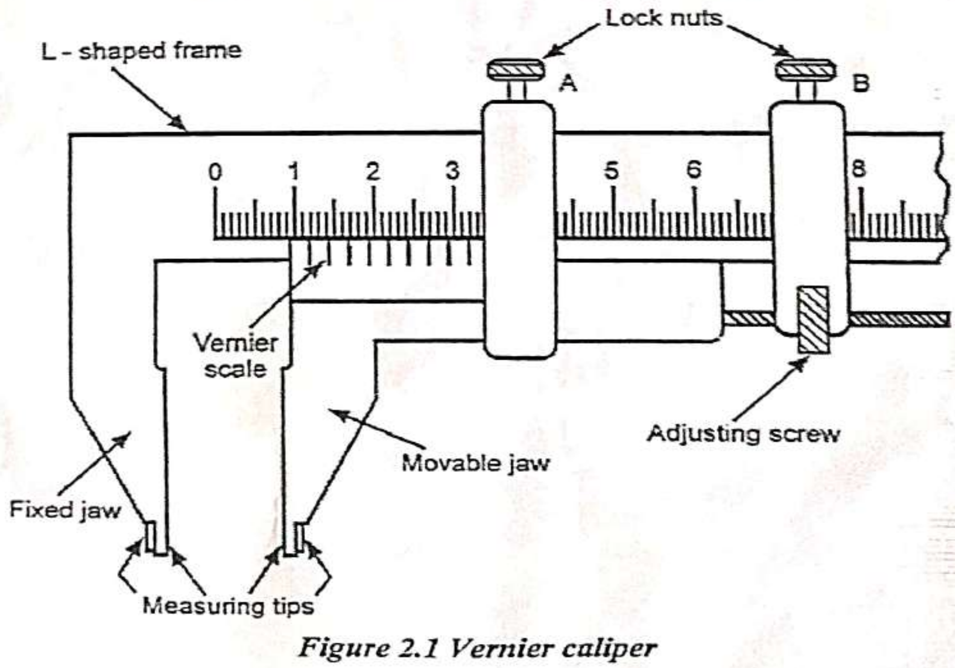
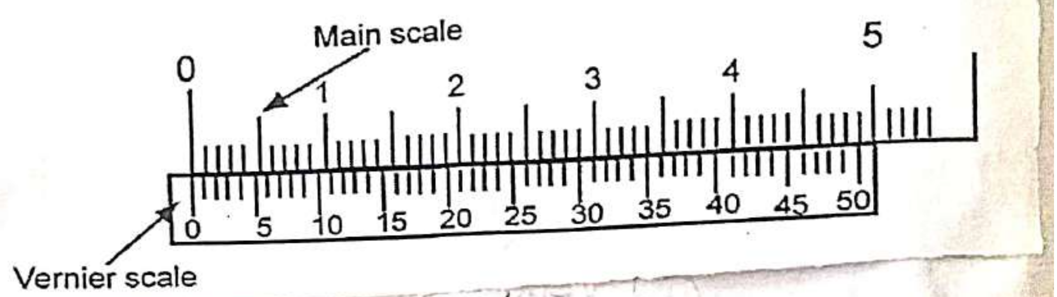


Figure 2.1 Vernier caliper

* Vernier calipers have two scales namely main scale and vernier scale. The vernier scale moves along the main scale. Verniers are used to measure both internal and external dimensions.

Least count calculation of the vernier caliper:



Forward vernier

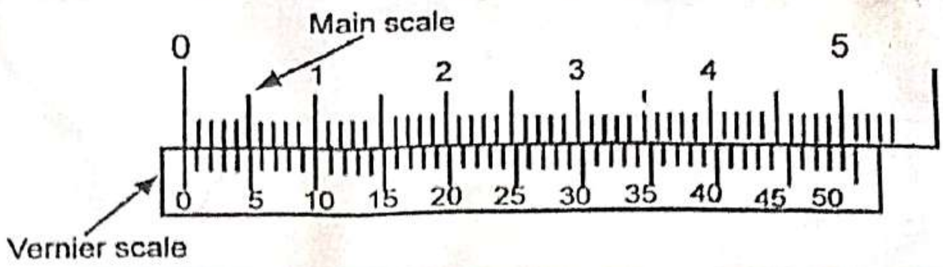
* In vernier scale, each small division on the main scale is equal to 0.02 units.

The vernier scale has 50 divisions. 49 divisions on the main scale are divided into 50 divisions on the vernier scale. Shown in figure. This vernier is called forward vernier.

$$50\,VSD = 49\,MSD$$

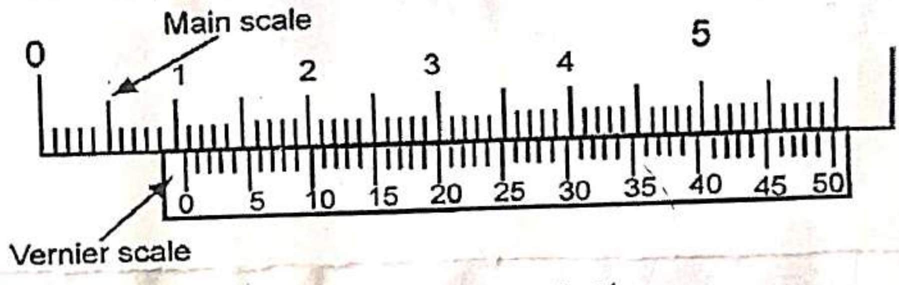
$$1\,VSD = \frac{49}{50}\,MSD$$

$$L.C = 1MSD - 1VSD = 1 - \frac{49}{50} = \frac{1}{50} = 0.02 \text{ units or mm}$$



Backward vernier

In backward vernier, 51 divisions on main scale are divided into 50 divisions on vernier scale.



Reading the vernier

An example for forward vernier is shown in figure, in which the measurement reading is noted.

MSD = 10 mm

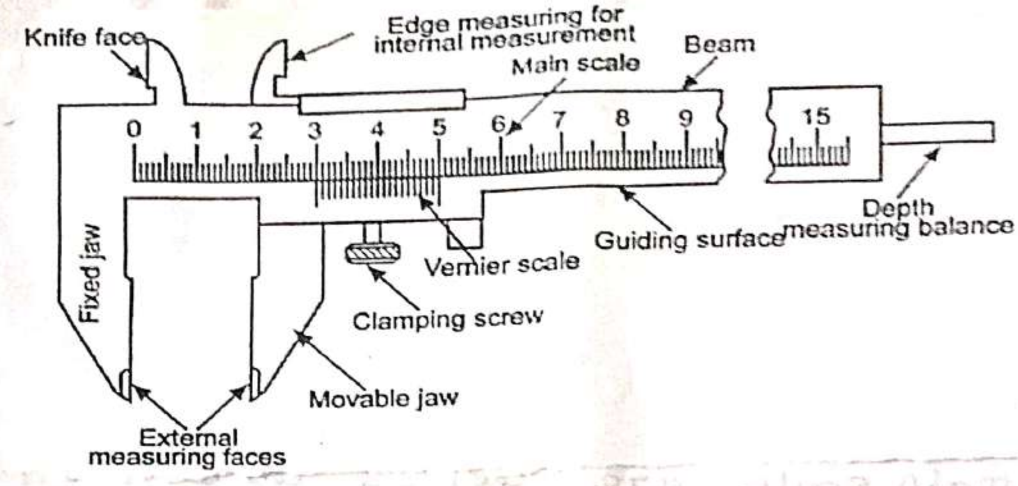
VSD = 15 division

∴ Actual dimension = MSD + VSD × L.C

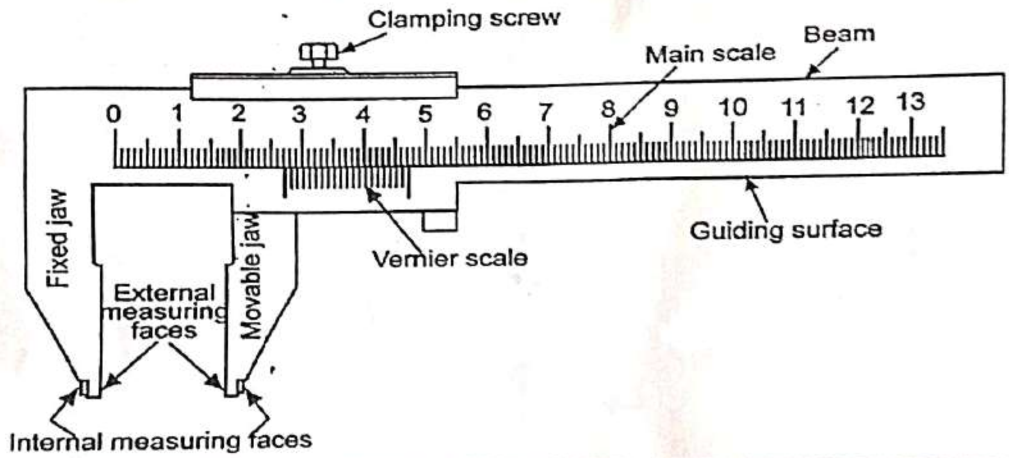
= 10 + 15 × 0.02

= 10.3 mm.

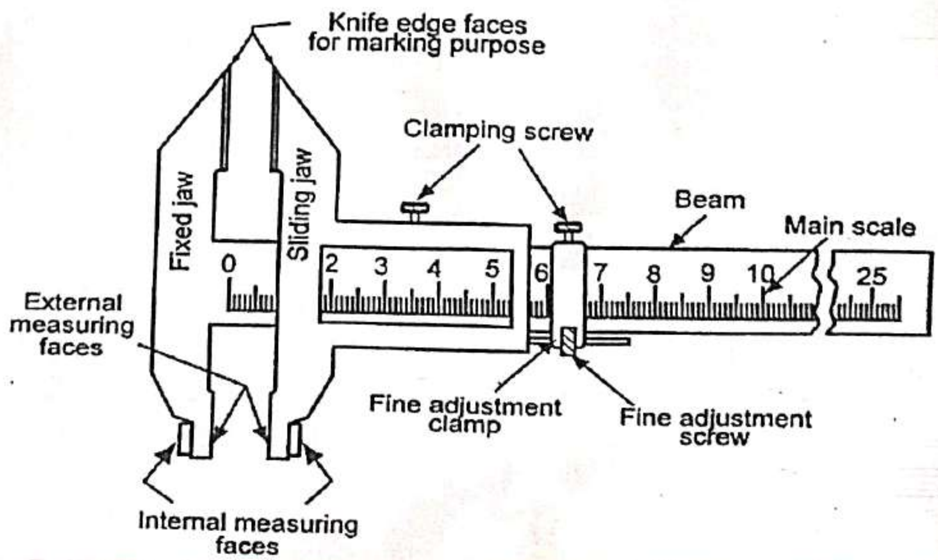
Types of Vernier calipers



Type A vernier caliper



Type B vernier caliper



Type C vernier caliper

* Based on IS 3651- 1974 (Specification for vernier caliper), three types of vernier calipers are used to meet the demand of both external and internal measurements up to 2000mm having accuracies of 0.02mm, 0.05mm. and 0.1mm. these three are named as A, B and C shown in figure.

* In type A, Jaws are provided on both sides for external and internal measurements. One blade is also fitted to measure depth of the part. In type B, Jaws are provided on only one side for both external and internal measurements. But in type C, Jaws are provided on both sides for marking and measuring dimensions. In both types B and C, there is no provision for depth measurements.

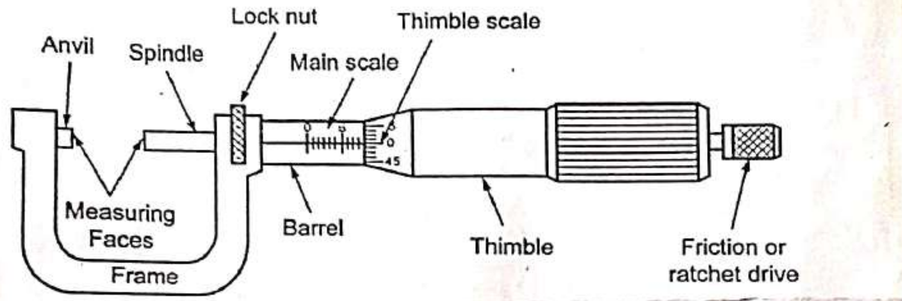
Errors in measurements with vernier calipers:-

* Errors may arise in manipulation of vernier caliper

* Jaw movement should be perpendicular to the scale readings otherwise, the measurement will no be correct.

(ii) Micrometer :-

The micrometer has an accurate screw consisting of 10 to 20 threads per mm. This screw rotates inside a fixed nut. The end of the screw acts as on measuring tip and fixed anvil acts other measuring tip.



* While measuring dimensions, the locknut arrests the movement of the Spindle to ensure Correct reading. A ratchet is provided to apply uniform pressure after just touching the ends of the part to be measured.

(a) Frame :-

The frame is made to the required shape but at the same time, it should be in such a way to permit the part to be measured.

(b) Anvil

* The Fixed anvil of the micrometer protrudes for 3mm from frame to support the part at one end.

* The measuring faces on the anvil should be strong enough to reduce wear and tear.

(c) Spindle :-

* The spindle is placed inside the barrel to slide freely. A bush is placed in the space between barrel and spindle to ensure free running of the spindle.

(d) Ratchet driver :-

* wear resistant material is used to make ratchet

(E) Thimble and barrel :-

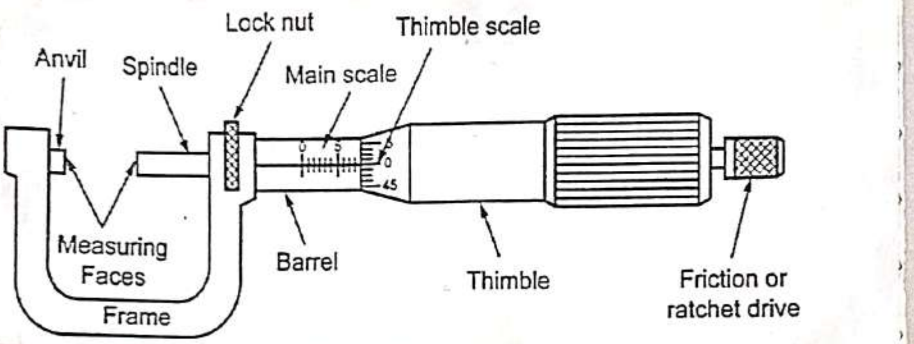
* Graduations are made on both barrel and thimble. These parts are made by using high wear resistant material.

Types of Micrometer :-

(a) Outside micrometer - to measure external dimensions

(b) Inside micrometer - to measure internal dimensions

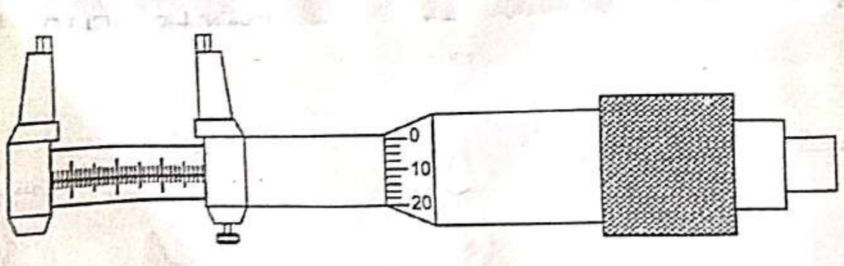
a) outside micrometer :-



* An outside micrometer is shown in figure. It consists of two scales, main scale and thimble scale

* while the pitch of barrel screw is 0.5 mm, the thimble has graduation of 0.01mm. The least count of this micrometer is 0.01 mm.

(b) Inside micrometer.



* Inside micrometer is used for measuring internal dimensions. It has mainly four parts such as measuring head, extension rods, spacing collars and handle.

(iii) Slip gauges:-

Slip gauges are used as measuring blocks. It is also called precision gauge blocks. They are made of hardened alloy steel of rectangular cross-section.

Classification of slip gauges:-

a) Grade 2

b) Grade 1

c) Grade 0

d) Grade 00

e) Calibration grade.

a) Grade 2:-

* It is a workshop grade slip gauge used for setting tools, cutters and checking dimensions roughly.

b) Grade 1

* The grade 1 is used for precise work in tool rooms.

c) Grade 0 :-

* It is used as the Inspection grade of slip gauges mainly by inspection department

d) Grade 00 :-

Grade 00 mainly used in high precision works in the form of error detection in instruments.

e) calibration grade :-

* The actual size of slip gauge is calibrated on a chart supplied by the manufactures.

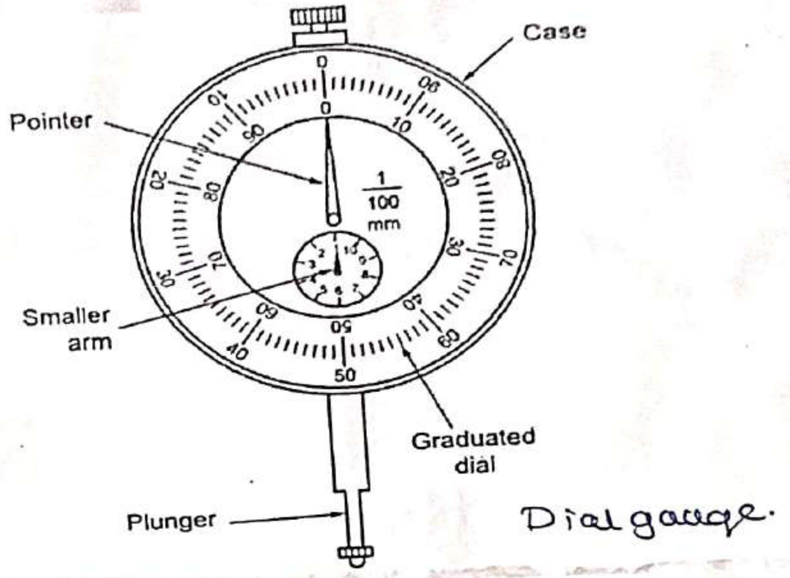
Manufacture of slip gauges :-

* First the approximate size of slip gauges is done by preliminary operations

* The blocks are hardened and wear resistant by a special heat treatment process.

(IV) comparators :-

* comparators are one form of linear measurement device which is quick and more convenient for checking the large number of identical dimensions.



Dial gauge.

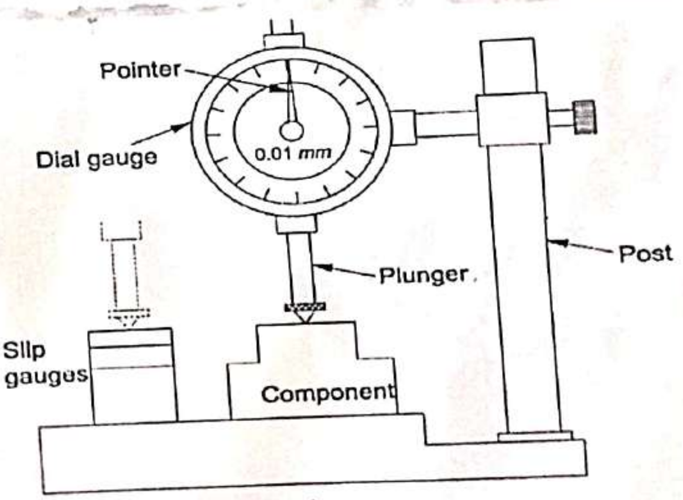


Figure 2.33

* The whole setup consists of worktable dial indicator and vertical post. the dial indicator is fitted to vertical post by an adjusting screw shown in figure. top surface of the worktable is finely finished. The dial gauge can be adjusted vertically and locked in

LIMIT GAUGES :-

* A Limit gauge is not a measuring gauge. They are just used as inspecting gauges. The limit gauges are used in inspection by methods of attributes

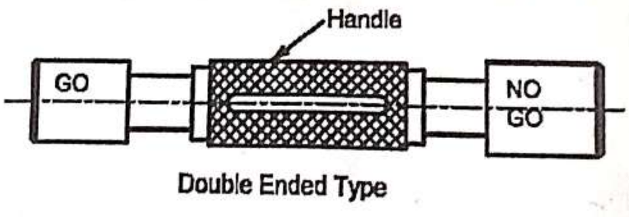
Purpose of using limit gauges:-

* components are manufactured as per the specified tolerance limits, upper limit and lower limit. the dimensions of each component should be within the upper and lower limits.

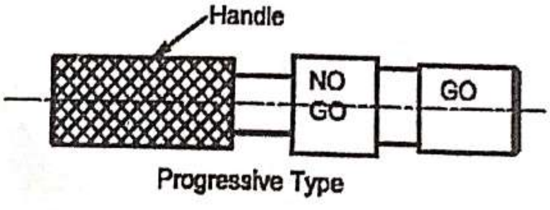
The common types are as follows

1) plug gauges
2) Ring gauges
3) snap gauges.

(1) Plug gauges ::



Double Ended Type



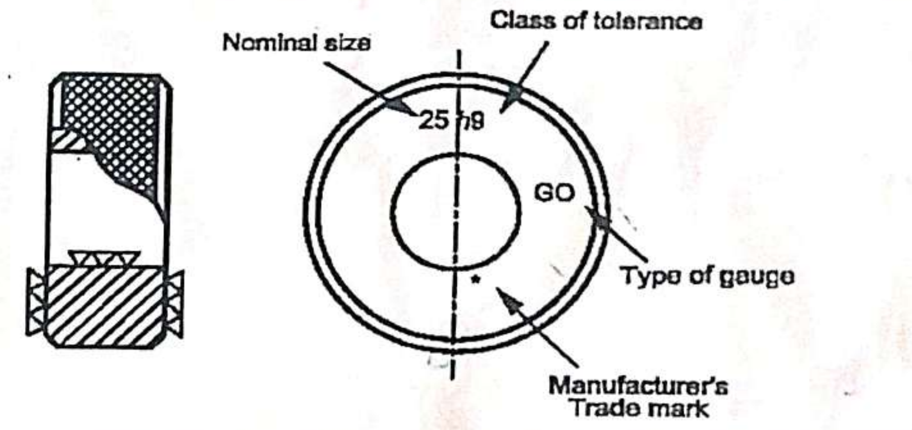
Progressive Type

* The ends are hardened and accurately finished by grinding. One end is GO end and other end is NOGO end.

* Usually, GO end will be equal to the lower limit size of the hole and NOGO end will be equal to the upper limit size of the hole.

* If the size of the hole is within the limits, GO end should go inside the hole and NOGO end should not go.

(ii) Ring Gauge :

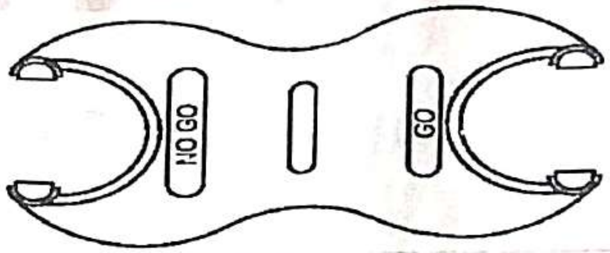


* Ring gauges are mainly used for checking the diameter of shafts having a central hole.

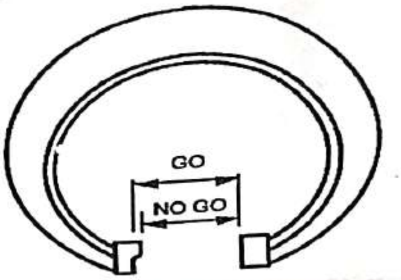
* The hole is accurately finished by grinding and lapping after hardening process.

* The periphery of the ring is knurled to give more grip while handling the gauges.

(iii) Snap gauge :-



Double ended Snap gauge.



Progressive snap gauge.

* Snap gauges are used for checking external dimensions. They are also called gap gauges. The different types of Snap gauges are as follows -

a) Double ended snap gauge :-

* This gauge has two ends in the Form of anvils. Here, the GO anvil is made to lower limit and NOGO anvil is made to upper limit of the Shaft. It is also known as Snap gauge.

b) Progressive snap gauge :-

* This type of snap gauge is also called caliper gauge.

* It is mainly used for checking large diameters up to 100mm.

* Both GO and NOGO anvils at the same end.

TERMINOLOGY USED IN GAUGE DESIGN:-

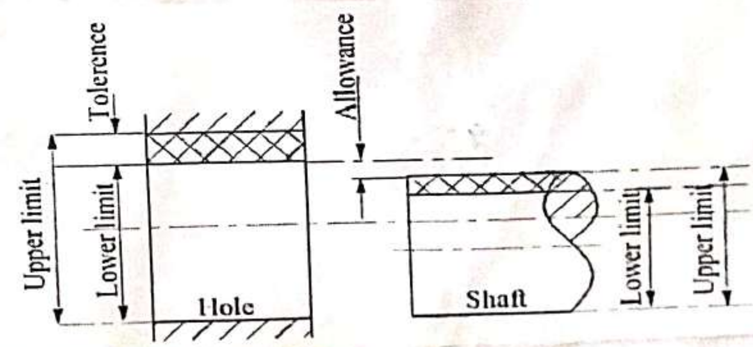
* In spite of recent advances in manufacturing methods, it is not possible to produce a part exactly conforming to the requirements.

(i) Shaft :-

It refers not only the diameter of circular shaft but also any external dimension on a component.

(ii) Hole :-

It refers any internal dimension on a component but not only the diameter of circular hole.



(iii) Basic size:

* Basic (or) nominal size is the Standard size for the part and it is same both for hole and shaft.

(iv) Actual size:

* Actual size is the dimension as measured actually on a part.

V. Limits of size

Limits of size are the maximum and minimum permissible sizes of the part.

VI maximum Limit:

* Maximum limit is the maximum permissible size of the part.

VII Minimum Limit:

* minimum limit is the minimum permissible size of part.

VIII Tolerance:

Tolerance is the difference between maximum limit and minimum limit.

PROCEDURE FOR GAUGE DESIGN :-

(i) Design of plug Gauges :-

* while designing the plug gauge, Go end is made to lower limit and NOGO end is made to upper limit

Go end diameter,

$$D_1 = (K+Z) \pm H/2$$

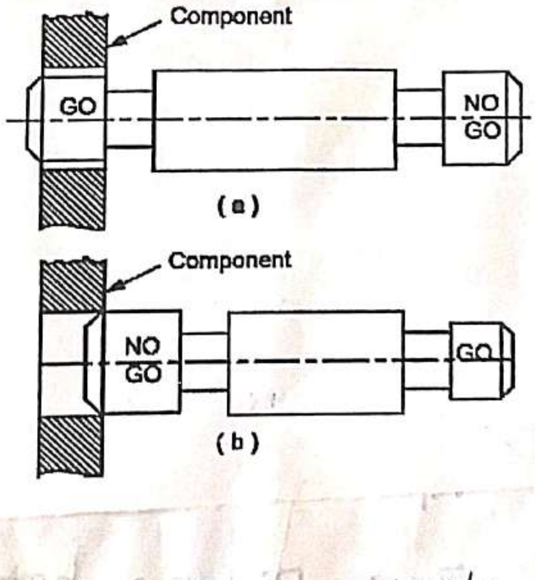
K = Lower limit

Z = Wear allowance.

H/2 = Manufacturing allowance.

Go end diameter (work out) = K − Y

Y = Wear allowance.

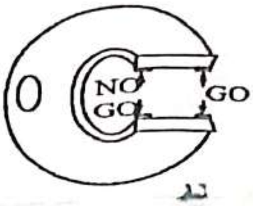


NO GO end diameter, $D_2 = G \pm H/2$

where G = Upper limit.

Work tolerance = Upper limit − Lower limit.

(ii) Design of snap Gauge



The snap gauges are mainly used to measure the diameter of the shaft. the size of Go end and NoGo end are calculated as follows.

Go gauge (new) size,

$D_1 = (G - z_1) + H/2$

Go gauge (worn out) size,

$= G + Y_1 - \alpha_1$

NoGo gauge size,

$D_2 = K + \alpha_1 \pm H/2$

G = upper limit,

K = Lower limit

$H/2$ = manufacturing tolerance

z_1 = Distance between center of tolerance zone of new Go gauge and Go work piece limit

Y_1 = Wear allowance

α_1 = Safety zone provided for Compensating Measuring uncertainties of

CONCEPT OF INTERCHANGEABILITY

* A part which can be substituted for the component manufactured to the same shape and dimensions is known as interchangeable part.

* In earlier days, components are produced to small number of units. To obtain the desired fit, the operator has to adjust the mating parts within the permissible limit.

Advantages of interchangeability :-

* Replacement of worn out parts is easy
* Repair is carried out easily
* Maintenance cost is less
* shut down of machines having interchangeable components is reduced.

International standards are mainly used to obtain universal acceptance. It can be obtained in two ways namely.

(i) Universal Interchangeability.

(ii) selective assembly.

(i) Universal interchangeability :-

* It means that parts which go into assembly may be selected at random from large number of parts.

* In this type of interchangeability, any component will mat with any other mating component without doing any minor alterations to mat.

(ii) Selective Assembly :-

* Now a days, people want not only quality, precision and trouble free products but also they want attractive products.

* Therefore, the tolerance varies for each and every group products

* In this System, an automatic gauging is used to seperate the manufacturing components.

ANGULAR MEASUREMENTS :-

* Angle is defined as the opening between two lines which meet at a point.

* If a circle is divided into 360 parts, then each part is called degree (°). If each degree is subdivided into 60 parts called minutes ('), and each minutes is further subdivided into 60 parts called seconds (").

Types of Angular Measuring Instruments :-

1. Line standard angular measuring devices
   - (i) protractors
   - (ii) Universal bevel protractors
2. Face Standard angular measuring devices
3. Measurement of inclines.
   - (i) spirit level.
   - (ii) Clinometer.
4. Angle comparators.

BEVEL PROTRACTORS :-

* Bevel protractors are angular measuring instruments.

Types of bevel protractors :-

(i) vernier bevel protractor

(ii) Universal protractor

(iii) optical protractor.

(i) vernier bevel protractor :-

(i) vernier bevel protractor : -

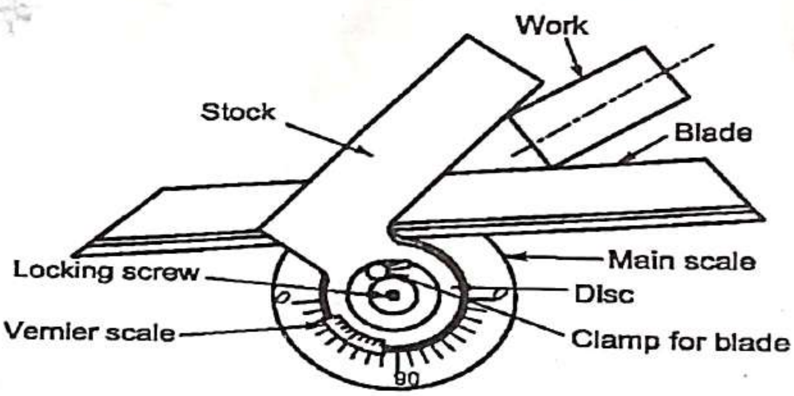


Figure 2.77 Bevel protractor

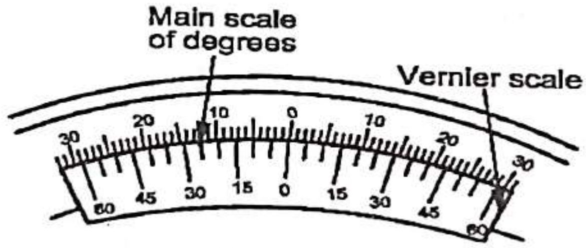


Figure 2.78

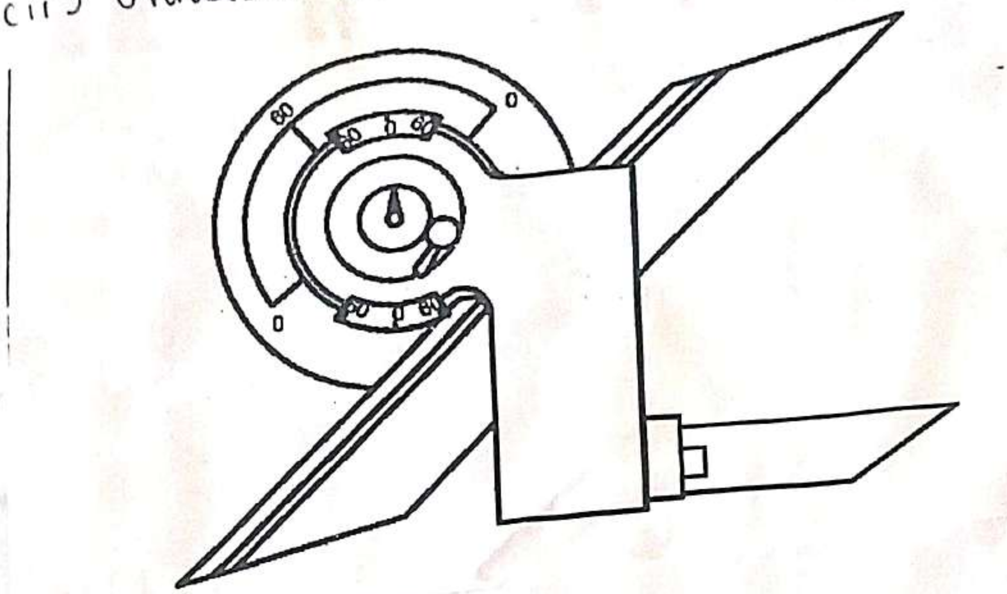
A vernier bevel protractor is attached with acute angle attachment. The body is designed such that its back is flat and no projections are beyond its back.

Least count = $\frac{\text{One main scale division}}{\text{No of division vernier scale.}}$

$= \frac{1^\circ}{12}$

$= \frac{1}{12} \times 60 = 5$ minutes.

(ii) Universal Bevel protractor.



Metrology and Measurements

2.98

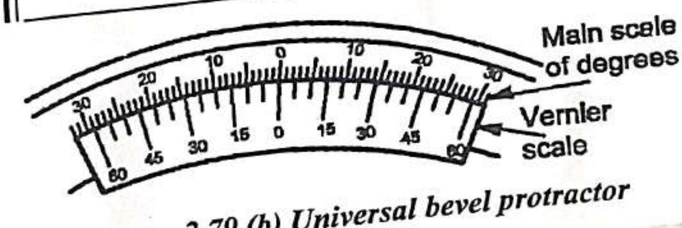
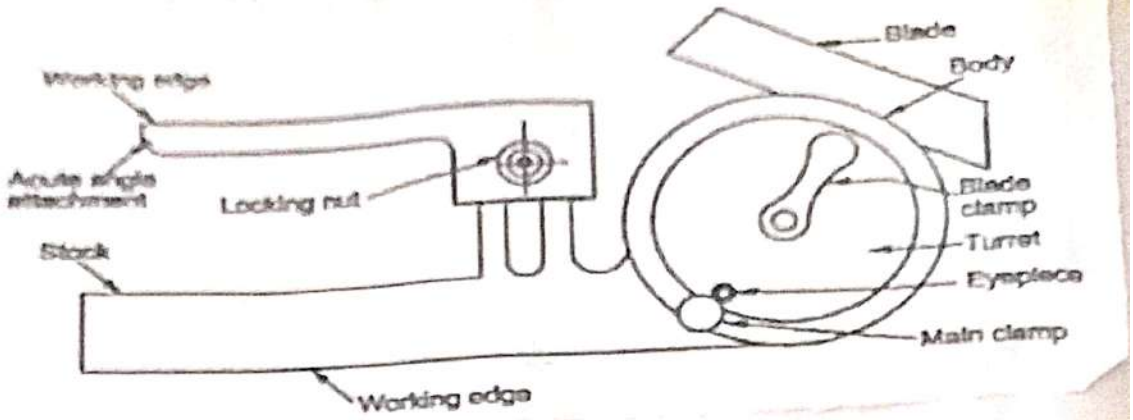


Figure 2.79 (b) Universal bevel protractor

* In this type of bevel protractor, the blade can be rotated to measure any angle which is made by providing a slot for the protractor dial.

* scale graduation and parts are similar to vernier bevel protractor.

(iii) optical bevel protractor :-



* The value can be measured to an accuracy of 2 minutes by using this type of bevel protractor

* The values are obtained against an index line or vernier by means of an optical magnifying system.

MEASUREMENT OF INCLINES

* Inclination of a surface generally signifies the deviation of the actual plane from the horizontal or vertical planes.

* Gravitational principle can be used in construction of measurements of such inclinations.

(i) spirit level.

* spirit level is one of most commonly used instruments for inspecting the horizontal surfaces for both straightness and flatness.

* It is used to evaluate the direction and magnitude of minor deviation from nominal condition.

(ii) Clinometers Angle Gauges :-

* An inclinometer or clinometer is an instrument for measuring the angle of slope, elevation or depression of an object with respect to gravity

* It is also known as a tilt meter, tilt indicator, slope alert, slope gauge, gradient meter gradiometer, level gauge, level meter, declinometer. and pitch and roll indicator.

* The angle of inclination of the rotary member carrying the level relative to its base is measured by this circular scale.

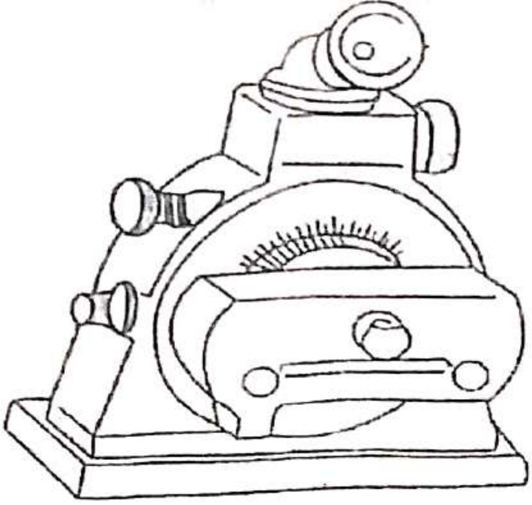


Figure 2.85 Clinometer

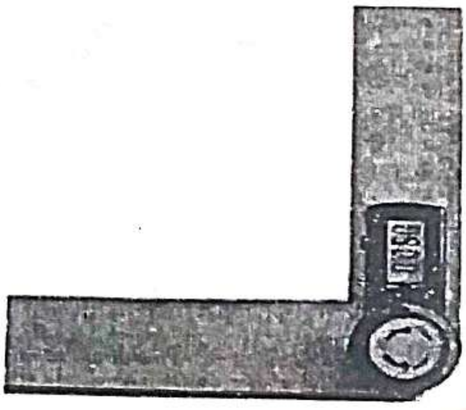


Figure 2.86 Clinograph

* A number of commercially available clinometers with various designs are available but they differ in their sensitivity and measuring accuracy

Applications :-

(i) Measurement of an incline plane with respect to a horizontal plane

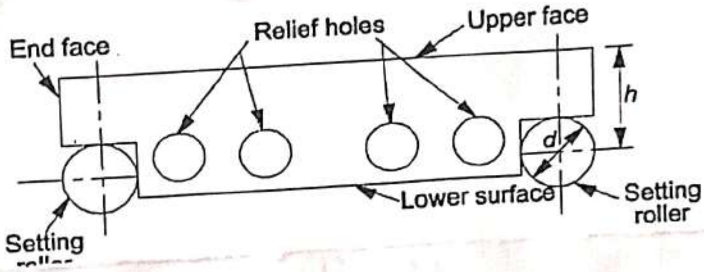
(ii) Measurement of the relative position of two mutually inclined surfaces.

SINE BAR:

Sine bar are always used along with slip gauges as a device for the measurement of angles very precisely. They are used to

(i) measure angles very accurately

(ii) locate the work piece for the given angle with very high precision.



* Generally, sine bars are made from high carbon, high chromium, and corrosion resistant steel.

* These materials are highly hardened, ground and stablished. In sine bars, two cylinders of equal diameter are attached at ends with its axes mutually parallel to each other.

* They are also at equal distance from the upper surface of the sine bar.

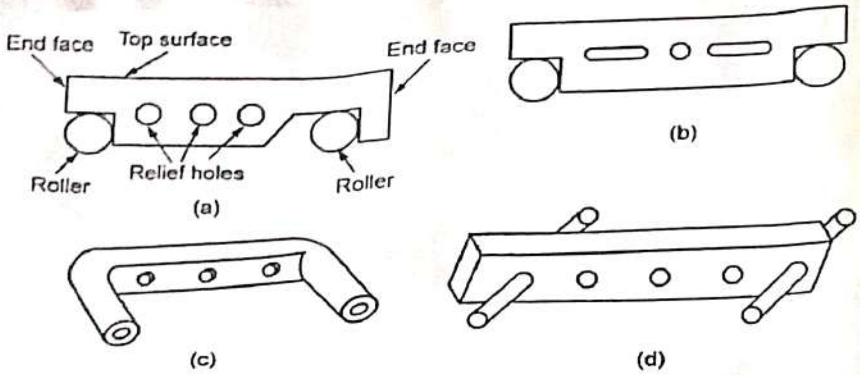


Figure 2.88 Various types of sine bar

* Figure 2.88(a) to 2.88(d) Show the various design of sine bar for different application

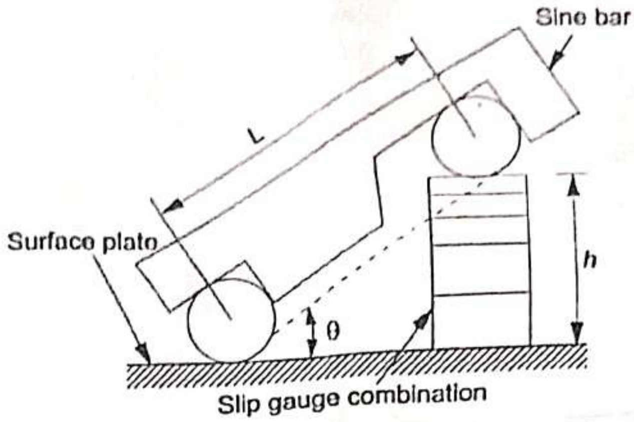
* Figure 2.88(a) shows the more preferred form of the sine bar since the distance between rollers can be adjusted exactly

* Figure 2.88(b) Shows the most commonly used Form of the Sine bar.

* Figure 2.88(c) Shows the hollow rollers are integral with the Sine bar and the outside diameter.

* Figure 2.88(d) Shows the special form Sine bar. This type is used where an ordinary type cannot be used on the top surface due to interruption

working principle of sine bar.



* The working of sinebar is based on the trigonometry principle. To measure the angle of a given specimen, one roller of the sine bar is placed on the surface plate and another one roller is placed over the surface of slip gauges

$$\sin\theta = \frac{h}{L}$$

$$\therefore \theta = \sin^{-1}(h/L)$$

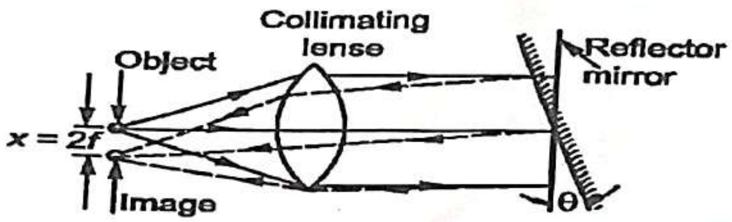
Accuracy requirements of a Sine bar:-

* The rollers must have equal diameters and equal cylinders

* The rollers should be placed parallel to each other and it is also parallel to the upper face.

AUTOCOLLIMATOR

* Auto-collimator is an optical instrument used for the measurement of small angular difference, change or deflection, plane surface inspection etc.

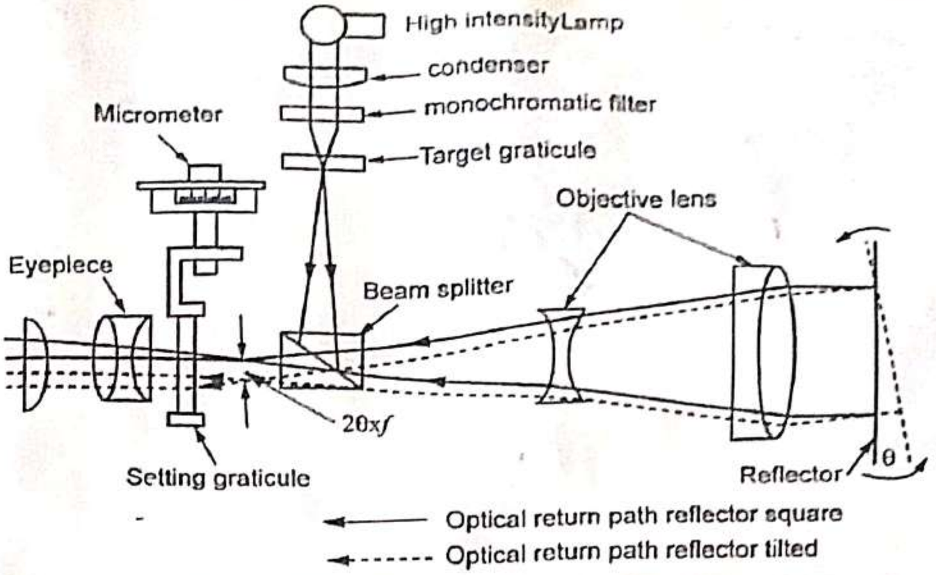


* If a light source is placed in the flows of a collimating lens, it is projected as a parallel beam of light.
* when this beam is made to strike a plane reflector and kept normal to optical axit.
* It is reflected back along its own path and it is brought to same focus.

$x = 2\theta \cdot f$

f = Focal length of the lens

θ = tilted angle of reflecting mirror



Line diagram of an graticule auto-collimator.

* A flat reflector is placed in front of the objective and exactly normal to the optical axis reflects the parallel rays of light back along their original paths.

* If the reflector is tilted through a small angle (θ), the reflected beam will be changed its path at twice an angle.

* It can also be brought to target graticule but linearly displaced from the actual target by amount 2θ xf.

ALIGNMENT TELESCOPE :-

* Alignment telescope is used for aligning of bores, surface and checks squareness, flatness, parallelism and levelling.

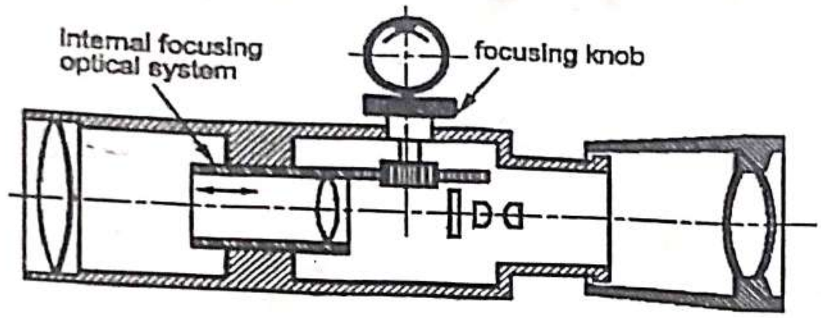


Figure 2.109 Optical system of an alignment telescope

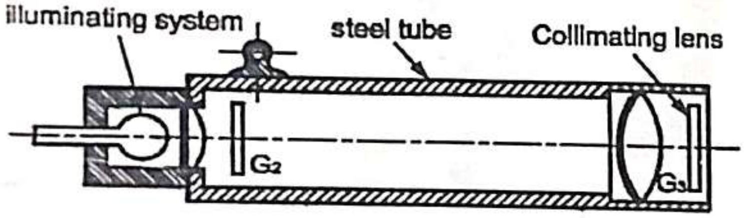


Figure 2.110 Optical system of autocollimator unit

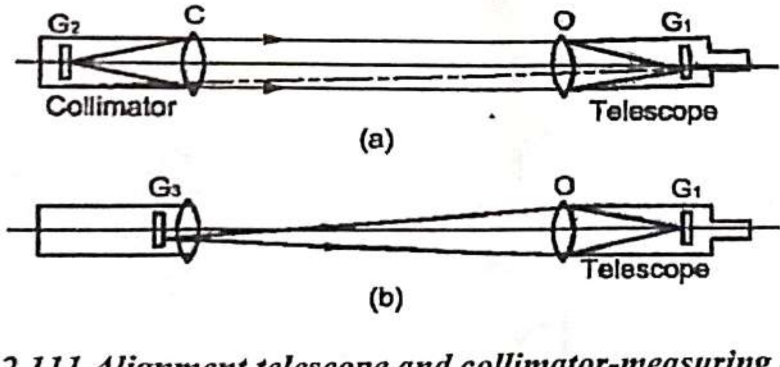


Figure 2.111 Alignment telescope and collimator-measuring angular displacement

* The telescope has an internal-focusing optical system, similar in principle to that of the surveyor's level built into a robust unit having a precisely ground external diameter.

* The focusing knob can be clearly seen in the optical system shown in figure 2.109.

* the collimating unit consists of another steel tube, ground to the same diameter as the telescope and containing an illuminating system, a graticule G2, a collimating lens and another graticule G3 shown in figure 2.110

* The use of telescope with the collimator is given in figure 2.111. If the telescope is aligned with the collimator and it is sighted on it with its focus adjusted to infinity target graticule G2 will appear in the field of view, since rays from this target will emerge parallel beams from the collimating lens.

Unit - 3

Tolerance Analysis

Tolerancing

* Tolerance is the permissible range of dimensional variation within the allowable limits for proper function. It is derived from the base measurement.

* Tolerance is also defined as the difference between the upper (maximum) and lower (minimum) limits.

Need of tolerance in measurements:-

No two manufactured objects are identical in all ways but they may be quite similar. some degree of variation will exist. So, it is impossible to make any product or process to an exact dimensions. Tolerances are mainly used on production drawings to control the parts.

Interchangeability :-

* A part which can be substituted for the component manufactured to the same shape and dimensions is known as an interchangeable part. (When one component assembled properly and satisfies the functionality aspect of the assembly)

Complete interchangeability :-

Under this interchangeability the parts which go into an assembly may be selected randomly from a large number of parts. In this type of interchangeability any component will mat with any other mating component without doing any minor alterations to mat them.

Selective Assembly

Now a days, people want not only the quality, precision and trouble free product but also they want attractive product. It is possible only by adopting an automatic gauging for selective assembly. In selective assembly, the parts are manufactured to rather wide tolerances.

For example, consider a bearing assembly

* Hole with $25^{-0.02}_{+0.02}$ mm and Shaft $25^{-0.02}_{+0.02}$ mm

* In this case, Clearance should be 0.14mm

* Randomly, if we take hole with $25^{-0.02}$ and shaft with $25^{-0.1}$, clearance will be 0.08mm.

Tolerance Representation:-

1. Direct limits or limits of size

2. By specifying basic size and tolerance symbols.

* Geometric tolerance

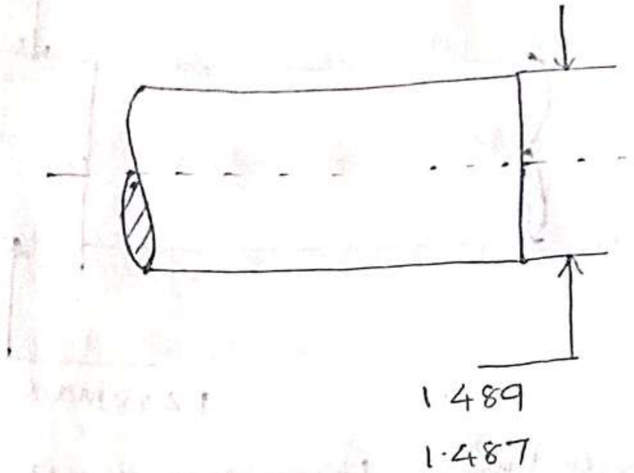
3. By specifying basic size and values of deviations

a) single limit tolerance

b) Unilateral tolerance.

c) Bilateral tolerance.

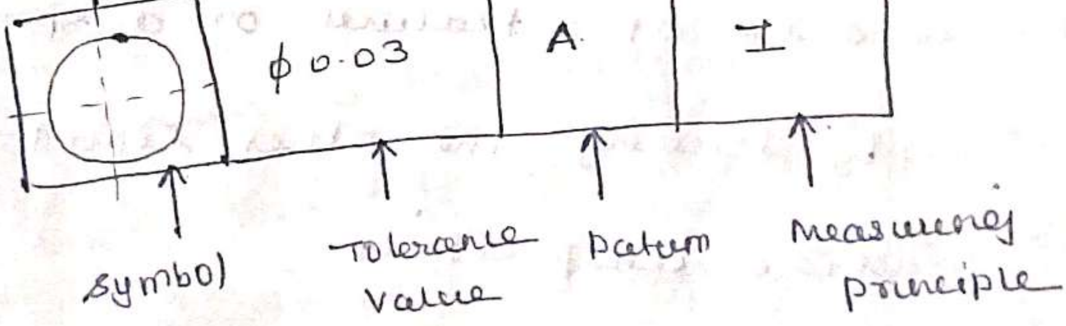
1. Direct limit



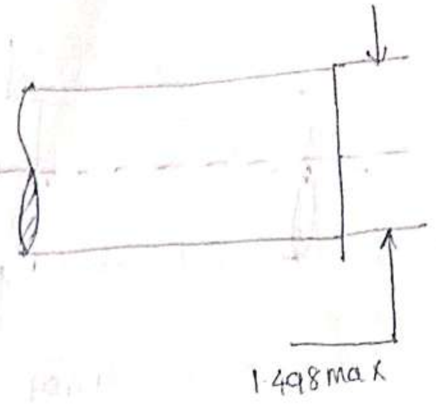
Tolerances can be applied directly to dimensional features using limit dimensioning. It is the American Society of Mechanical Engineers (ASME) preferred method such as maximum and minimum sizes specified as part of the dimension.

2. Geometric tolerances:-

Geometric tolerances specify the maximum variation that is allowed in form or position from true geometry. They are indicated by special symbols related to part surfaces.

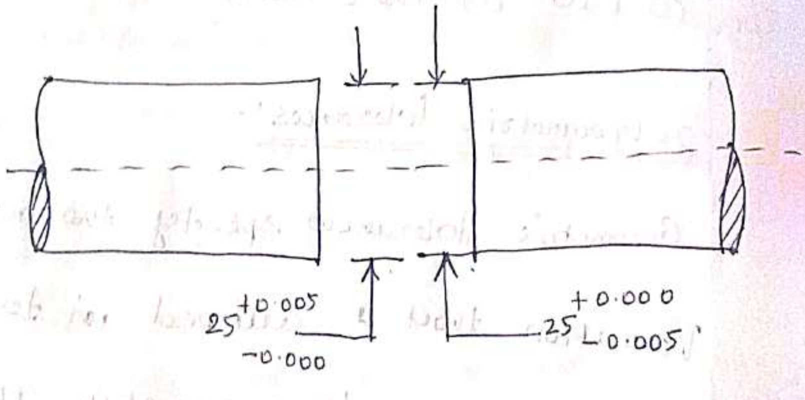


3. Single limit tolerance



A single limit tolerance only defines one limit dimension, normally either the maximum or minimum value for a features or dimension.

4. Unilateral tolerance :-



Unilateral tolerance is indicated by setting the limit either the maximum or minimum size of a features or a space just by leaving the other limit of size unspecified.

Terminology Used in Tolerance :-

Shaft :-

Shaft refers not only to the diameter of circular shaft but also to any external dimension on a component

Hole

Hole refers to any internal dimension on a component, not only the diameter of circular hole.

Actual size

Actual size is the dimension as measured actually on a part

Limit of size

Limit of size are the maximum and minimum permissible sizes of the part

Allowance :-

Allowance is the difference between the basic sizes of the mating parts.

Tolerance :-

Tolerance is the difference between the basic sizes of the mating parts. the basic between maximum limit and minimum limit

Fits :-

In spite of recent advances in manufacturing methods, it is not possible to produce a part exactly conforming to the requirements. It is because of that the parts are produced within a range of dimensions rather than exact dimension.

Types of fits :-

The degree of tightness or Looseness between mating parts is known as fits. The nature of fit is characterized by the presence and size of clearance or interference. There are three types of fits

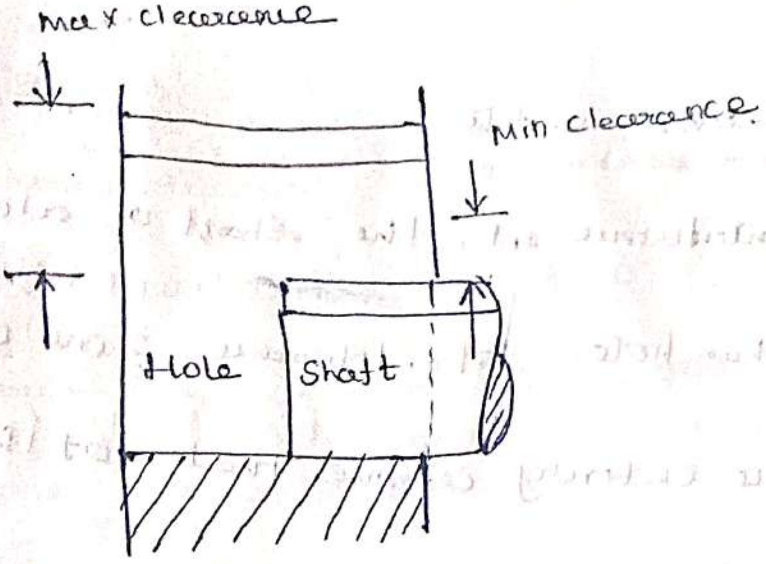
a) Clearance fits

b) interference fits

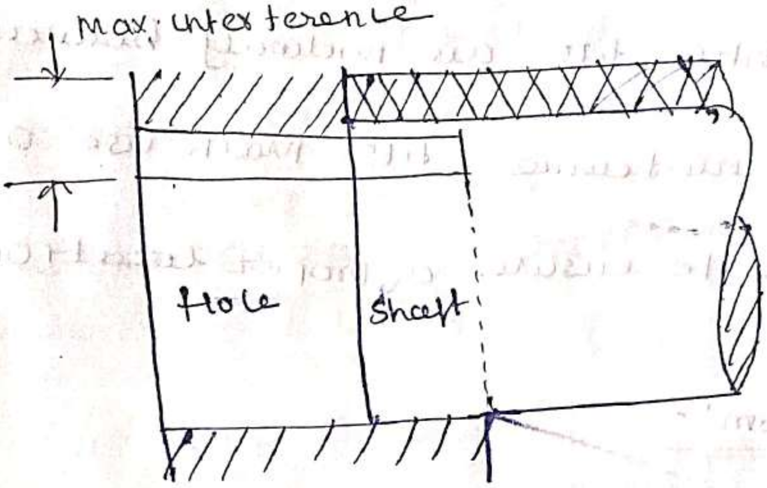
c) Transition fits.

Clearance fits :-

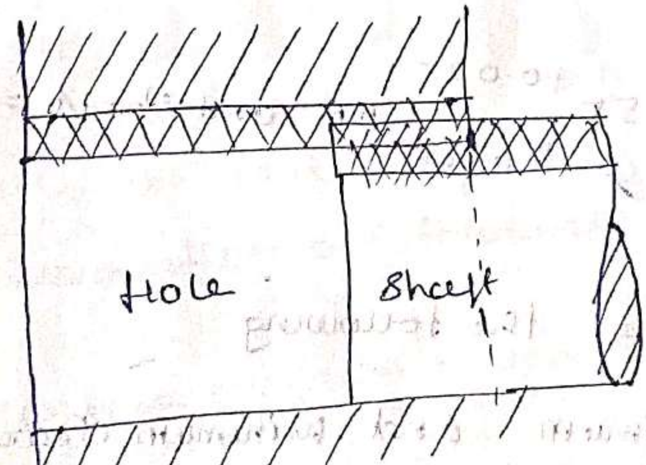
In clearance fits, the shaft is always smaller than the hole



a) clecercence fit.



b) Interference fit



c) Transition fit

(ii) Interference fits :-

In interference fit, the shaft is always larger than hole. The tolerance zone of the shaft is entirely above that of the hole

(iii) Transition fits :-

Transition fits are midway between clearance and interference fits. main use of these fits is to ensure a proper location of

Problem :-

Tolerances for a hole and shaft assembly having a nominal size of 55mm are as follows

$$\text{Hole} = 55^{+0.025}_{+0.000} \text{ mm and shaft} = 55^{+0.03}_{-0.06} \text{ mm}$$

Determine the following

a) maximum and minimum clearances

b) Tolerances on shaft and hole

c) Allowance

d) maximum metal Limit (MML) of hole and shaft

e) Type of fit.

Given data:-

Nominal diameter = 55mm

Upper limit of hole = 55 +0.025 = 55.025mm

Lower limit of hole = 55 +0.000 = 55 mm

Upper limit of shaft = 55 − 0.03 = 54.97mm

Lower limit of shaft = 55 − 0.06 = 54.94m

Solution

(a) Determination of clearances:-

maximum clearance = Upper limit of hole − Lower limit of shaft

= 55.025 − 54.94 = 0.085mm

minimum clearance = Lower limit of hole − Upper limit of shaft

= 55 − 54.97 = 0.03 mm

b) Determination of tolerance:-

Tolerance on hole = Upper limit of hole − Lower limit of hole

= 55.025 − 55 = 0.025 mm

Tolerance on shaft = Upper limit of shaft − Lower limit of shaft

= 54.97 − 54.94 = 0.03 mm

c) Determination of allowance

Allowance = Maximum metal Condition of hole

— maximum metal condition

= Lower limit of hole — Upper limit of shaft

= 55 − 54.97 = 0.03 mm

d) Determination of MMLs :-

MML of hole = Lower limit of hole = 55 mm

MML of Shaft = Upper limit of shaft = 54.97 mm

e) Since both maximum and minimum Clearances are positive, it can be concluded that the given pair form a clearance fit

According to the shape or purpose for which each is used

(i) Plug gauge

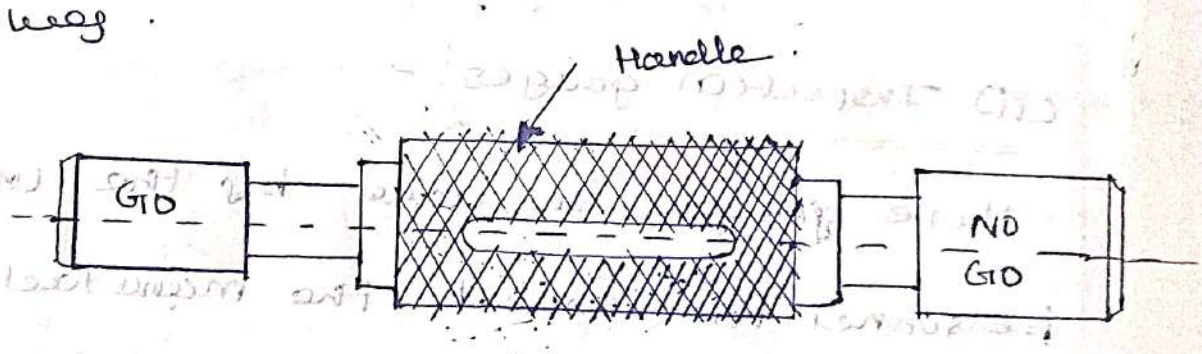
(ii) Ring gauge

Plug gauge :-

Plug gauges are used for checking holes of many different shapes and sizes. There are plug gauges for straight cylindrical holes, tapered, threaded square and splinded holes.

a) Double ended plug gauge :-

In this type, Go end and NoGo end are arranged on both the ends of the plug.



Ring gauge :-

- Ring gauge are mainly used for checking the external diameter of shafts. The hole of the ring gauge is accurately

Finished by grinding and lapping after hardening process. The periphery of the ring is knurled to give more grips while handling the gauges. there are two ring gauges such as GO ring gauge and NOGO ring gauge made seperately to check the shaft diameter

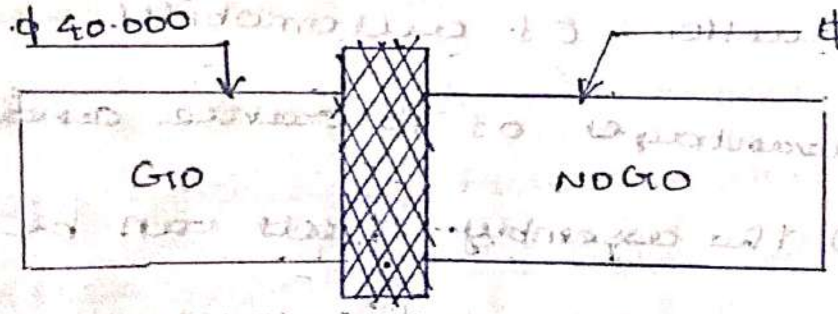
Problem :-

A Limit gauge is to be designed for checking a hole of $40^{+0.050}_{+0.000}$ mm. sketch the Go and NOGO gauge with dimension

Solution :-

Maximum diameter of hole = 40 + 0.050 = 40.050mm

Minimum diameter of hole = 40 + 0.000 = 40.000mm



GO gauge should check the maximum metal Condition and NOGO gauge should check the minimum metal condition. So the maximum metal condition will arise on the hole when it has the minimum diameter

Tolerance Analysis in manufacturing

Tolerance analysis is known as variational analysis to determine how much variation on dimensions and geometry can be allowed on a manufactured product's components. The analysis includes one or more techniques that depend on the type of the complexity of the product.

Need of tolerance in manufacturing:

Standardization of tolerance representation on engineering documents and formalization of tolerance analysis methods helped to accelerate with the emergence of mass production of automobiles.

Advantages of tolerance analysis:

(i) The assembly parts can be readily replaceable and interchangeable.

(ii) It reduces the manufacturing cost by reducing accuracy but maintaining functionality and design intent.

(iii) It reduces part to part variations and improves quality.

Process capability :-

Process capability is an index where design meets manufacturing. It measures how consistently a manufacturing process can produce parts within specification. Otherwise process capability defines to what extent the process is likely to satisfy the customer's wish.

The basic idea of process capability is for manufacturing process to :

(1) be centered over the Nominal desired by the design engineer.

(2) a spread narrower than the specification width.

Tolerance stackup :-

Tolerance stackup is the process of adding tolerances together before manufacturing to realize their cummulative effect on part production. Final results from a tolerance stack are associated to tolerancing standard, regulations and other limits to ensure the part design for producing high - quality components.

Tolerance charting:-

Tolerance chart is a graphical representation of a process plan and a manual procedure for controlling tolerance stack-up when machining a component that involves interdependent tolerance chains. It shows how a particular data item is compared to the maximum and minimum permissible value. It is also used to represent a manufacturing sequence and checking the tolerance stack-ups to meet design specifications.

Steps to create a tolerance chart

Step 1:-

First, the data table should be prepared. It must have minimum, maximum, range and average values (Total dimensions). We know that the range of dimension is the difference between maximum value and minimum value.

Step :- 2

Next, the tolerance chart is prepared in a graph sheet.

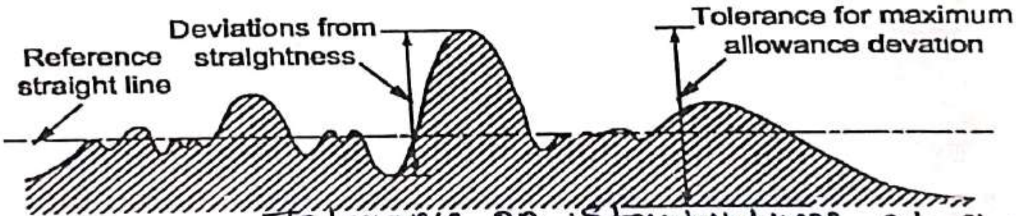
Unit - 4

FORM MEASUREMENT.

(Metrology of Surfaces)

STRAIGHTNESS MEASUREMENT :-

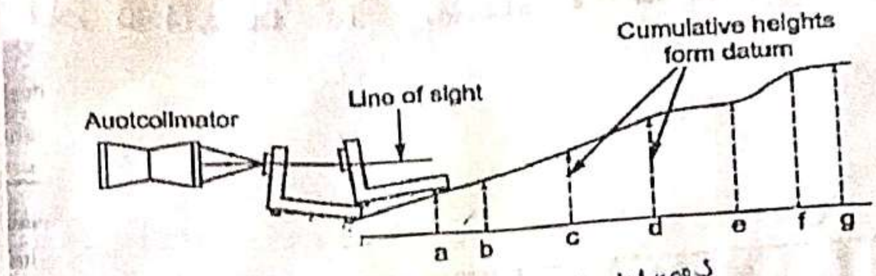
* A line is said to be straight over a given length if the variation of the distance from two planes perpendicular to each other and parallel to general direction of the line remaining within the specified tolerance limit.



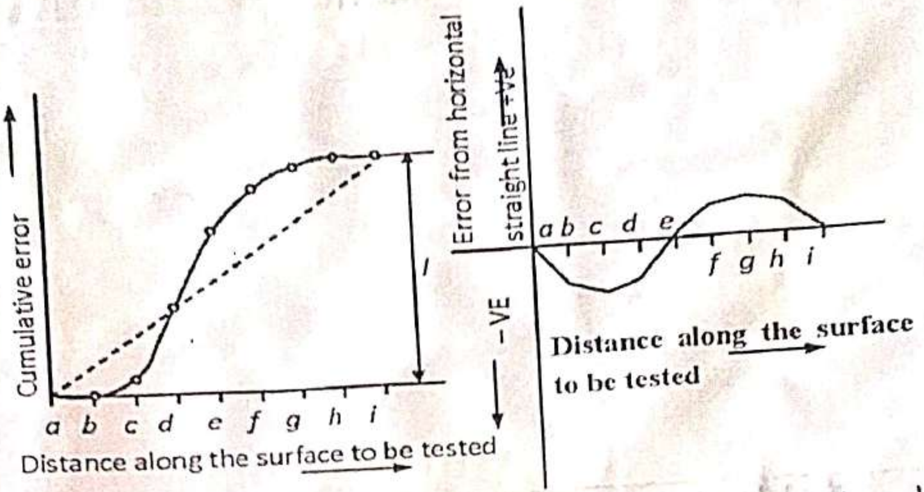
Tolerance on straightness of a line.

* A straight edge is a measuring tool which consists of a length of a steel of narrow a deep section in order to provide the resistance to bending in the plane of measurement without excessive weight.

Test for straightness by using sprit level and Autocollimator :-



Test for straightness



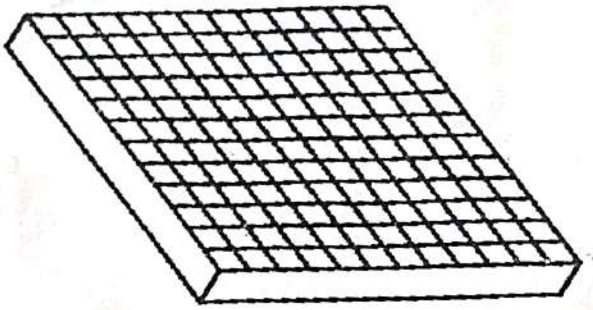
Cumulative error with respect to straight edge

* The straightness of any surface could be determined either these instruments or by measuring the relative angular positions of number of adjacent sections of the surface to be tested.

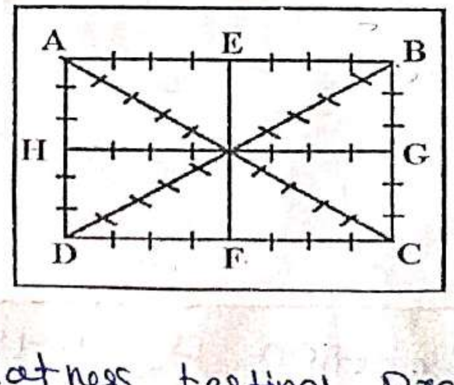
* First, a straight line is drawn on the surface and then it is divided into number of sections. The length of each section is equal to the length of sprit level base or the plane reflector's base in case of auto-collimator.

FLATNESS TESTING

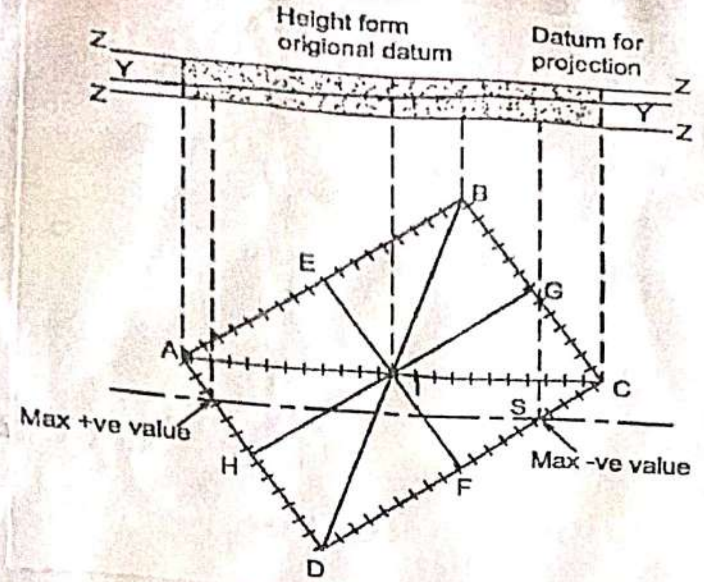
* Flatness testing is possible done by comparing the surface with an accurate surface. This method is suitable for sm



* Mathematically, flatness error of a surface states that the departure from flatness is the minimum separation of a pair of parallel planes which will contain all points on the surface



Flatness testing procedure.



(i) The straightness test is carried out and the readings are tabulated up to the cumulative error column

(ii) Ends of lines AB, AD and BD are corrected to zero and thus the height of the points A, B and D are zero

(iii) The height of point I is determined relatively to the arbitrary plane ABD = 000

IV Point C is now fixed relative to the arbitary plane and points B and D are set ~~are~~ at zero, all intermediate points on BC and DC can be corrected accordingly

V The positions of H and G, E and F are known. So, it is now possible to fit in lines HG and EF.

MEASUREMENT OF SCREW THREADS:

* Form measurement includes screw thread measurement, gear measurement, radius measurement, surface finish measurement straightness measurement, flatness and roundness measurement.

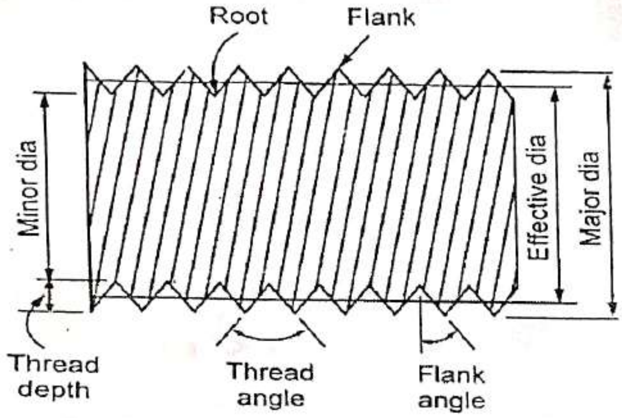


Figure 4.7 External thread

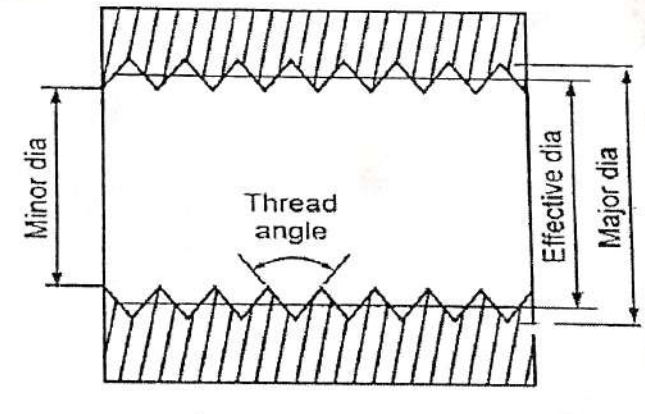


Figure 4.8 Internal thread

* Screw threads are used to transmit power and motion.
* It is also used to fasten two components with the help of nuts, bolts and studs.

SCREW THREAD TERMINOLOGY.

Lead = number starts × pitch

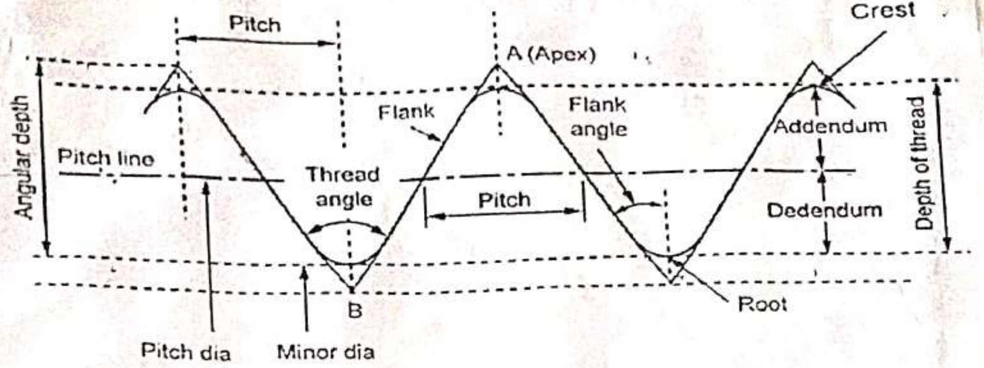


Figure 4.9 Screw thread terminology

1. Screw thread :-
   * It is a continuous helical groove of specified cross-section produced on the external or internal surface

2. Crest :-
   * It is top surface joining two sides of thread

3. Flank
   * It is the surface between crest and root

4. Root
   * The bottom of the groove between two flanks of the thread.

5. Pitch
   * The distance measured parallel to the axis form a point on a thread to the corresponding the same point on the next thread.

6. Helix angle:-

* The helix is the angle made by the helix of the thread at the pitch line with the axis

7. Flank angle:-

* Angle made by the flank of a thread with the perpendicular to the thread axis is called flank angle.

8. Depth of thread:-

* The distance between crest and root of the thread is called depth of thread

9. Included angle

* Angle included between flanks of a thread measured in an axial plane is called included angle

10 Major diameter:

* It is the diameter of an imaginary co-axial cylinder which would touch the crest of external or internal thread.

11. Minor diameter :-

* It is the diameter of an imaginary co-axial cylinder which would touch the roots of an external thread.

12 Addendum :-

* For external thread, it is the radial distance between major and pitch cylinders.

13. Dedendum :-

* For external thread, it is the radial distance between pitch and minor cylinder

* For internal thread. it is the radial distance between major and pitch cylinder.

MEASUREMENT OF GEARS :-

* Gear are Mechanical drives which transmit power through toothed wheel. In this gear drive, the driving wheel is in direct contact. with the driven wheel.

* The accuracy of gearing is very important factor when gear are manufactured. The transmission efficiency is almost 99% for gears.

TYPES OF GEARS

1. Spur gear :-

A cylindrical gear whose tooth traces is straight line. They are used for transmitting power between parallel shafts.

2. Spiral gear :-

* The tooth of the gear traces is in the form of curved lines.

3. Helical gears :-

* These gears are used to transmit the power between parallel shaft as well as non-parallel and non-intersecting shafts.

4. Bevel gears :-

* The tooth traces are straight-line generators of cone. The teeth are cut on the conical surface. It is used to connect the shaft at right angle.

5. Worm and Worm wheel :-

* It is used to connect the shaft whose axes are non - parallel and non-intersecting

6. Rack and pinion :-

* Rack gears are straight spur gear with infinite radius.

Gear Terminology.

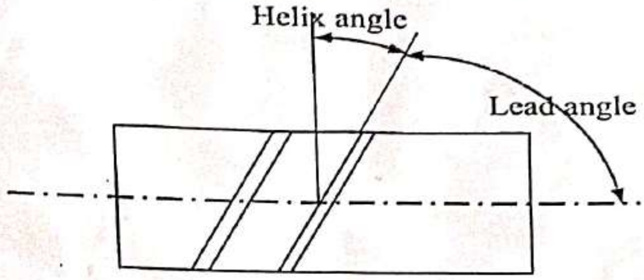


Figure 4.34 Helix angle

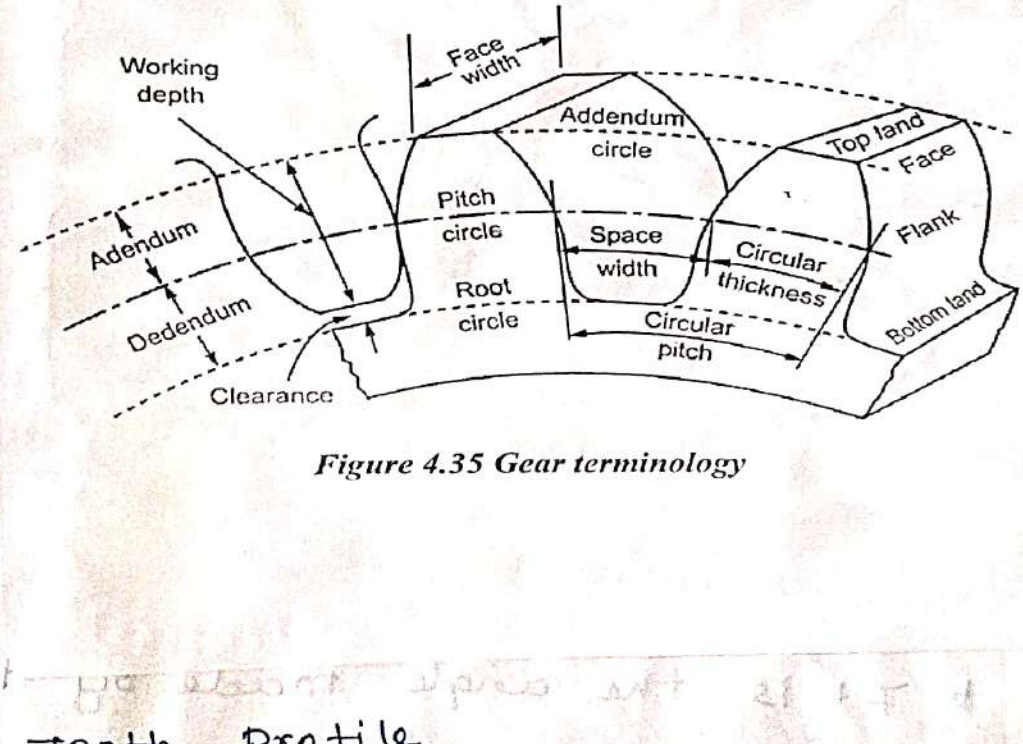


Figure 4.35 Gear terminology

1. Tooth profile

* It is the shape of any side of gear tooth in its cross section

2. Base circle :-

* It is the circle of gear from which the involute profile is derived.

3. pitch circle diameter

* It is the diameter of a circle which will produce the same motion as the toothed gear wheel

4. pitch circle

* It is the imaginary circle of gear that rolls without slipping over the circle of its mating gear.

5. Addendum circle:

* It is the circle coinciding with the crests (or) tops of teeth

6. Dedendum circle:

* This circle coincides with the roots (or) bottom of teeth called dedendum circle.

7. Pressure angle (α)

* It is the angle made by the line of action with the common tangent to the pitch circles of mating gears.

8. Module (m):-

* It is the ratio of pitch circle diameter to the total number of teeth.

9. Circular pitch

* It is the distance along the pitch circle between corresponding points of adjacent teeth

10 Diametral pitch (Pd):-

* It is the number of teeth per inch of the PCD

11. Addendum:-

* It is the radial distance between tip circle and pitch circle

12. Dedendum:-

* It is the radial distance between pitch circle and root circle

13 Clearance

* The distance covered by the tip of one gear with the root of mating gear.

14 Blank diameter:

* It is the diameter of the blank up to outer periphery

15 Face:

* It is the part of the tooth in the axial plane existing between tip circle and pitch circle.

16 Flank:

* It is the part of the tooth lying between pitch circle and root circle.

17 Helix angle:-

* It is the angle between tangent and helix angle

18 Top land

Top surface of a tooth is called top land

19 Lead angle:

* It is the angle between the tangent to the helix and plane perpendicular to the axis of cylinder.

20 Back lash :-

* It is the difference between the tooth thickness and the space into which it meshes. if we assume the tooth thickness as t_1 and width 't_2'.

SURFACE FINISH MEASUREMENT :-

* components are produced by various methods of manufacturing process. So, it is not possible to produce perfectly smooth surface and some irregularities are formed

* The factors which are affecting surface roughness are as follows

1. work piece material
2. Vibration
3. machine type
4. tool and fixture

The geometrical irregularities can be classified into the following categories

1. First order
2. second order
3. Third order
4. fourth order.

Elements of Surface Texture:

1. Profile:

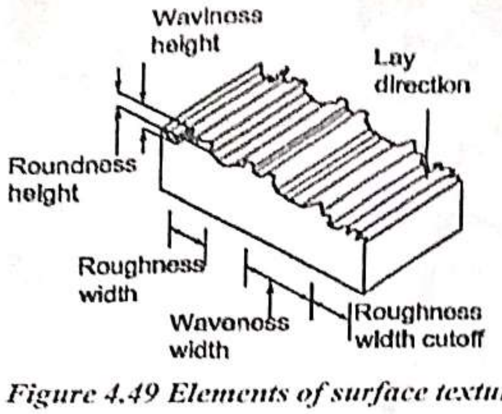


Figure 4.49 Elements of surface texture

* It is the contour of any section through a surface

2. Lay:

* It is the direction of the predominate surface pattern.

3. Flaws:-

* It is the surface irregularities or imperfection which occurs at frequent intervals.

4. Actual surface:

* It is the surface of a part which is actually obtained

5. Roughness:

* It is finely spaced irregularities. It is also called primary texture.

6. Sampling lengths :-

* It is the length of profile necessary for the evaluation of the irregularities.

7. Waviness :-

* It is the surface irregularities which are of greater spacing than roughness.

8. Roughness height :-

* It is rated as the arithmetical average deviation

9. Roughness width

* It is the distance parallel to the normal surface between successive peaks

10 Mean line of profile

* A line divides the effective profile such that within the sampling length is called mean line or profile

11 Centre line of profile

* A line divides the effectiveness profile such that the areas embraced by the profile above and below the line are equal.

ROUNDNESS MEASUREMENTS:

* Roundness is defined as a condition of a surface of revolution. All points of the surface are intersected by any plane perpendicular to a common axis in case of cylinder and core.

Devices used for measurement of Roundness:

1. Diametral gauge
2. Circumferential centering gauge ⇒ a shaft is confined in a ring gauge and rotated against a set indicator probe
3. Rotating on center
4. V - Block.
5. Three - point probe
6. Accurate Spindle.

1. Diametral method :-

* The measuring plungers are located 180° apart and the diameter is measured at several places. This method is suitable only when the

specimen is elliptical or it has an even number of lobes.

2. Circumferential confining gauge:-

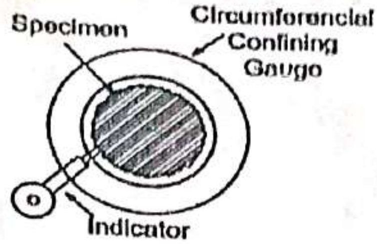


Figure 4.61 Circumferential confining gauge

* Figure shows the principle of the method. It is useful for the inspection of roundness in large production.
* This technique does not allow for the measurement of other related geometric characteristics such as concentricity, flatness of shoulders etc.

3. Rotating on centers:-

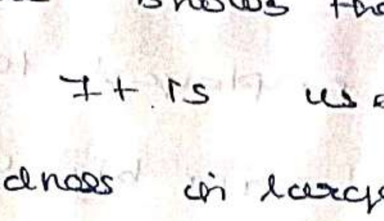


Figure 4.62 Inspecting shaft for roughness

* Figure shows shaft is inspected for the roundness while mounted on center. In this case, the reliability is dependent on many factor such as angle of centers, alignment of centres.

4. V. Block.

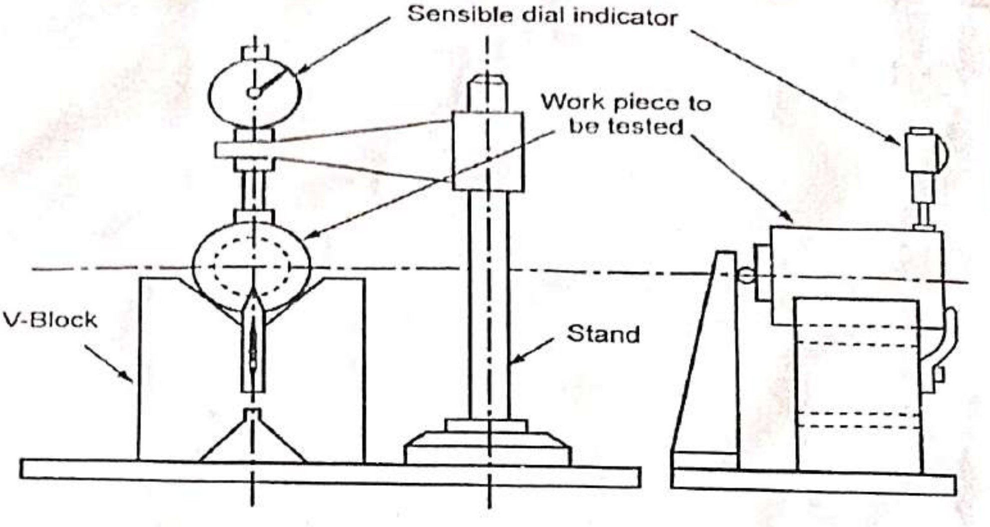


Figure 4.63 V-block to check lobes on workpiece

* The set up employed for assessing the circularity error by using a V-block is shown in figure.

* The V-block is placed on a surface plate and the work to be checked is placed upon it.

Limitations:

* The instrument position should be in the same vertical plane as the point of contact of the part is with V-block

* A leaf spring should always be kept below the indicator plunger and the surface of the part.

5. Three point probe.

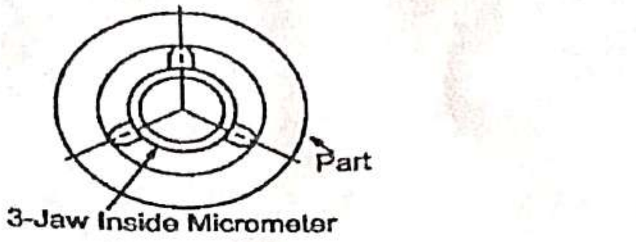


Figure 4.65 Three point probe

* Figure shows three probe with 120^0 spacing is very usefeel for determining the effective size

* They perform similar to a 60^0 V-block.

* A 60^0 V-block will show no error for 5 but 7 lobes magnify the error.

6. Accurate Spindle :-

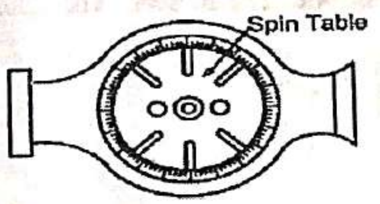


Figure 4.66 Accurate spindle

* Accurate spindle method is a method to provide a definite value for the calibration of roundness when compared to other method.

* It is more suitable for ball bearing, roller bearing etc.

Unit-5

Advances in Metrology

Precision Instruments Based on laser:-

* Laser instruments are devices to produce powerful monochromatic collimated beam of light in which waves are coherent.

* The development of laser gives the production of clear coherent light. The biggest advantage of this coherent light is that the whole energy appears to be emanating from a very small point.

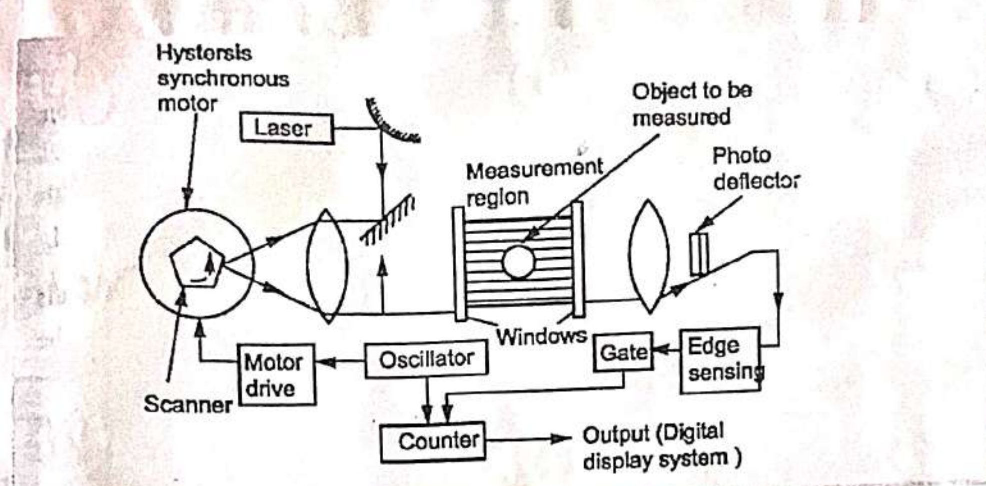
Laser metrology:-

* A laser beam projected directly onto a position detector is a method of alignment used in a number of commercially available systems.

* Laser diodes and semiconductor laser have more advantages at low cost. Laser instruments are very much suitable in surface inspection and dimensional measurements.

Laser Telemetric System :-

Laser telemetric system is a non contact gauge which measures a collimated laser beam. It measures at the rate of 150 scans per second.



* The laser telemetric system consists of mainly three co

1. Transmitter
2. Receiver
3. Processor electronics

* The transmitter produces a collimated parallel scanning laser beam moving at a high constant linear speed. the beam appears at red lens after scanning.

* The receiver collects the laser beam and photo electrically senses the laser light transmitted through the object being measured.

The transmitter has the following components.

* Low power helium neon gas laser
* Synchronous motor
* Collimating lens
* Reflector prism
* Synchronous pulse photo detector
* Replaceable window

Working :-

* The object to be measured is placed in the measurement region High constant and linear speed laser beam form the transmitter which is focused on the object to the measured. The receiver module collects and it senses the laser light transmitted past the object to be measured

* After sensing the processor electronics take the received signals and converts them into a convenient form and then display the dimensions being gauged.

Advantages:-

* It is possible to detect changes in dimensions when components are moving

* It is possible to detect changes in dimensions when the product is in continuous processes.

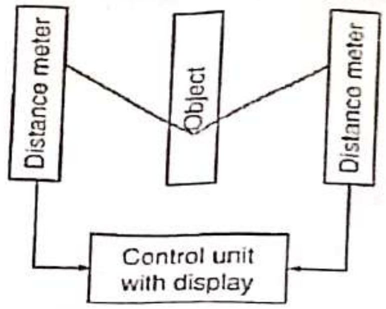
* There is no need to wait for taking measurements when the product is in hot conditions

* It can be applied on production machines and controlled there with closed feed back loops.

Laser and Led Based Distance measuring Instruments:-

* It can measure distance from 1m to 2m with accuracy of the order of 0.1 to 1%. of the measuring range.

* 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.



Distance meter

* When the light emitted by laser or LED hits an objects, it scatters and some of this scattered light is seen by a position sensitive detector

* The angle at which the light enters the detector will change the distance between measuring head and object. The change in angle of deviation is measured and calibrated in term of distance.

Advantages :-

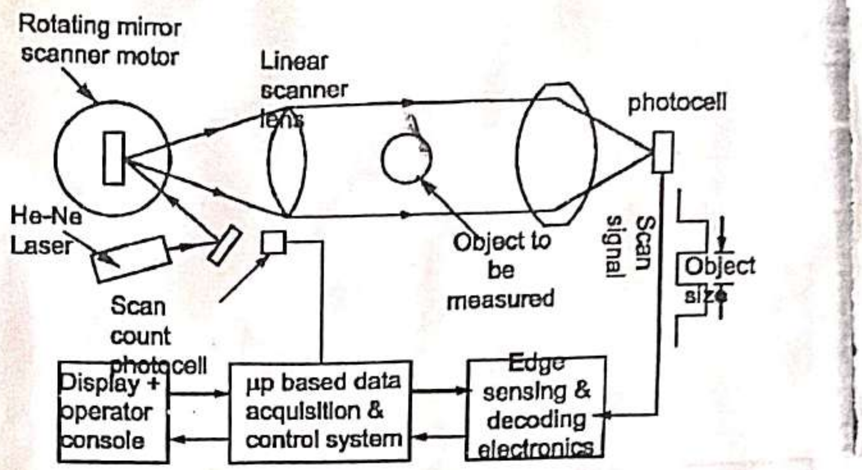
* These types of instruments are very reliable because there is no moving part.

* Instrument response time is in milliseconds

* The output is provided as 0 – 20mA.

SCANNING LASER GAUGE :-

* The scanning laser gauge is used for dimensional measurements. It consists of transmitter, receiver and processor electronics.



scanning laser gauges

* A scanning laser light is made to pass through a linear scanner lens as a parallel beam. The object is placed in a parallel beam.

* The signals from the light entering the photocell are processed by a microprocessor to provide the display of the dimension represented by the time difference between shadow edges.

Advantages :-

* Accuracy of ± 0.25 µm for 10-50mm diameter objects.

* It is used for objects of 0.05 mm to 400 mm diameter.

PHOTODIODE ARAAY IMAGING:-

* This method is also used for dimensional measurements. In this method, a shadow of stationary part is projected on a solid state diode array image sensor. It consists of four parts namely.

1. Laser source
2. Imaging optics
3. photodiode array
4. signal processor and display unit

Advantages:-

1. It is used for large parts
2. The accuracy of measurement is as high as ± 0.05 µm.

DIFFRACTION PATTERN TECHNIQUE:-

* This method is also used in dimensional measurements. In this method, a parallel coherent laser beam is diffracted by a small part and the resultant pattern is focused by a lens on a linear diode array.

Advantages:-

* It is used to measure small gaps and small diameter parts.
* measurement accuracy is more for smaller parts

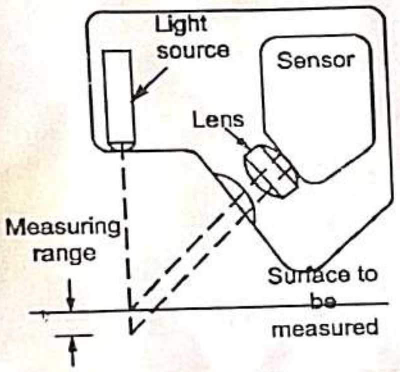
Disadvantages:-

* It is not suitable for large diameter.

LASER TRIANGULATION SENSORS:-

* This basic principle of laser triangulation sensor for dimensional measurement is shown in figure.

* In this sensor, a finely focused laser spot of light is directed at the part surface and this light comes from the laser source.



* After focusing the light on the surface to be measured, the light beam is converted into digital solid state beam by the use of lens in the sensor.

* The measuring range is very small and the stand off distance is calculated and fixed carefully. The image spot from the surface is directly related to the stand - off distance from the sensor to the object surface.

Advantages :-

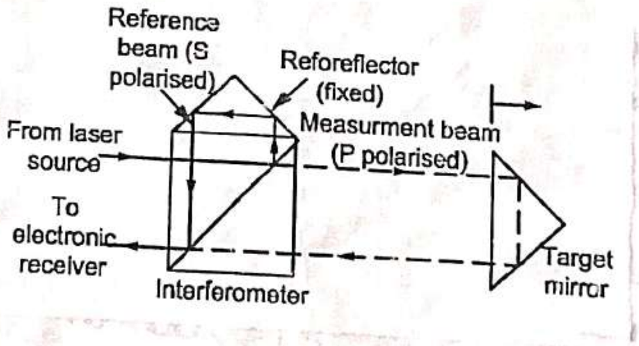
* Quick measurement of deviations is due to change in surface.

* It can perform automatic calculation on sheet metal stampings

* By using the two sensors, it is possible to measure the inside diameter of bores.

TWO FREQUENCY LASER INTERFEROMETER :-

* The two frequency laser head provides one frequency (say f_1) with a "P" polarization (measuring beam) and another frequency (say f_2) with "S" polarization (reference beam).



* After splitting the beams, the measuring beam is directed through the interferometer to reflect off a target mirror or retro reflector attached to the object to be measured.

* Another reference beam is reflected from fixed retro reflector. The measurement beam is combined with the reference beam when it is returned from target mirror and it is directed to the electronic receiver.

Advantages

* It is ideally suited for measuring linear positioning straightness in two planes.
* It is highly sensitivity.
* It is free from noise disturbance.

GAUGING WIDE DIAMETER FROM THE DIFFRACTION PATTERN FORMED IN A LASER.

* Figure shows a method of measuring the diameter of thin wire using the the interference fringes thereby resulting the diffraction of light by the wire in the laser beam.

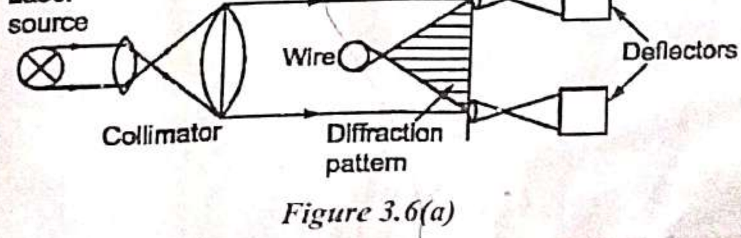
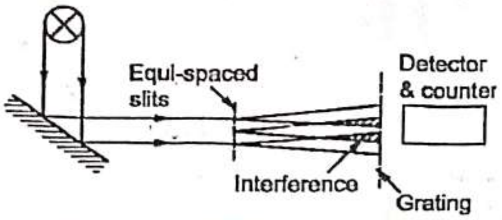


Figure 3.6(a)

* The system uses the change in fringes formed by diffraction with wire diameter which causes a variation in the output from the photo detector.



* The fringe movement is determined by a detector on the other side of a short length of grating.

* The number of slits in the first plane is governed by the length over which the measurement is required.

* Using He-Ne laser at 0.63 μm, a fringe spacing of 1μm will be obtained at 1.4 μm from the slits

Advantages

1. Accurate measurements are possible relatively for short distances.

2. Wire diameters from 0.005 to 0.2mm can be measured.

PRINCIPLE OF LASER:-

* The principle involved in laser is when the photon emitted during the stimulated emission has the same energy, phase and frequency as the incident 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.

USE OF LASER IN INTERFEROMETRY:-

* The laser in interferometry is to find the accurate measurement of length. It reduces the most time taken and skill required similar to other method used for finding the length.

* In modified laser designs, a single frequency is selected from the coherent beam and used for interferometric measurement.

INTERFEROMETRY :-

* To understand about interferometry, it is very important to know the nature of light. The light is considered as wave motion propagated in the ether.

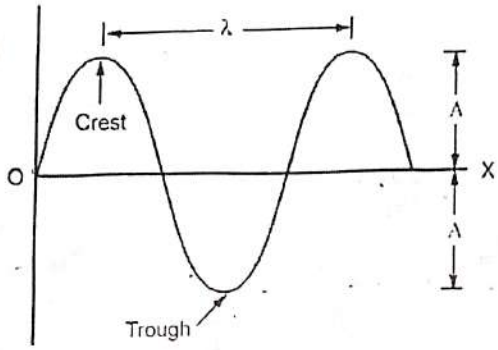


Figure 3.6(c)

* The high point of wave is called crest and the low point is called through. The distance between two through or two crests is called wavelength λ.

* This monochromatic light is used for measuring flatness and determining the length of slip gauges. It is the basic principle of interferometry.

LASER INTERFEROMETRY :

The laser interferometry involves the following components

1. Two Frequency laser source
2. optical elements.
3. laser heads measurement receiver
4. Measurement display.

Two frequency laser source :-

* The two frequency laser sources generally become He-Ne type which generates stable coherent light beams of two frequencies.
* Laser slightly oscillate at two frequencies by a cylindrical permanent magnet around the cavity.

Optical Elements :-

(i) Beam splitter
(ii) Beam bender
(iii) Retro reflector.

(i) Beam splitter :-

* It is used to divide the laser beam into separate beams along different axes.
* It is possible to adjust the splitted lasers output intensity by having a choice of beam splitter reflectively.

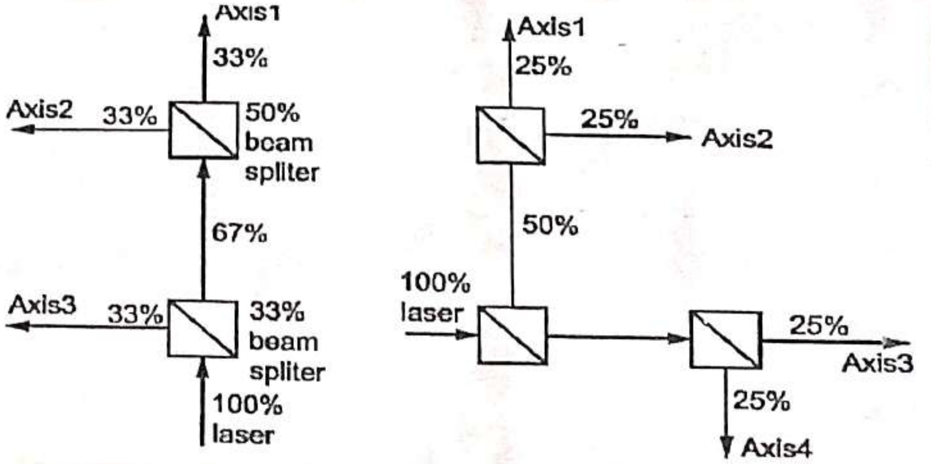
(ii) Beam benders :-

* It is used to deflect the light beam around corners on it path from the laser to each axis.

* the beam benders are just flat mirrors but they have absolutely flat and high reflectivity.

(iii) Retro reflectors

* They are plane mirrors, root prisms or cube corners. the cube corners are three mutually perpendicular plane mirrors and the reflected beam is always parallel to the incident beam in these devices.



* In case of Ac laser interferometer measurements, two retro reflectors are used.

a) Laser head's measurement receiver :-

* It is used to detect the part of the returning beam as $f_1 - f_2$ and a Doppler shifted frequency component δf.

b) Measurement display :-

* The measurement display has a microcomputer to compute and display results.

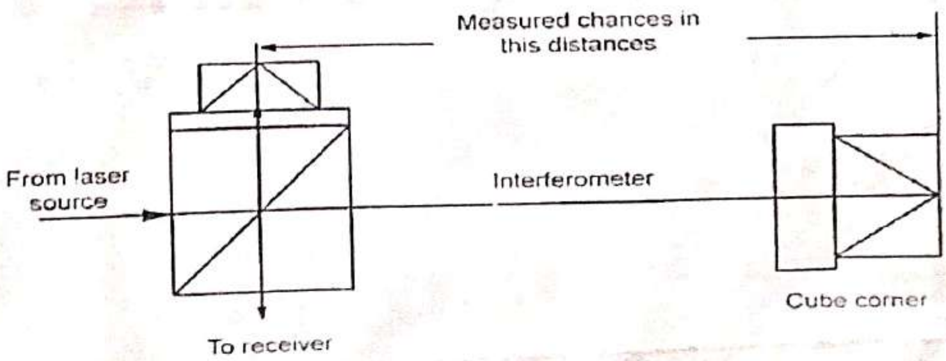
* The signals from the reference receiver and measurement receiver located in the laser head are counted in two seperate pulse counters and subtracted.

TYPES OF AC LASER INTERFEROMETER (ACLI)

The various version of ACLI is given below

1. standard interferometer
2. Single beam interferometer

1. Standard interferometer

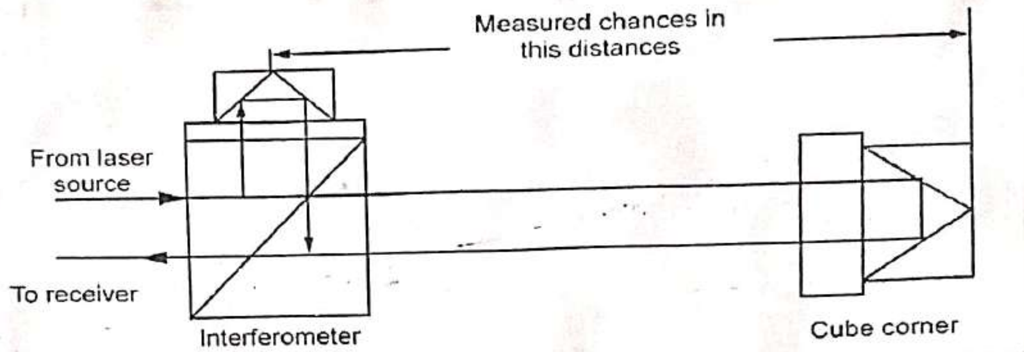


* In this interferometer, the displacement is measured between the interferometer and Cube corner.

* The measurement retro reflector for this interferometer is a cube corner

* It is least expensive and it can be used wherever it is possible.

2. Single beam interferometer :-



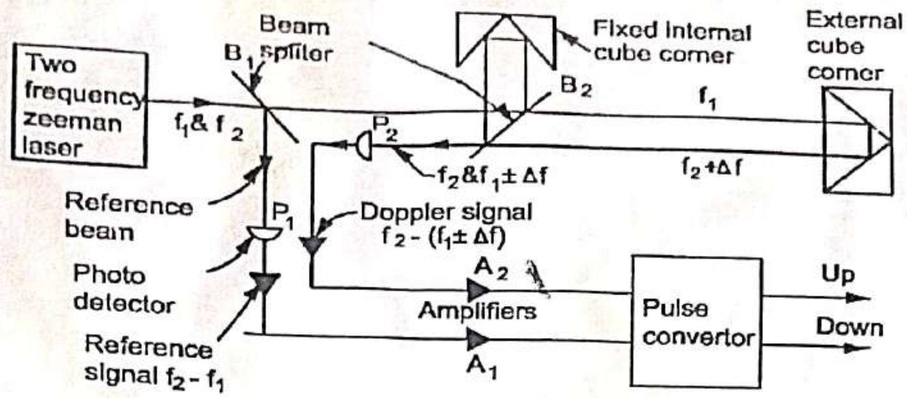
* It is operated similar to a standard interferometer. It has the outgoing and returning beam super imposed on each other and it gives the apperance of only one beam traveling between the interferometer and retro reflector.

LASER INTERFEROMETER :-

* Laser interferometer uses Ac laser as the light source and thus, it enable the measurements to be made over longer distance.

* Laser represents a sources of intensively monochromatic optical energy

which can be collimated into a directional beam.



* The two frequencies Zeeman laser generates light of two slightly different frequencies with opposite circular polarizations.

* The beams are splitted by the beam splitter B_1. In this interferometer, one part travels towards B_2 and from B_2 to external cube corners where the displacement is measured.

* Beams splitter B_2 optically separates the frequencies f_1 which is sent to a fixed reflector and then it rejoins f_1 at the beam splitter B_2 to produce alternate light and dark interference.

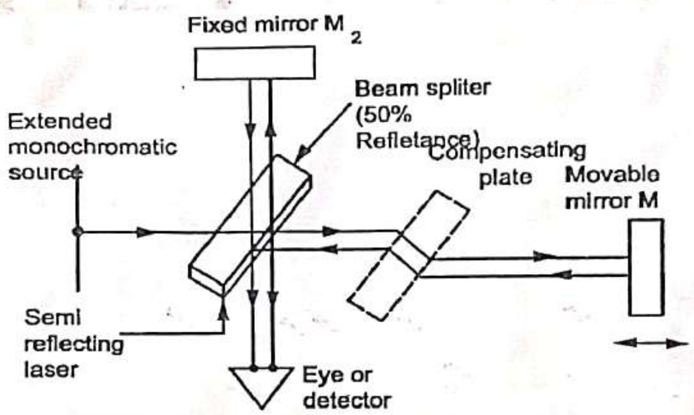
* Now, the external cube corner moves which will produce a change in f_1 (i.e., Δf_1) in the returning beam frequency.

OTHER TYPES INTERFEROMETERS:

Michelson interferometer:-

* It consists of a monochromatic light source, beam splitter and two mirrors.

* The basic principle involved in michelson interferometer constructive and destructive interference when one mirror remains fixed and the other is moving.



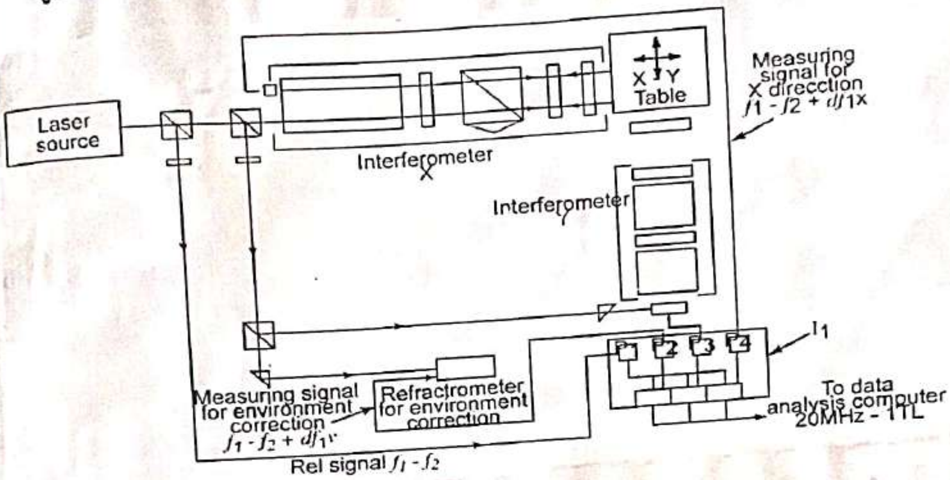
* A monochromatic light from an extended source falls on a beam splitter which splits the rays into two equal rays of same intensity at right angle to each other

* In two rays, one ray is transmitted to mirror M_1 and other one is reflected through a beam splitter to mirror M_2.

* The ray are reflected back from both mirrors M_1 and M_2 reunited at the semi-reflecting surface.

Dual frenquency Laser interferometer :-

* It is used to measure the displacement, high precision measurement of length, angle, speed and refractive indices as well as derived static and dynamic quantities.



* The laser source generates two 0 frequencies f_1 and f_2. The reference signal $f_1 - f_2$ is detected in the photo detector P2.

* The measuring signals $f_1 - f_2 \pm \Delta f_1(x)$ for x direction measurement and measuring signal of $f_1 - f_2 \pm \Delta f_1(Y)$ are sensed by photo dectectors P3 and P4.

* The environment correction is made by the photo detector P_1.

* In the dual frequency laser interferome there are two interferometer used for x and y directions.

Twyman - Green Interferometer :-

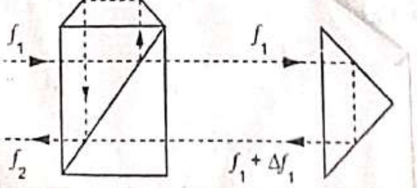
* The Twyman - Green Interferometer is used as a polarizing interferometer with variable amplitude balancing between sample and reference waves

* For an exact measurement of the test surface, the instrument error can be determined by an absolute measurement.

LASER INTERFEROMETER APPLICATIONS :-

1. Linear measurement :-

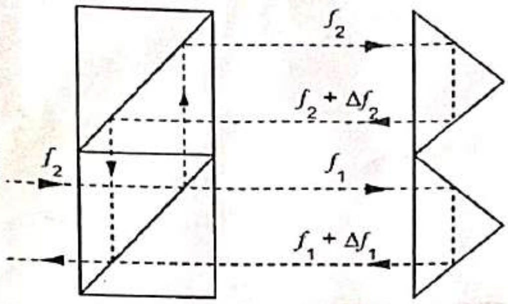
* In linear measurement, the beam exiting from the laser head is splitted up at the surface of polarizing beam splitters shown in figure.



* In splitted two frequencies, one frequency is reflected to the reference cube corner and the other beam is transmitted to the measuring retro. reflector.

2. Angular measurement

* In angular measurement, a 45° mirror is mounted in place of the reference retro reflector so that the two frequencies f_1 and f_2 are sent out parallel shown in figure.



* The angular displacement of the retro reflector mount causes a differential Doppler shift in the returned frequencies which is not done by axial displacement.

* It is positive to measure angle up to 10±10° with a resolution of 0.1 second with laser interferometer. The change in the path difference of the reflected beam represents the side of the triangle opposite to the angle being measured.

LASER EQUIPMENT FOR STRAIGHTNESS:-

* For checking the straightness of any surface, autocollimator and alignment telescope can be used.

MACHINE TOOL METROLOGY:-

* Rigidity and stiffness of machine tool and its components
* alignment of various components in relation to one another.
* Quality and accuracy of the control devices and the driving mechanism.

VARIOUS GEOMETRICAL CHECKS ON MACHINE TOOL:

* Straightness
* Flatness
* Parallelism, equidistance and coincidence
* Squareness of straight line and plane
* Rotations
* Movement of all the working components.

MACHINE TOOLS TESTS:-

* Test for leveling the installation of machine tool in horizontal and vertical planes.
* Test for perpendicularity of guide ways to other guide ways.

* Test for flatness of machine bed, straightness and parallelism of bed ways on bearing surface.
* Test for axis of movement of various members such as spindle, table and cross slides.
* Test for parallelism of spindle axis to guide ways or bearing surfaces.

ALIGNMENT TESTS ON LATHE.

* Levelling the machine
* True running of locating cylinder of main spindle.
* True running of headstock center
* Parallelism of main spindle to saddle movement
* True running of taper socket in the main spindle.
* Parallelism of tailstock guide ways with the movement of carriage.
* Parallelism of tailstock sleeve taper socket to saddle movement.
* Pitch accuracy of lead screw
* Alignment of lead screw bearings with respect to each other.

ALIGNMENT TETS ON MILLING MACHINE

* Cutter Spindle axial slip or float
* Eccentricity of external diameter
* True running of internal taper
* Surface parallel with longitudinal movement.
* Traverse movement parallel with spindle axis
* Tests on column
* Over arm parallel with the spindle

ALIGNMENT TESTS ON PILLAR TYPE DRILLING MACHINE:-

* Flatness of clamping surface of base
* Flatness of clamping surface of table
* perpendicularity of drill head guide to the base plate
* perpendicularity of spindle sleeve with base plate
* parallelism of the spindle axis with its vertical movement.

COORDINATE MEASURING MACHINE (CMM)

* Measuring machines are used for the measurement of length over the outer surface of a length bar or any other long member.

* Co-ordinate Measuring Machine (CMM) is used for contact inspection on parts. When used for computer-integrated manufacturing it is used.

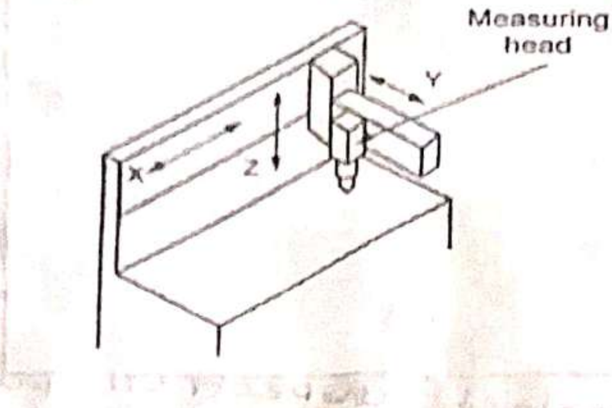
Types of measuring machines;

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

Types of CMM :-

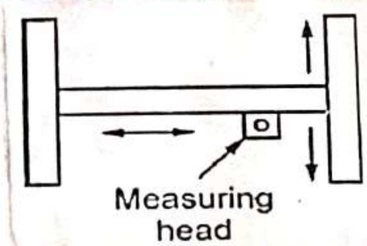
1. Cantilever type
2. Bridge type
3. Horizontal boring type
4. Vertical boring type.

1. cantilever type :-



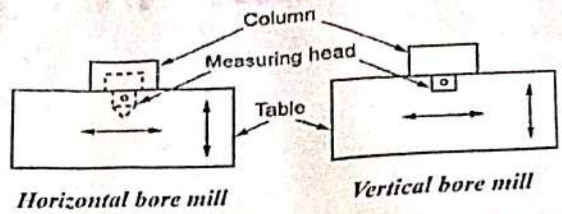
* It is easy to load and unload but it is most sensitive to mechanical error because of sag or deflection in Y axis beam

2. Bridge type.



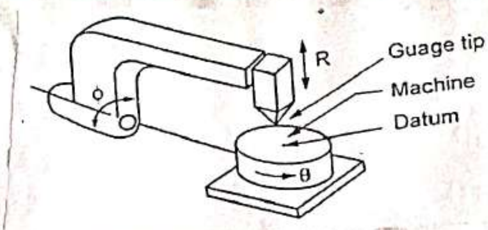
* It is difficult to load but it is less sensitive to mechanical errors. A floating bridge type machine is also available in which the complete bridge can slide in Y — direction

3. Horizontal boring mill type :-



* It is best suited for large heavy work pieces.

4. Vertical boring mill type :-



* Vertical boring mill is highly accurate but it is slower to operate.

* When the distance is measured between two holes using cmm, the work piece should be clamped to the worktable and it is aligned for three measuring slides X, Y and Z.

* The probe is than moved to successive holes the read out represents the co-ordinate part print hole location with respect to the datum hole.

Advantages of CMM

* The main advantage of co-ordinate measuring machine is quicker inspection and accurate measurements,

FEATURES OF CMM :-

* In faster machines with high accuracies, the stiffness to weight ratio has to be high in order to reduce dynamic forces

* All the moving members, the bridge structure Z- axis carriage and Z-column are made of hollow box construction

* All machine are provided with their own computers and CMM can measure three - dimensional object from variable datum.

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 for computer controlled CMMs can be subdivided into four basic typed

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

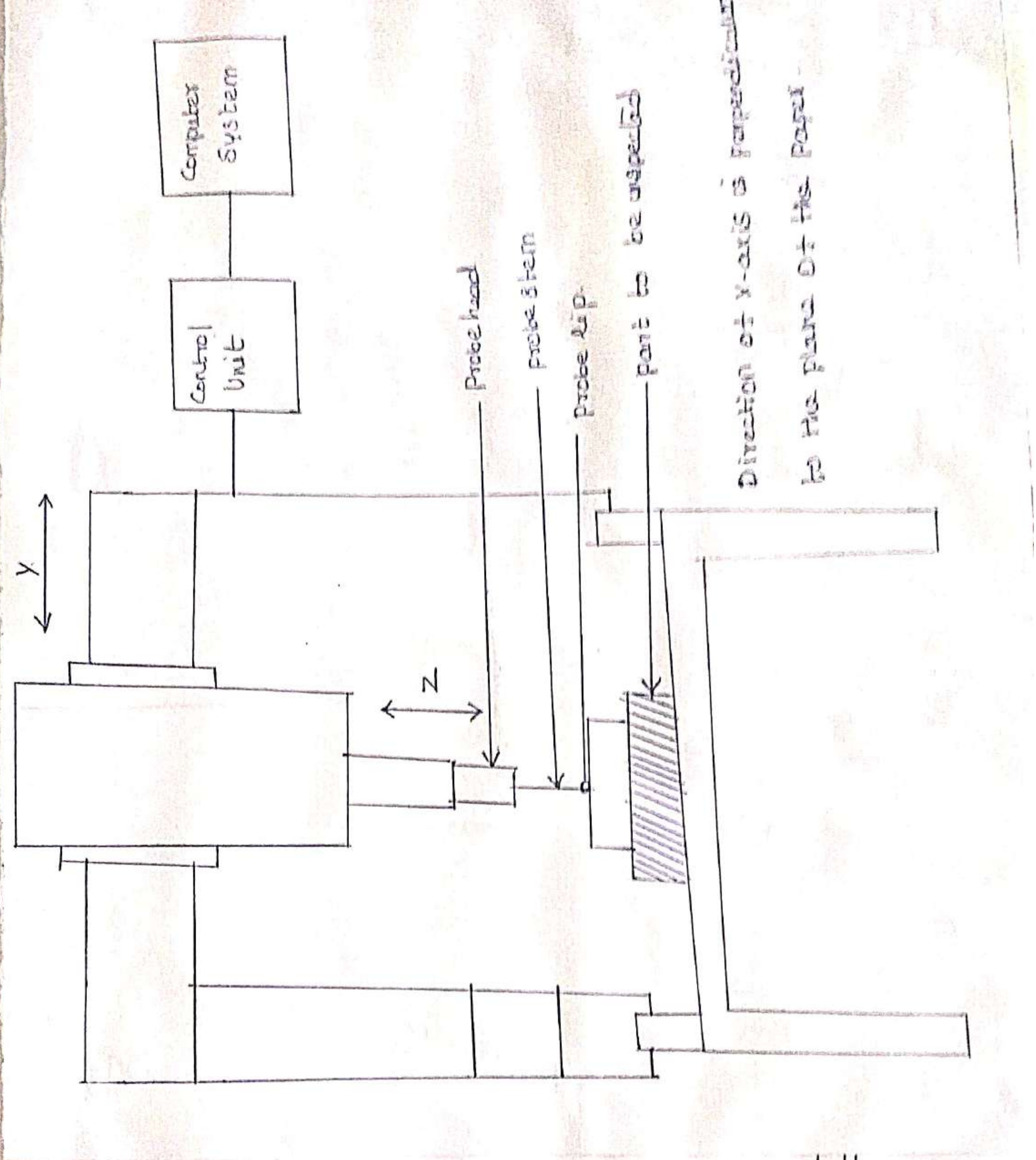
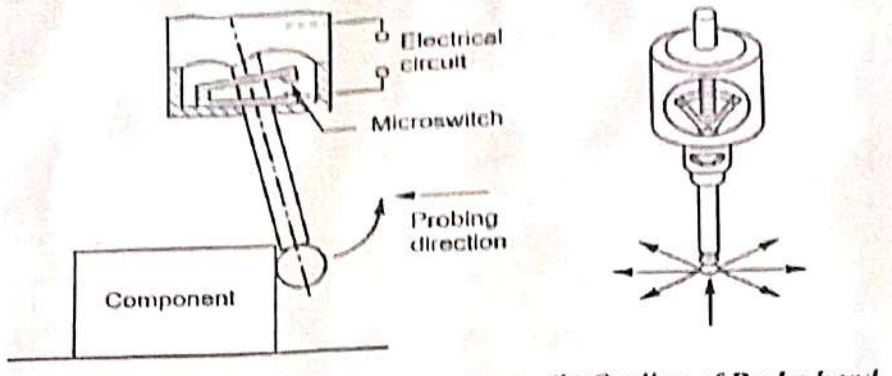


Figure 3.29 Mechanical system of computer controlled CMMs

* The probe used in all these machines may be trigger type or measuring type. It is connected to the spindle in z-direction.

(i) Trigger type probe system :

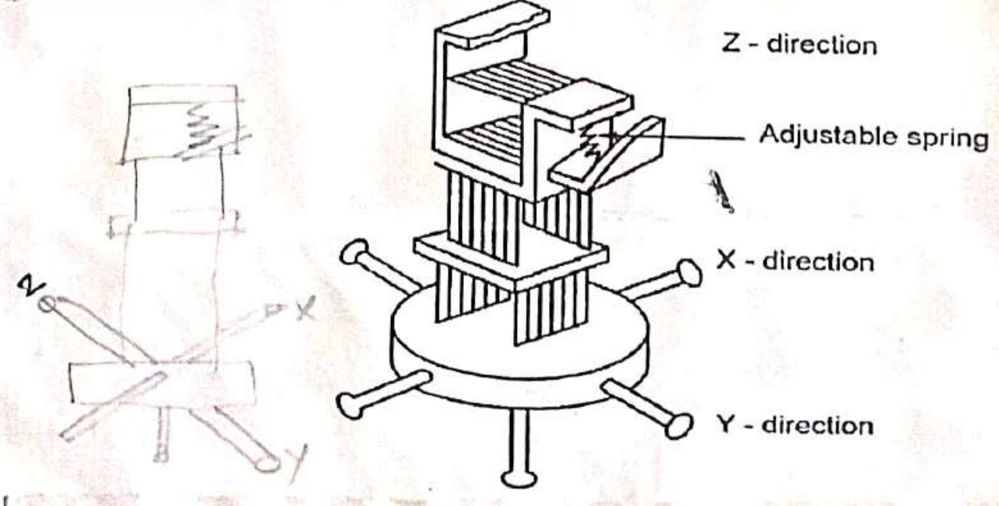


(a) Part section of Probe head *(b) Outline of Probe head*

* The main features of these system are shown in figure. The "buckling mechanism" is a three point bearing contacts of which are arranged at 120° around the circumference.

* The probing force is determined by the prestressed force of the spring

(ii) Measuring type probe system



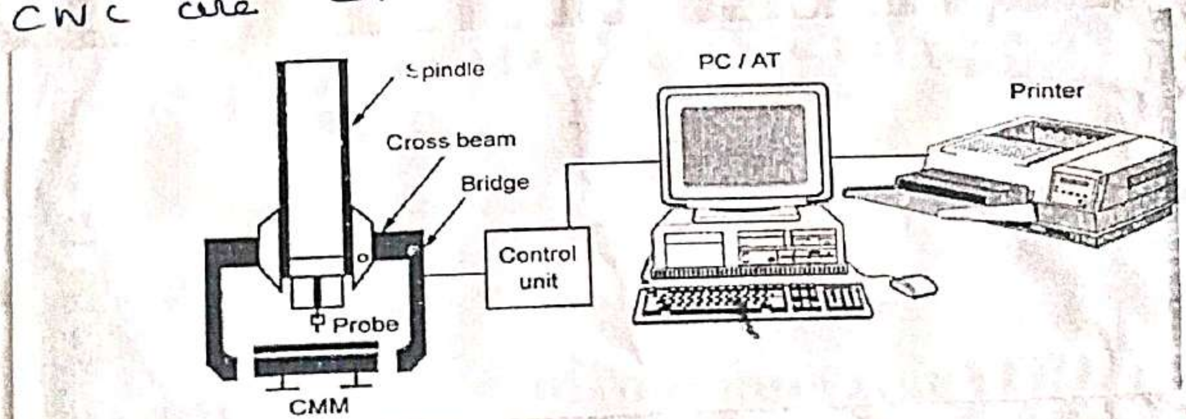
* Measuring type probe mechanism is a small co-ordinate measuring

machine in itself. the "buckling mechanism" of this system consists of parallel guide ways shown in figure.

* At the moment of probing, the spring parallelograms are deflected from their initial position.

CNC-CMM:-

* The main features of CNC-CMM are shown in figure. The stationary granite measuring table, length measuring system, air bearings, control unit and software are the important parts of CNC are CMM.



1. 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 the part mounting

2. Length measuring system :-

* The three axes CMM are provided with digital incremental length measuring system for each axis

3. Air bearing :-

* The bridge cross beam and spindle of the CMM are supported on air bearing

4. Control unit

* The control unit allows the manual measurement

5 Software

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

FEATURES OF CMM SOFTWARE :-

* Measurement of diameter, centre distance length

* Measurement of plane and spatial curves.

* Minimum CNC programme.

* Data communications

* Digital input and output command

* programme for the measurement of spur, helical, bevel and hypoid gears.

* Interface to CAD software.

BASIC CONCEPTS OF MACHINE VISION SYSTEM :-

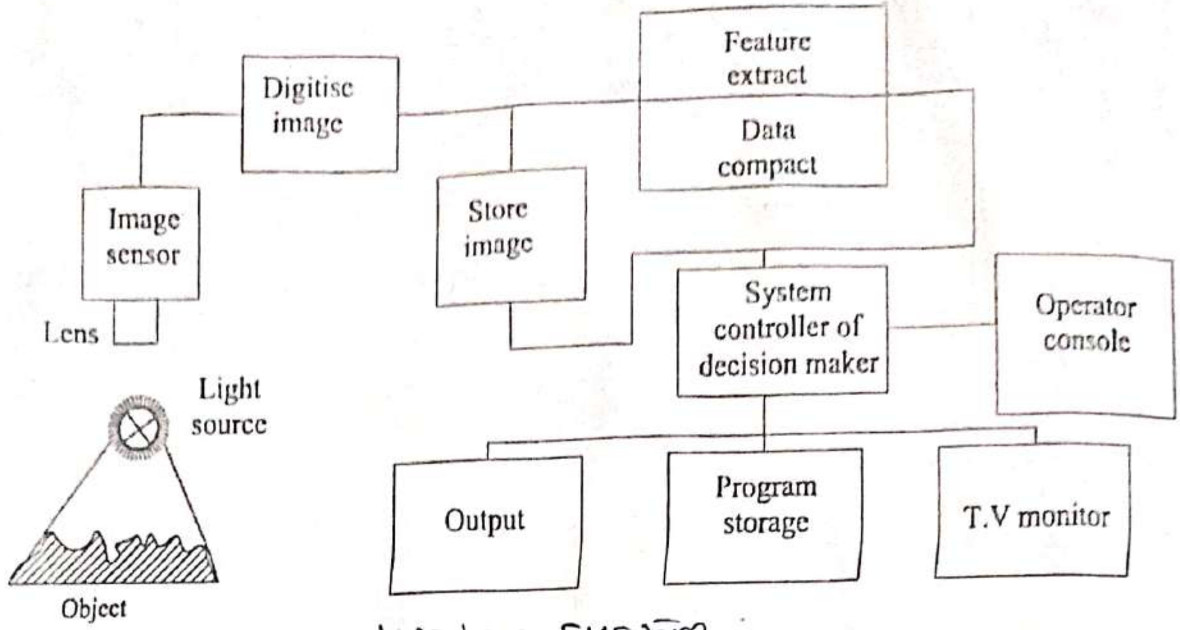
* Machine Vision can be defined as the simulating the image recognition and analysis capabilities of the human system with electronic and electromechanical technique.

Types of Machine Vision System :-

1. Image formation
2. processing of image.
3. Analyzing the image
4. Interpretation of image

Elements of machine Vision System

* A vision system has a light source, an image sensor, an image digitiser



Vision system

* The features data compactor provides the high speed processing of input image data.

* pattern recognition algorithms are employed to generate a simple feature data set

* In a digital System, the template is stored in memory as a two dimensional matrix

* This matrix is used as the reference Image. when a frame of Video is loaded by the Camera.

Important fields of Machine Vision system :

* Inspection
* Part identification
* Guidance and control

Advantages of Machine Vision system :-

* It reduces the tooling and fixture cost
* It eliminates the need for precise part location
* It integrates the automation of dimensional verification
* It helps to detect defects.

Application of Machine Vision system

* It can be used to replace, Machining for applications such as welding, machining to maintain relationship between tool and work.
* It is for the recognition of object from its Image.
* It achieves 100 % accuracy.