Exp. No ← 1

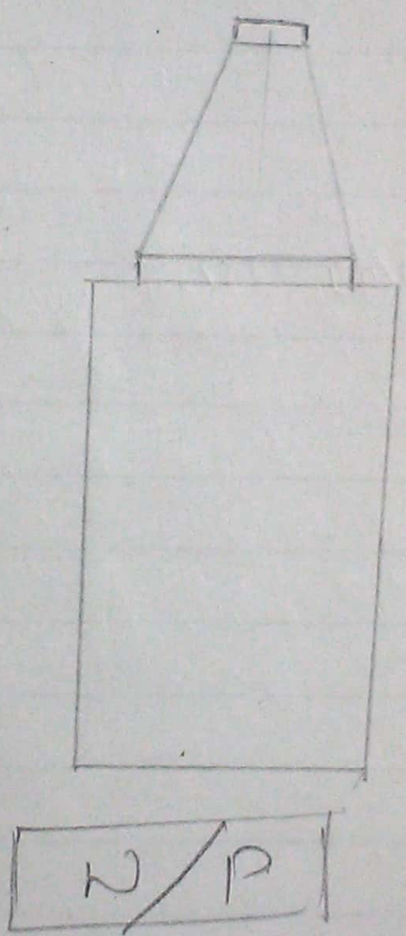
Aim ←

Measurement of linear dimensions

A) By using Vernier Calliper

B) By using vernier dial gauge Calliper

C) By using digital vernier Calliper



Exp. No. 1

Aim ←

Measurement of linear dimention.

I) By using Vernier Calliper
II) By using Vernier dial guage
III) By using digital vernier Caliper.

Apparatus ←

Vernier Calliper, Vernier dial gauge, digital vernier Calliper.

Theory ←

Linear dimentions are placed betn selected points. The dimentions are aligned to the horizontal or vertical axis of the view. The selected points are endpoints of the element or the intersection of references.

Importance of measurement ←

1) The evaluate newly developed products ~~throughly~~. So as to ensure that the components designed are within the process & measuring instrument capabilities & ensure that these are better than the relevent component to leronce.

2) To determined the process Capabilities & to ensure that those are better from the relevant Component tolerence.

3) To determined measuring instruments Capabilities & ensure that these are adequate for their respective measurments.

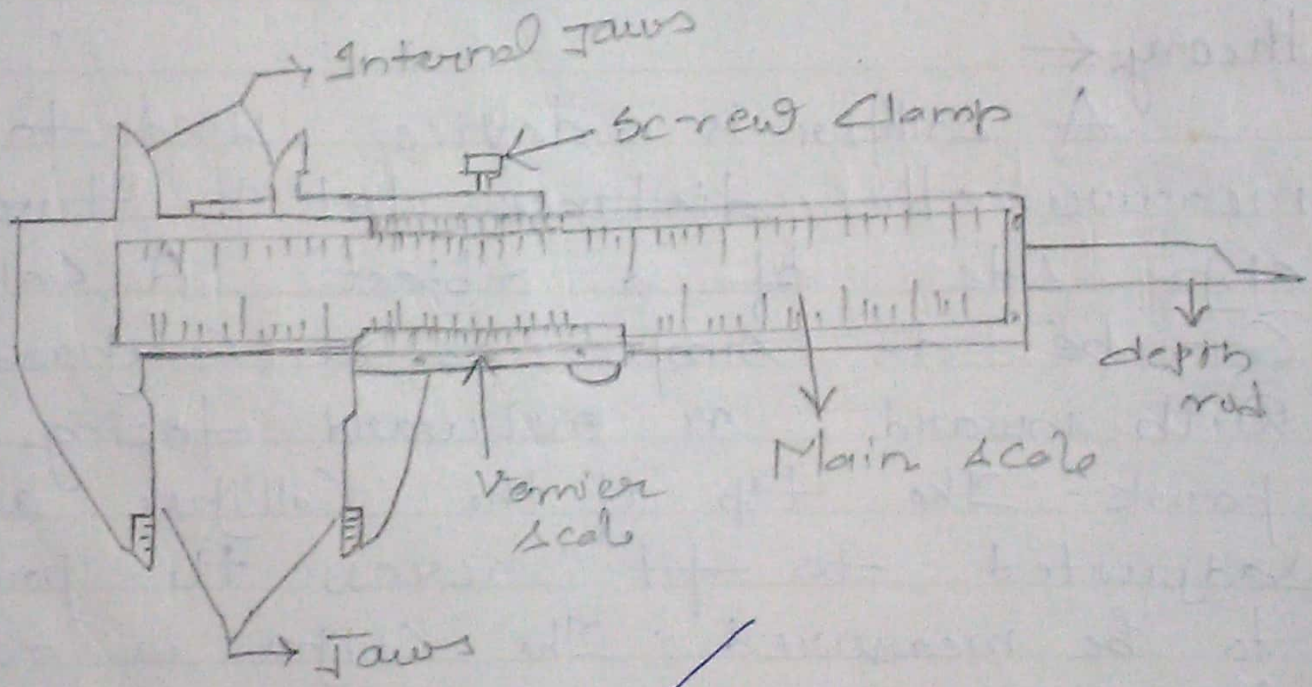
Part A ← By using Vernier Calliper

Theory ←
A Calliper is a device used to measure the distance bet^n two opp. side ~~of~~ a object. A Calliper Can be as simple as a Compass With inward or outward facing points. The tip of the Calliper are adjusted to ~~fit~~ across the points to be measured. The Calliper is removed & the distance is read by measuring between the ~~tip~~ with a measuring tool. such as ruler.

Manually operated vernier calliper can still be bought & remain popular because they are much cheaper than the digital Calliper version.

Part A ← Measurement by using manual Vernier Calliper.

Sr. No	M.S.R (a)	V.S.R x Least count (b)	Total reading (a+b)
1	25	4 x 0.02	25.18 mm
2	22	7.5 x 0.02	22.15 mm
3	15	8 x 0.02	15.16 mm



Also digital verson require as small battery where as manual verson does not need power source.

Least Count ←

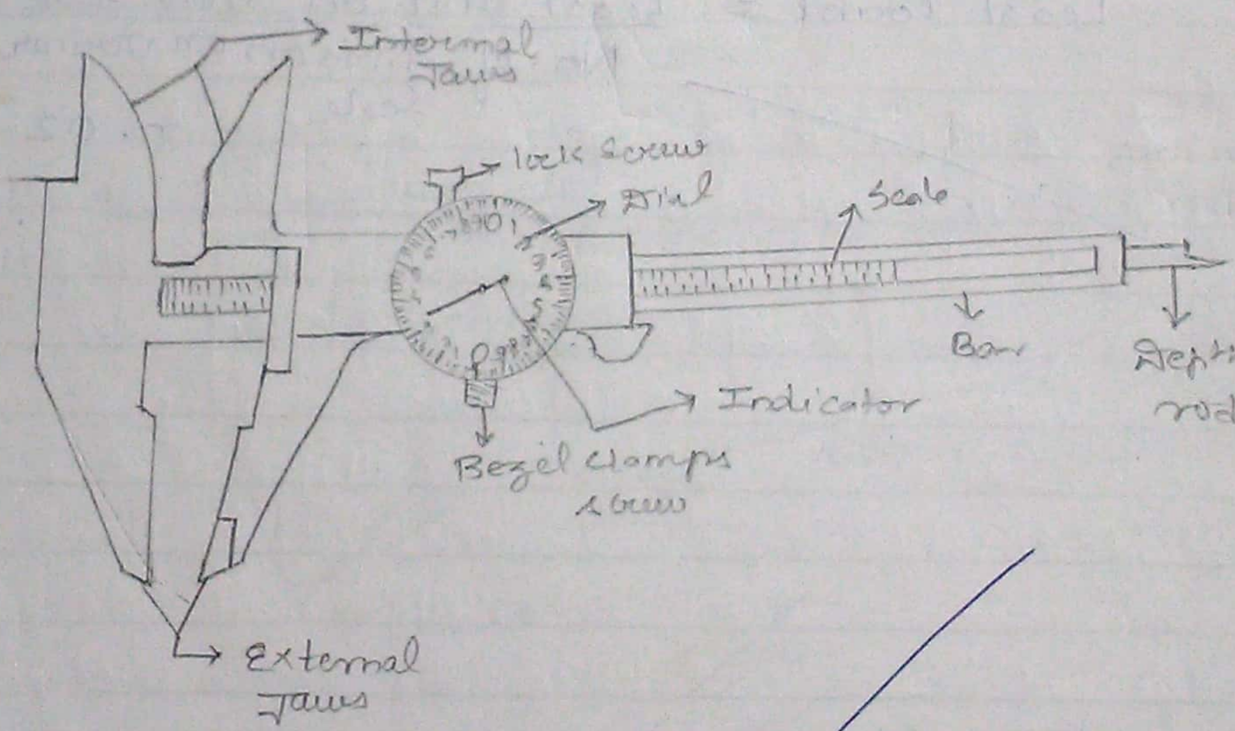
Least Count is the ratio of least unit that Can be measured on main scale to the No. of divison of verinier scale.

$$\text{Least Count} = \frac{\text{Least unit on main Scale}}{\text{No. of divison on verinier Scale}} = \frac{1}{50}$$

$$= 0.02$$

Part B ← Dial gauge vernier Calliper ←

S.No	MSR (a)	V.S.R × L.C (b)	Total reading (a+b)
1	25	3 × 0.02	25.06mm
2	22	5 × 0.02	22.1mm
3	15	14 × 0.02	15.28mm



Year

Date

Part B: Dial gauge Vernier Calliper ←

Theory ←

An indicating gauge exhibits Usually the Variation in the uniformity of the diamention or Counter.

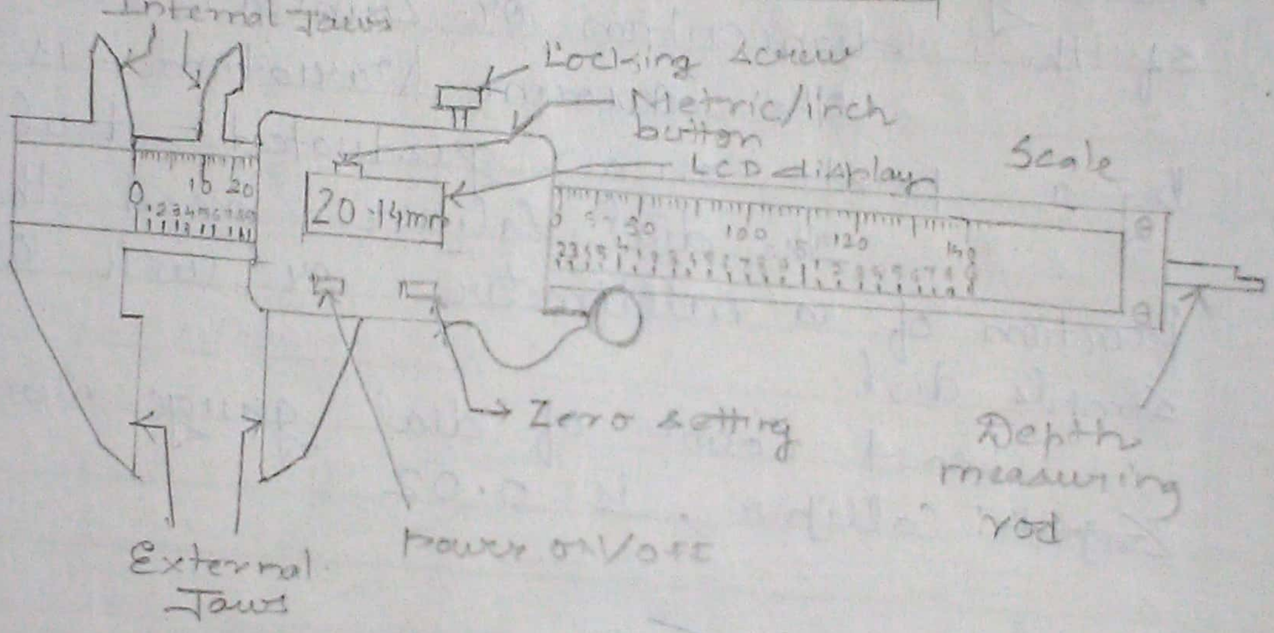
The amount variation is indicating By a points on a graduated dical.

The dial Caliper read the findl fraction of a millimeter or inch on a simple dial.

Least Count of dial gauge Vernier Capitte Calliper, is 0.02

Part C ← Digital vernier Calliper

S.No	Total reading
1	25.01 mm
2	22.07 mm
3	15.01 mm



Result ←

The diameter of the W/P is found to be,
1) Using single vernier Calliper ← 25.02 mm
2) Using dial gauge vernier Calliper ← 25.06 mm
3) Using digital vernier Calliper ← 25.01 mm

Date

Part C ← By using Digital Vernier Calliper ←

Theory ←

The replacement of analog dial with an electronic digital display on which the reading display as a single value some digital vernier Calliper can be switched between Centimeter or millimeter or inches. All provides for zeroing the display at any point along the side ordinary. 6 inch /150 digital vernier Calliper are made of stainless steel & have a rated accuracy of 0.01.

Result ←

The diameter of w/p is found to be ←

1) Using Simple vernier Calliper ← 25.08mm
2) Using dial gauge vernier Calliper ← 25.06mm
3) Using digital Vernier Calliper ← 25.01mm

18/07/13

(B)

by optical projectors, is best suited to relatively small, intricate components and tools.

3.3 Optical Projectors

The optical projector is a versatile and indispensable instrument in the metrology laboratory. The projector may be used to check the components which are otherwise difficult to do so due to typical of their size, material and dimensional characteristics. The instrument displays the magnified images of the objects located on the working platform - on an appropriate viewing screen. The magnified image serves as an aid to more precise determination of dimension, form, etc.

The optical system of a projector consists of

1. a projector - light source and condenser
2. suitable work holding table either fixed or movable
3. projection optics - mirrors and lenses
4. screen - for viewing the image and checking is made possible
5. measuring devices - precise mechanical system of measuring aids.

The following measurement techniques are employed on optical projectors

1. measurement by comparison
2. measurement by movement - table travel and measuring facilities must be available.
3. measurement by translation - special tracer accessories are required.

3.3.1 Nikon optical profile projector

Optical measuring instruments offer a number of advantages over mechanical instruments and provide suitable alternative. These are preferred when contact measurement cannot be used, as in the case of the fragile components or when the shape is highly complex or object is too small. In contrast to the optical comparator which employs an optical system to magnify the movement of a measuring probe, optical measuring instruments use a system of lenses to give a magnified image of the object. The use of light as a means of measurement can often involve a level of accuracy which cannot be achieved by mechanical instruments. A beam of light is unaffected by distortion and temperature variation although it is dependent on the quality of the optical system.

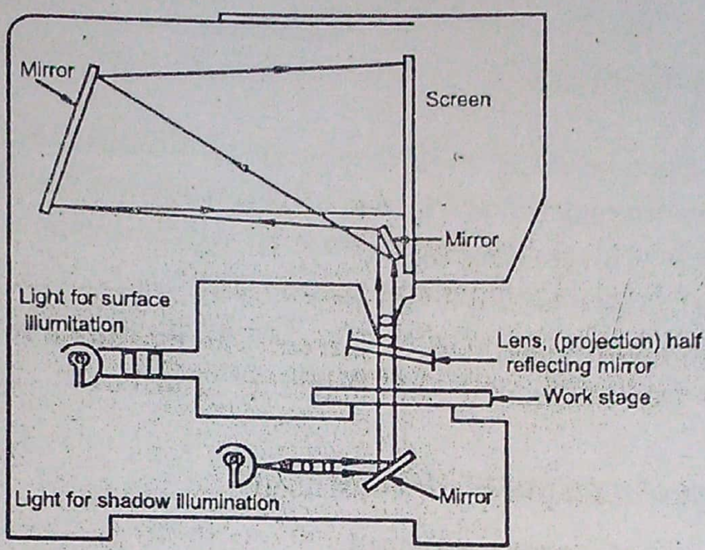


Fig. 3.3 Profile projector (Optical system)

Figure 3.3 shows Nikon profile projector which has swiveling turret above the stage for mounting the projection lenses. This enables different magnifications to be selected fairly rapidly. The illumination can be switched from shadow to surface by a selector on the front of the instrument. The hand wheel on the right hand side will raise or lower the stage and hence position a component placed on it at the focal point of the lens.

A sliding hood can be positioned to prevent extraneous light shining on the screen. From the above figure it can be seen that, when used for shadow illumination, collimated light is transmitted up through the translucent stage back lighting any object placed on it. Alternatively, when surface illumination is selected, the light strikes a half reflecting mirror placed below the projection lens, which reflects it down on to the object on the stage.

Whichever means of illumination is used, the image is projected by the lens via the two mirrors in the upper part of the instrument, on the screen.

All objects are not suitable for placing directly on the stage. Awkwardly shaped objects can be mounted between the centers. The stage can be moved on its longitudinal and transverse direction and the movement is controlled by micrometers which have a vernier resolution down to 0.001mm.

3. Compound indexing.

4.4.1.2.9. Optical instruments for angular measurement

Autocollimator. An autocollimator is an instrument designed to measure *small angular deflections* and may be used in conjuction with a plane mirror or other reflecting surface. An *autocollimator is essentially an infinity telescope and a collimator combined into one instrument.*

An autocollimator is based on the *principle that a collimating lens can project and receive a parallel beam of light and that the reflected beam of light will change its direction by changing the angle of the surface reflecting the light.*

The Autocollimator's principle is shown in Fig. 4.88. It shows the collimator lens that projects a parallel beam of light along the optical axis of the system when the light source (electric bulb) is placed at the focus of the collimator lens. A reflector, which can be a slip guage block, an optical flat or a mirror is attached to the surface under rest. If this reflection is accurately normal to the optical axis, the effected beam will return along its original incident path back to the lens and will be collected at a point '*p*' exactly at the length of the lens where cross-wires are placed. Therefore the image of the cross wires formed by the reflected light

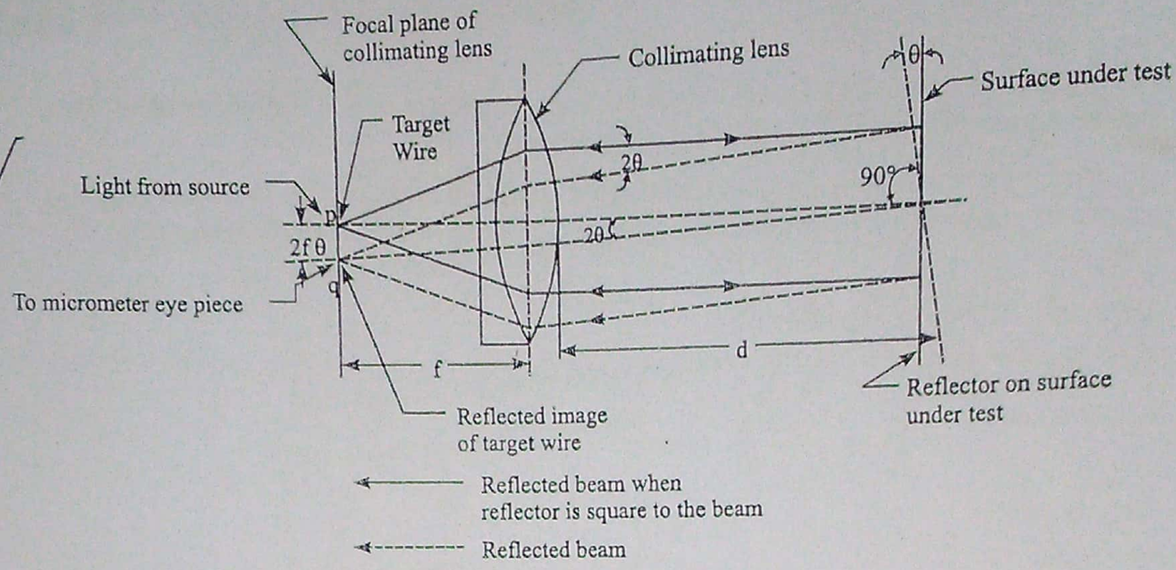


Fig. 4.88. Principle of autocollimator.

beam will, in this case coincide with the cross-wires at point '*p*'. If the reflection is slightly tilted at an angle θ, the reflected beam will change its path at twice the angle θ. The reflected beam will, therefore, form an image '*q*' at the cross-wires at distance '*pq*', the value of which is a measure of the angular deflection θ, where $pq = 2f \cdot \theta$.

- It may be noted that the position of the final image does not depend upon the distance of reflector from the lens, *i.e.*, separation '*d*' is independent of the position of reflector from the lens. But if reflector is moved too much back then reflected rays will completely miss the lens and no image will be formed. Thus, for full range of readings of instrument to be used, the maximum remoteness of the reflector is limited.

  For high sensitivity, *i.e.*, for large value of '*d*' for small angular deviation θ, a long focal length is required.

Hilger angle dekkor :

Fig. 4.89 shows a typical auto-collimator–the Hilger Angle Dekkor, the description of which is given below:

- It consists of a *tubular body* containing the *collimating lens* at one end and viewing *eye piece* at the other end.
- At the focal plane of the collimating lens, there is a scale instead of cross-wires which is illuminated by means of an electric lamp mounted by the side.
- The *eye piece* is provided with a *fixed scale* similar to and at right angles to the illuminated one.

  Both scales are divided from 0 to 40 and each division represents 1' of arc.

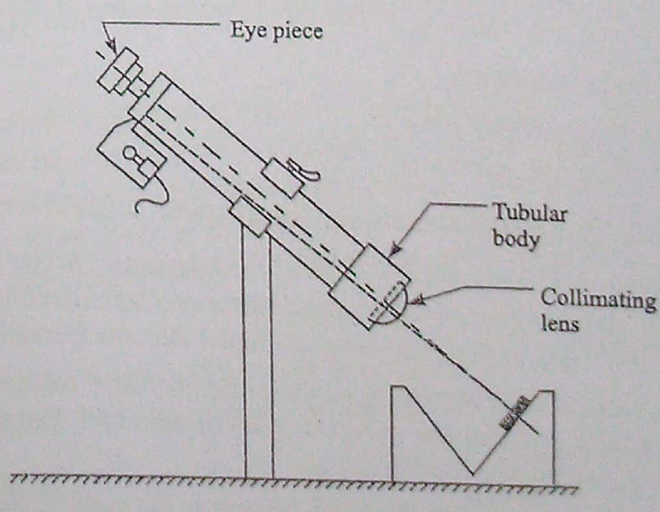


Fig. 4.89. Hilger angle dekkor.

between the particular pair of polygon faces, to give the angle of face plate.

4.4.2. Taper Measurement

4.4.2.1 Gauges for tapers

- A taper is tested by using taper plug and ring gauges. The important thing in testing a tapered job is to check the diameter at bigger end and the change of diameter per unit length. For testing the correctness of a taper, three light lines are drawn with persian blue about equidistant along the length on the (male portion) plug gauge or spindle to be tested and it is fitted in the gauge (female) and rotated once or twice. If persian blue *marks do not rub off evenly,* the *taper is incorrect* and setting must be adjusted until persian blue marks are rubbed equally all along its length.
- ***Taper holes*** can be checked by a '*Go*' *and* '*Not Go*' taper plug limit gauge as shown in Fig. 4.92. At the large end of the gauge where the large diameter of the taper hole should theoretically lie, a flat surface

is machined on the gauge on which two lines are engraved, the distance between them is equal to the tolerance on the base distance. The line nearer to the small end represents the '*Go*' limit and the other near the large end represents the '*Not Go*' limit of the taper hole. The *dimensional accuracy of the taper hole will be accepted when the taper gauge fits in the hole such that the "Not Go" limit remains outside the hole.* This *does not provide a positive check* of the type of contact between the mating parts along the whole length of the fits. These geometrical inaccuracies can be checked by marking light lines with persian blue as explained earlier.

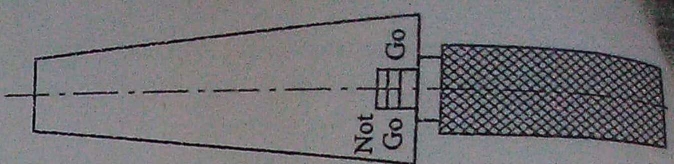
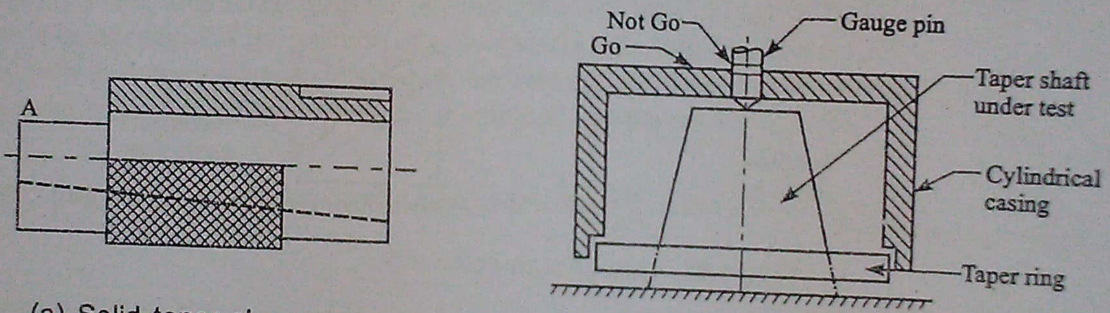


Fig. 4.92.

- *Taper shafts* can be checked by the reversible procedure using taper hole gauges as shown in Fig. 4.93(*a*, *b*). The *solid taper sleeve gauge* [Fig. 4.93(*a*)] has cut away portion A, on which the "*Go*" and "*Not Go*" limits are engraved. By inserting the taper shaft in the hole gauge, the small end of the taper shaft should lie between these two limits. The geometrical accuracy of the shaft can be checked by the persian blue procedure.
- The *taper ring gauge* [Fig. 4.93(*b*)] consists of a taper ring that can be placed on the taper shaft under test. A cylindrical casing is mounted on the taper ring and the position of the taper ring relative to the small end of the shaft can be checked by a gauge pin on which "*Go*" and '*Not Go*" limits are marked. To check the geometrical accuracy of the taper shaft, more than one taper ring should be used.



(a) Solid taper sleeve gauge.

(b) Taper ring gauge.

Fig. 4.93.

A positive check of the dimensional and geometrical accuracies of taper shafts can be achieved by using "*May*" *taper gauge* [Fig. 4.94). It consists of two similar side members separated by a standard central taper gauge. The taper gauge is provided with a taper work support on which the taper shaft has to rest. The height of the work support is made such that the two side members make contact with the taper shaft at two enveloping lines diametrically opposite. The two side members and the taper gauge are made separate for the universal use of the gauge and they can be screwed together. On the top surface of one of the side members the two "*Go*" and "*Not Go*" limits are provided within which the large diameter of taper shaft should lie. Geometrical

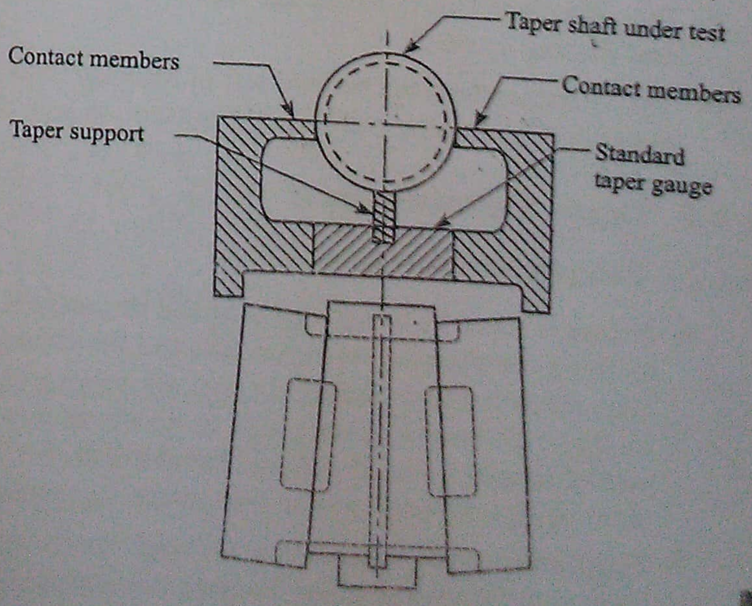


Fig. 4.94.

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...is can be measured by means of slip gauges blocks which should be inserted without force to avoid errors. The two balls are then placed on equal columns of slip gauges of height h and the distance L_1 separating the balls is also measured with slip gauges. The taper angle then be calculated as follows :

$$\tan \alpha = \frac{L_2 - L_1}{2h}$$

C. Measuring a taper hole on the sine table using internal adaptor : Fig. 4.100 shows the set-up for measuring a taper hole on the sine table using internal adaptor. The internal adaptor used consists of a hollow cylinder with suitable external diameter and a lever, hinged in the cylinder, whose magnification ratio is 1. The taper ring as placed on one of the centres and adapter is made to contact the bottom surface of the taper hole. The sine table is adjusted by slip gauges until the lower surface of the taper hole is set parallel to the surface plate. This can be ensured when the reading of the dial gauge, in contact with the adaptor, remains constant during the axial movement of the adaptor inside the taper hole. In this position, the angle made by the sine table is equal to the taper angle, angle of the component being tested.

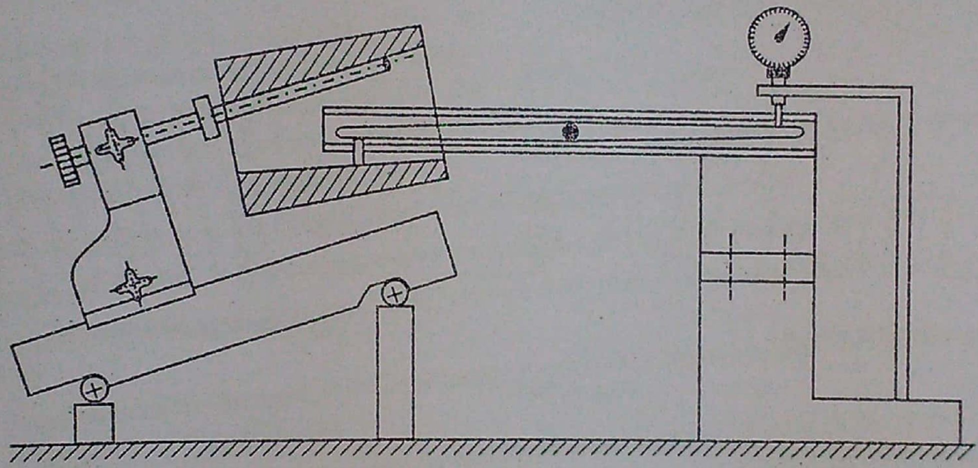


Fig. 4.100. Set-up for measuring a taper hole on the sine table using internal adaptor.

4.5. SCREW THREAD MEASUREMENTS

4.5.1. Introduction

A screw thread *is helical ridge formed on uniform section round the curved surface*. The shape of the normal section of the thread depends upon the shape of the tool which produces its groove. A screw is a male threaded piece generally cylindrical in form, but sometimes, conical (or tapered), used in most cases as a temporary fastening; less frequently used as a means of transmitting motion or power.

The screw threads are applied to many devices for various *purposes* as follows :

1. To hold parts together as in the case of fastening.
2. To transmit power.
3. To control movement as in micrometer.
4. To increase the effect of applied effort as in auto jack.
5. To convey materials as in the case of fastening.

4.5.2. Classification of Threads

The threads may be *classified* as follows :

1. *According to the surface on which the threads are cut :*

   (*i*) External threads

   (*ii*) Internal threads.

   The external threads are cut into the surface of a *cylindrical bar.*

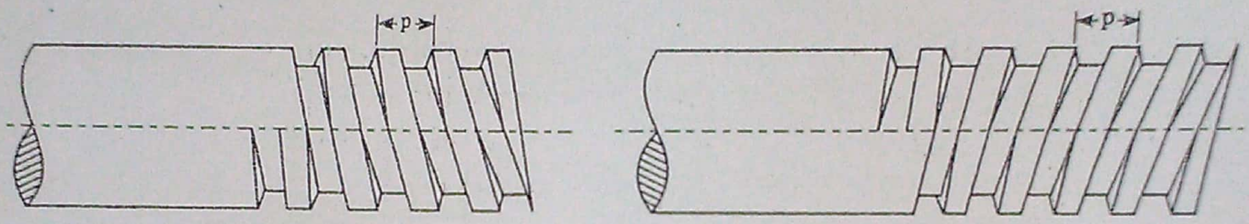
   The internal threads are cut into the surface of the *cylindrical hole* of a bar or cone.

2. *According to the direction of rotation of the threaded cylinder with respect to engagement or disengagement with the other part :*

   (*i*) Right handed thread

   (*ii*) Left handed thread.

   A *right handed thread* is one in which the nut must be turned in a right handed direction to screw it on (Fig. 4.101(*a*)). A left handed thread is one in which the nut would be screwed on by turning it to the left (Fig. 4.101(*b*)).



(a) Right handed thread. (b) Left handed thread.

Fig. 4.101.

3. *According to number of starts :*

   (*i*) Single start threads

   (*ii*) Multi-start threads.

In a piece of work it is possible to have separate and independent threads running along it. Accordingly, there are single threaded screw and multiple or multi-start threaded screw. The independent threads are called starts and we may have single start, two start, three start etc. (Fig. 4.102).

A *single start threaded screw* is one in which there is a movement of one thread for one complete turn round the screw or bolt. In the *multi-start threaded screw* there is a movement of more than one thread. In the case of double start thread, for one complete turn, the thread advances two times as if it were a single thread.

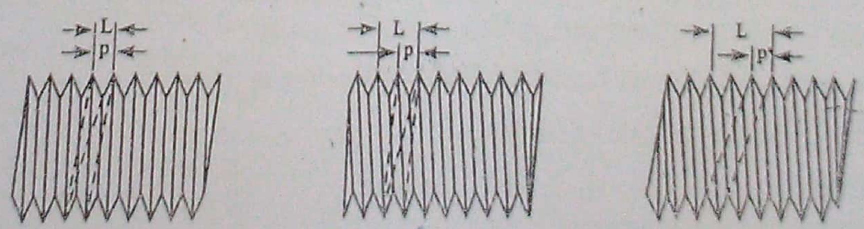


Fig. 4.102. (i) Single-start, (ii) Two-start, and (iii) Three-start threads.

se of multi-start threads. Multi-start threads are used on those cases where *rapid movement or motion is required.*

Examples: Fountain-pen cap, screw press, bottles, tooth paste etc.

4.5.3. Elements of Screw Threads

To designate different parts of the screw threads the following *terms* are commonly employed :

Refer Fig. 4.103.

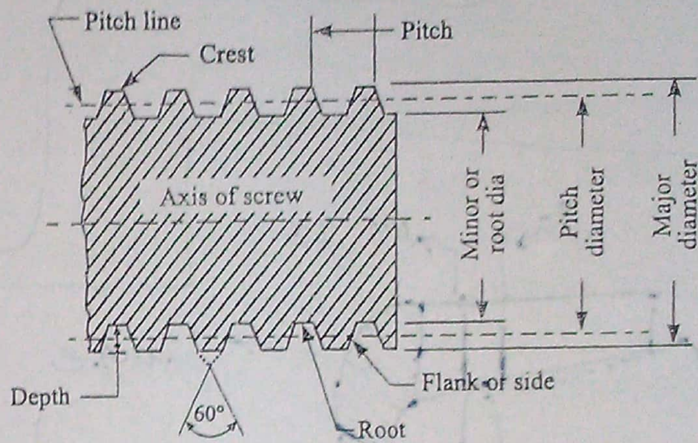


Fig. 4.103. Nomenclature of a screw thread.

1. **Major diameter.** It is the *largest diameter of a screw thread.* It is also termed as *outside* or *crest diameter.*
2. **Minor diameter.** It is the *smallest diameter of a screw thread.* It is also known as *root* or *core diameter.*
3. **Effective or pitch diameter.** It is *an imaginary diameter in between the major and minor diameters, and is equal to the major diameter less than an amount equal to the single depth of a thread.*
4. **Axis of screw.** It is the *longitudinal central line through the screw.*
5. **Angle of thread.** It is the *angle between the two sides of a thread measured in an axial plane.*
6. **Depth of the thread.** It is the *angle between the crest and the root of a thread measured normal to axis.*
7. **Thickness of the thread.** It is the *distance between the adjacent sides of the thread measured along or parallel to the pitch line.*
8. **Side.** It is the *slant surface of the thread which connects the crest with the root.*
9. **Helix angle.** It is the *angle made by helix of the thread at the pitch or effective diameter with the plane perpendicular to the axis.*
10. **Crest.** It is top *surface joining the two sides of a thread.*
11. **Root :** It is the *bottom surface joining the two sides of a thread.*
12. **Pitch.** *It is the distance from a point on one thread to the corresponding point on the next thread measured parallel to the axis of the thread.* It is denoted by '*p*'.
13. **Lead.** *It is the distance a screw thread advances axially in one turn on a single thread screw, the lead is equal to pitch and for a double threaded screw, the lead becomes two times the pitch and so on.*

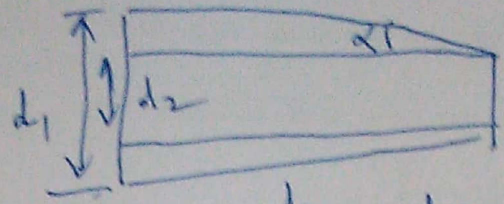
Note : A screw is specified by a *nominal diameter*, it is the diameter of the cylindrical piece on which the threads are cut.

4.5.4. Specifications of a Screw Thread

To specify a screw thread the following points are given due considerations :

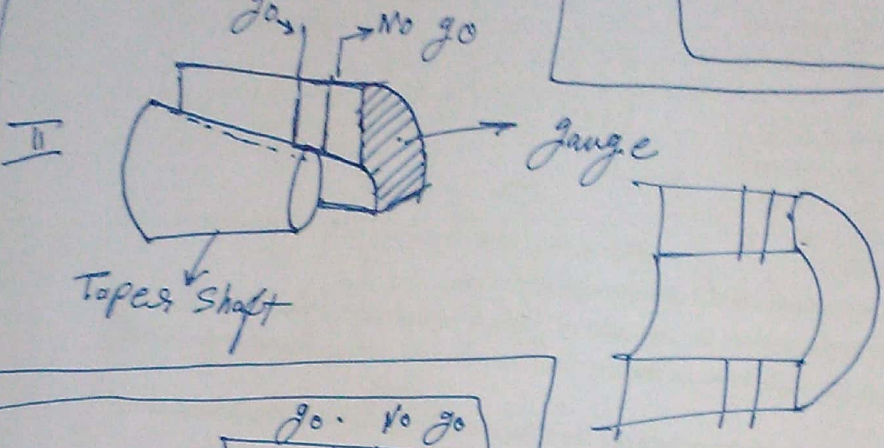
1. Shape or form of thread
2. Pitch
3. Size (diameter)
4. Length
5. Number of starts
6. Material
7. Direction of threads
8. Internal or external threads.

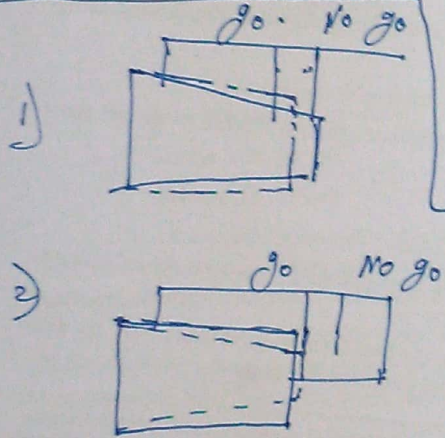
I



$$\tan\alpha = \frac{\frac{d_1}{2} - \frac{d_2}{2}}{l} = \frac{d_1 - d_2}{2l}.$$

II





III

Go Gage For Checking Tapered Shaft

→ The small end should lie or cross the go limit of the taper hole gauge.

No Go Gage For checking —||—

→ The small end should not cross or should remain between go and no go limits.

IV th

Selective Assembly :- It is process in which first the mating components are divided into number of groups. Now (this components are again manufactured in different industries by providing wider tolerance. After manufacture the parts are placed in separate groups. Assembly is then made by selecting one component from group A and another mating component from corresponding group.

The product should function properly with full efficiency. Its application is in Automobile Industry.

Q- Explain the following terms used in measurements :-

Repeatability :- It is the ability of measuring system to reproduce the same results for the measurement of same quantity when the measurements are carried out under identical conditions.

Reproduceability :- It is closeness of agreement between the results of measurements of same quantity when the measurements are carried out by different observer, different instrument, different method under different conditions.

Sensitivity :- It is the ability of measuring instrument to detect small variation in quantity being measured immediately (or) It is the ability of measuring instrument that how quickly it responds when the measuring tip of measuring instrument brought in contact with object.

High sensitive instruments should not be preferred because it is affected by temperature and vibrations, and also it will be difficult to operate such instruments.

Readability :- It is the ability of measuring instrument to convert the indications into a meaningful number which can easily read by observer.

In order to increase readability of an instrument it is provided with magnifying glass or vernier scale.

Magnification :- Increasing the magnitude of an output signal is known as magnification.

Explanation: when there is small change in the quantity being measured then it is not possible for observer to read it clearly with the help of naked eye as the divisions are lying very closer, therefore magnifying glass is used to read the value easily. This process is called magnification.

Magnification of measuring instruments can be done in different ways like mechanical, electrical, electronic, optical & pneumatic.

Calibration :- [illegible] or marking of scale of the instrument by applying some standards by the [illegible] is known as calibration. Normally calibration should be done under environmental condition in which the instrument is used.

[illegible] :- It is the difference between measured value [illegible] quantity.

→ (i) The set of experimental operations carried out to determine the value of an unknown quantity is called measurement. The sequence of operations performed is called process of measurement.

Based on the different instruments available methods of measurements are classified as follows

1. **Method of direct measurement** :- In this method of measurement the value of unknown quantity can be obtained directly by the use of measuring instrument. Ex Measurement by using scale.

2. **Method of indirect measurement** :- In this method of measurement inorder to know the value of an unknown quantity first we have to measure the value of other unknown which are functionally related to the required value. Ex.- Angle measurement by sine bar.

3. **Contact method of measurement** :- In this method of measurement the value of unknown quantity is obtained by placing the measuring tips or plunger or jaws is comes in contact with the object. Ex Vernier Caliper.

4. **Contactless method of measurement** :- In this method of measurement inorder to measure the value of unknown quantity the measuring tip or plunger or jaws of instrument doesn't comes in contact with the object. Ex. Tool makers microscope and all optical instruments.

5. **Comparative method of measurement** :- In this method of measurement the value of unknown quantity can be only compared to that of standard i.e. the deviation of the measured dimension from standard can be compared Ex. Comparator.

6. **Absolute or fundamental method** :- In this method of measurement first the zero setting is done by matching zero of main scale with zero of vernier or circular scale then only measurements is taken. If zero is not coinciding then the error is either added or substracted from the result obtained.

Ex. Micrometer screw gauge.

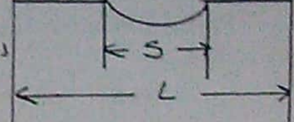
Q. What are the factors which effects upon the accuracy of measurement ?

Ans; The different factors which effects upon the accuracy of measurement are as follows i) Temperature variation ii) Elastic deformation iii) Contact pressure.

i) **Temperature variation** :- The standard temperature for carrying out measurement in metrology is 20°C, because all the measuring instruments, gauges and devices are manufactured to its correct size at this temperature. If the measurements are carried out at temperature other than standard then error will be introduced because expansion happens if temperature is more and contraction happens if temperature is less of both instrument & object. But if the instrument and object are of same metals then expansion or contraction is of same amount so it doesn't effects accuracy in this case.

Elastic deformation :- Straight edges are used to check the straightness and flatness of parts. If this is placed simply supported then due to self weight it gets deformed or deflection. The amount of deflection depends upon the position of supports. This causes error in straightness of working surfaces.

In order to have minimum deflection the object when placed should be supported at 0.554 times the length of object. ($\frac{S}{L} = 0.554$)



S – distance between supports
L – length of object

when measurements are taken the instruments measuring faces be parallel to each other to maintain this and to avoid slope at the ends the ratio of $\frac{S}{L}$ should be 0.577.

Contact Pressure :- while carrying out measurements the applying pressure should be minimum otherwise if you apply more pressure it results in either deformation of object or measuring tip of instrument depending on type of metals which results in error in measurement. To reduce Contact pressure error the racket mechanism is introduced in micrometer or fine adjust screw is provided with verniers.

What are different sources of error in measurement ?.

→ The different sources of error in measurement are
i) Controllable error or systematic error ii) uncontrollable error or random error.

i) Controllable error :- These are those errors which occurs repeatedly if the measurement operation is repeated and if analysed properly it can be controlled both in magnitude and sense of it can be reduced. Types of controllable errors are Calibration error, Environmental error, contact pressure and avoidable error.

Calibration error is caused due to variation in calibration from nominal value, it can be controlled by checking the instruments calibration with standard gauges before using it for measurement.

Environmental error is caused if temperature is not 20°C and pressure 760 mm of Hg ; it can be controlled by using instrument at 20°C with airconditioners help.

Contact pressure explained earlier

Avoidable errors are caused due to not taking the reading by coming in parallel with instrument (i.e parallax error) also due to non alignment of work piece with object.

ii) Uncontrollable error or Random error :- These are those errors which are accidental in nature and cannot be controlled as they are inherent in the measuring instrument. The possible source of these errors are

a) Slight displacement of lever joints of measuring instruments
b) Small variation in the position of setting standard and workpiece (it mean if there is slight change in position of object to that of standard)
c) Operator not reading the correct value of measurement on scale (operator error)
d) Friction and fluctuation in the instrument and backlash in instrument.

* Random errors cannot be predicted from the knowledge of measuring system and conditions of measurement.

to physical nature of various components of

Basic sources of static error are reading error, environmental error and characteristics error.

Reading error include parallax error and interpolation error.

Inorder to eliminate parallax error, the use of mirror behind the readout pointer is placed also it is recommended to take the reading by coming in parallel to the instrument.

Interpolation error can be ~~eliminating~~ eliminated either by using magnifying glass over the scale in the range of pointer. (Interpolation means if pointer is in between two division which are lying very nearer to each other then observer couldn't read properly the result).

Now a days introduction of digital instruments reduced reading error to a large extent.

~~Loading~~ Environmental error :- It is introduced in the measuring system if instrument is not used in recommended temperature, pressure and humidity.

Characteristics error :- It is the deviation of output of the measuring system from theoretical predicted performance. ex. calibration error and hysteresis.

Loading error :- This error is introduced when the value of measurand changed by itself when it comes in contact with measuring instrument. This error happen when the measurand or object is made up of softer metal.

Dynamic error :- This error is caused due to time variation in the measurand which cannot be detected by measuring instrument. Due to inertia or damping.

→ Define three elements of measurement with example.

→ The three elements of measurements are i) Measurand ii) Reference iii) Comparator.

Measurand :- It is the physical quantity or property to be measured ex. length, angle, diameter, thickness etc

Reference :- It is the physical quantity or property to which quantitative comparisons are made ex-scale or any measuring instrument

Comparator :- It is the means by which comparison of measurand are made with reference. ex- Eyes

In case of measuring length of Bar. with the help of vernier caliper. Now first align the bar in between the jaws of vernier caliper and ~~scale~~ see the reading with eyes. Here Bar is Measurand. vernier caliper is reference and eyes are comparator.

Q- Define Standard and distinguish clearly between line standard and end standard?.

Standard → A standard is defined as something which is set up and established by authority as a rule for measurements of quantity, weight, extent, value or quality.

	Line standard	End standard
1.	When length is expressed as the distance between two lines it is called line standard.	When length is expressed as the distance between two flat parallel faces it is called as end standard.
2.	Measurement is quick and easy	Measurement is time consuming
3.	These are not subjected to wear except on leading ends	Those are subjected to wear on measuring surfaces.
4.	Parallax error can be introduce	No parallax error
5.	Close tolerance length measurement is not possible	Close tolerance length measurements is possible
6.	Alignment is not possible Ex— Metre scale	Alignment is easily possible. Ex. Micrometer screw gauge.

→ What is wave length standard. State the advantages of wavelength standard.

- Length Line standards and end standards are subjected to wear and their dimension changes slightly with time. Also difficulty is experienced in aligning, comparing and verifying the size of gauges by using line & end standards. After experiencing this difficulties during the year 1829 Babinet suggested to use wave length of monochromatic light as natural and invariable unit of length. In 1960 orange radiation of isotope krypton-86 was used for new definition of length. Standard metre and yard were defined in terms of wavelength.

1 metre = 16,50,76,373 wavelengths.

1 Yard = 0.9144 metre

Following are the advantages of wave length standard

1. No wear and tear as wave length is not a physical one
2. Dimension do not change with time
3. Comparing & verifying is simplified
4. Measurement is repeated to a high degree of accuracy as the error in reproduction is 1 part per 100 million. 1×10^6

Define Least Count ?. and what do you understand from L.C.

It is the ratio of smallest division on main scale to the number of divisions on vernier scale.

$$L.C. = \frac{\text{smallest division on main scale}}{\text{No. of division on vernier scale}}$$

Let us say smallest division on main scale is '1mm' and no. of divisions on vernier scale is 50

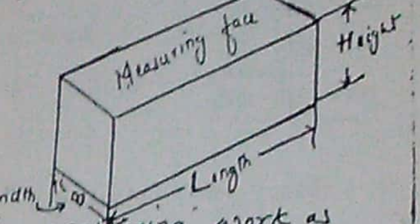
$$LC = \frac{1}{50} = 0.02\,mm.$$

We can measure the smallest dimension/value with the instrument equal to its least count. ←

Scanned by CamScanner

wear (these are hardened throughout by heating to about 760°C and quenched in water. They are then stabilised by heating and cooling simultaneously in stages to remove hardening stresses. They are then cut into pieces and finished by high grade lapping on measuring faces so that wringing can take place.

Dimension of this gauges is 9 mm x 30 mm for sizes upto 10mm height and 9mm x 35mm for size above 10 mm height.
(w) (l) (w) (l)



→ Slip gauges are used in every precision engineering work as standard of measurement. It is being invented by C.E. Johansson of sweden therefore it can be called as Johansson gauges.

Slip gauges are available in five grades.

Grade II : These are used in workshop for setting up machine tools.

Grade I : These are used for setting sine bars and gap gauge.

Grade 0 : These are used for tool room or machine shop inspection

Grade 00 : These are used for measuring grade I and grade II. It is highest precision grade.

Calibration Grade :- These are used for calibration of other grades and measuring instruments. ←

Q. → Define wringing and construct a dimension of 36.685mm by using a set M87 by using minimum number of gauges.

Range (in mm)	step (in mm)	Pieces
1.005	—	1
1.001 to 1.009	0.001	9
1.01 to 1.49	0.01	49
0.5 to 9.5	0.5	19
10 to 90	10	9

→ Wringing:- When two clean, accurately flat surfaces under the presence of thin film of grease or moisture slide or rotate over each other. They join firmly. This phenomenon is called wringing. ←

explanation:- In order to wring two slip gauges first clean the slip gauges with petrol then apply thin film of grease over measuring or contacting surfaces. Now keep them in cross or slide one over other to have minimum rubbing of measuring surfaces. This wringing is happening because of molecular attraction, thin film of grease and atmospheric pressure. The combination of slip gauges is called as stack which can be used as a unit. ←

[After use of slip gauges place them in their proper case by applying thin film of grease over it] Use of slip gauges should be with [illegible]

Now to construct a dimension of 36·685 mm from the set of M87

36·685 mm

i) Aim to remove last digit after decimal i.e ·005 mm therefore we have to select a piece of 1·005 mm from the set

ii) Aim to remove ·08 mm but while removing take care to bring next number into a proper digit which can removed easily. so select 1·18 mm

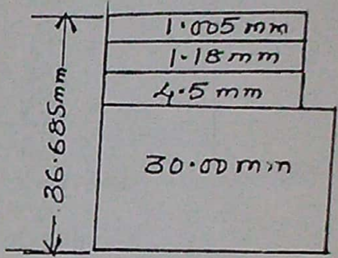
iii) Aim to remove 0·5 mm but with the gauge of 4·5 mm we can remove and bring the combination into proper number i.e 30·00

iv) 30·00 mm piece is available.

36·685 mm
− 1·005 mm
35·68 mm
− 1·18 mm
34·50 mm
− 4·50 mm
30·00 mm

Therefore we have used four slip gauges i.e 1·005, 1·18, 4·5 & 30 mm.

Minimum four slip gauges are used. ←



NOTE:- As it is possible that if we are using set of slip gauges wear of gauges can happen due to which whole set will be of no use. So to avoid it protector gauges are available of size 2·5 mm each which has to be placed on top and at the bottom to safeguard the slip gauges. Because set of protector gauges is less costly than whole set of slip gauges.

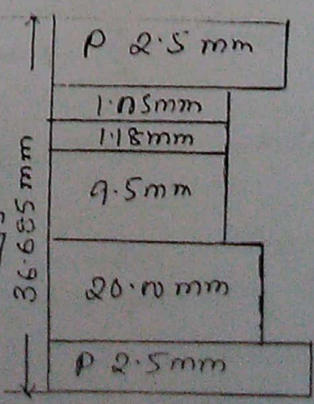
Let us take the question as construct a dimension of 36·685 mm by using set M87 and a pair of protector gauges of 2·5 mm each.

→ In this case first remove the dimension of 5·0 mm (2×2·5 mm protector gauge) then apply the procedure mentioned above

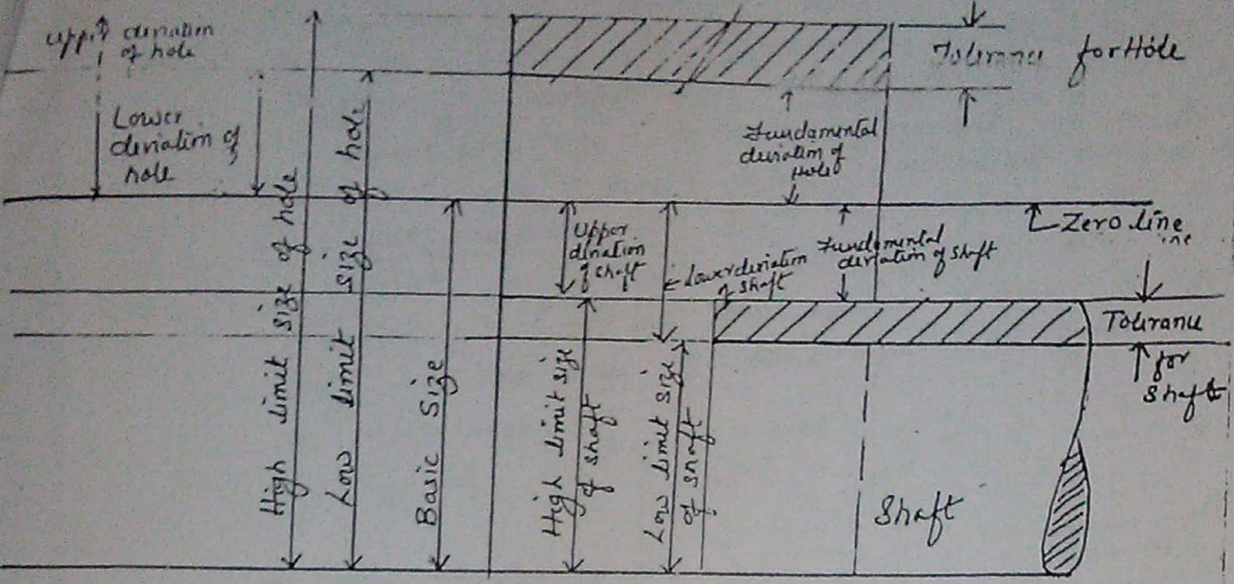
36·685 mm
5·000 mm (P)
31·685 mm
1·005 mm
30·68 mm
1·18 mm
29·50 mm
9·50 mm
20·00 mm

Here two protector gauges & four slip gauges are used to construct a dimension 36·685 mm

i.e 2·5 (P) + 20·00 + 9·5 + 1·18 + 1·005 + 2·5 (P)



[Practice to construct a dimension of 58·835 mm, 63·458 mm by using protector gauges of 2·5 mm each]



Basic Size It is the standard size of part with reference to which all variations in limits of part is determined. It is same for both hole and shaft. Ex- 20 H7 f6 20mm is basic size for both hole and shaft.

Limits :- As it is very difficult to manufacture a part of exact size due to variation in men, machine and material. Besides that it is costly affair to attain exact size. Seeing this ranges of permissible difference in dimensions have been standardised under the name limits.

Limits of size :- It is the two extreme permissible size of a part between which actual size of the part lies. The greater among two limits is known as high limit of size whereas the smaller among two limits is known as low limit of size.

Deviation :- It is defined as the amount by which the size of the part deviates from its basic size.

Upper deviation :- It is the difference between high limit of size and corresponding basic size.

Lower deviation :- It is the difference between low limit of size and corresponding basic size.

Zero Line :- It is the line of zero deviation and it represents the basic size.

Fundamental deviation : It is either upper deviation or lower deviation which is chosen to define the position of tolerance zone in relation to zero line. Fundamental deviation exists only when unilateral tolerance is provided on the parts. (It is that deviation which is nearest to zero line. In case of shaft it is upper deviation & in case

Q. What is tolerance. Explain in brief unilateral tolerance & bilateral torelance

A> **Tolerance** :- It is the difference between high limit of size and low limit of size of a part. (Either shaft or hole)

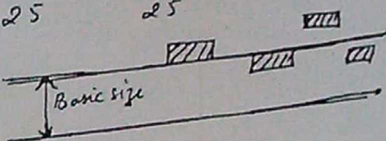
Tolerance is provided because it is very difficult to manufacture a part of exact size, so some variation in the parts are permissible to manufacture easily.

Tolerance is considered with part alone. It is an absolute value without sign.

Based on the tolerance provided on a part it is classified into two types. 1. unilateral tolerance 2. Bilateral tolerance

UNILATERAL TOLERANCE :- In this system the dimension of a part is allow to vary only on one side of Basic size. (or) In this system tolerance is provided only on one side of Basic size. This system is preferred in interchangeablity.

eg. $25^{+.02}_{+.01}$ $25^{+.06}_{+.04}$ $25^{+.02}_{+.00}$ $25^{+.02}_{-.00}$ $25^{-.01}_{-.02}$ $25^{-.04}_{-.06}$

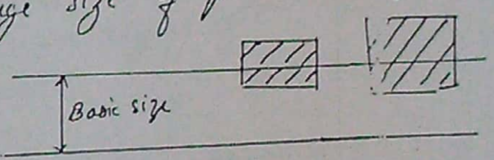


BILATERAL TOLERANCE :-

In this system the dimension of a part is allow to vary on both the sides of Basic size (or) In this system tolerance is provided on both the sides of Basic size.

This system is preferred in large size of parts manufacture.

eg. $25^{+.02}_{-.01}$ $25^{+.04}_{-.04}$



Q. What is fit. Classify them ?.

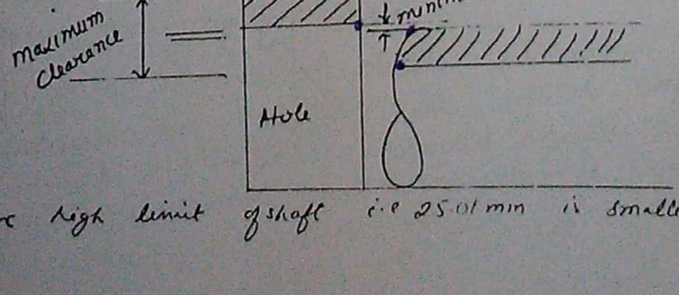
FIT :- It is the relationship existing between two mating parts when assembled together. (or)

It is the degree of tightness or looseness of mating parts while performing any function.

Depending upon the limits provided on shaft and hole fits are classified in three types

i) Clearance fit ii) Interference fit iii) Transition fit.

i). **Clearance fit** :- when the high limit size of shaft is smaller than the low limit size of hole; then the relation which occurs after mating is clearance. The fit is called clearance fit. Ex. Sliding fit & Running fit



Ex. for same basic size

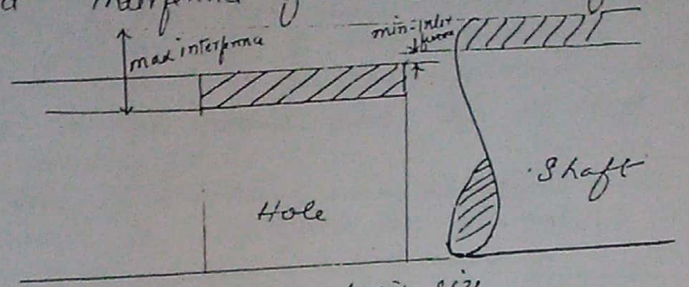
for Hole limit $25^{+.04}_{+.02}$

Shaft limits $25^{+.01}_{+.00}$ for clearance fit

Here high limit of shaft i.e 25.01 mm is smaller than low limit of hole i.e 25.02 mm

When the upper Limit of ~~shaft~~ hole is ~~more~~ less than the lower limit of ~~hole~~ shaft, then the type of fit is

exists after mating shaft and hole is interference. The fit is called interference fit Ex. Press fit, shrink fit



Ex. Hole limits for same basic size $25^{+.02}_{+.00}$

Shaft limits $25^{+.05}_{+.03}$

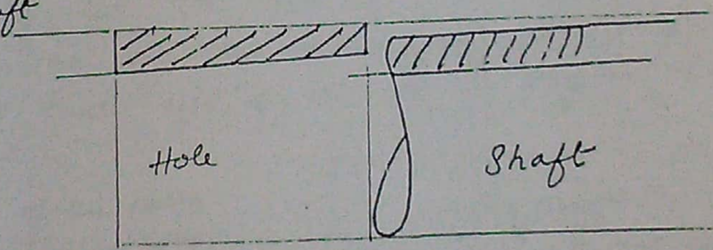
Here high limit size of hole i.e 25.02 is less than low limit size of shaft i.e 25.03 mm.

<u>Transition fit</u> :- In this type of fit the limits of shaft and hole are so selected that either clearance fit or interference fit may occur depending upon the actual size. Ex. push fit or keying fit.

Limits for Hole & shaft for same basic size

Hole $25^{+.04}_{+.01}$

Shaft $25^{+.02}_{+.00}$



→ <u>Allowance</u> :- It is the prescribed difference between the dimensions of two mating parts.

Whenever we are mating two parts inorder to achieve necessary type of fit allowance is provided.

Allowance is said to be <u>positive</u> when there is clearance between two mating parts.

Allowance is said to be <u>negative</u> when there is interference between two mating parts.

<u>Gauge</u> :- It is a device which is used to determine whether the object lies within the limits or not.

It is not calibrated one or it is scaleless. Measurement with gauges is easy and rapid which can be done by unskilled workers.

Q. Explain briefly Hole basis system and shaft basis system of limits & fits?

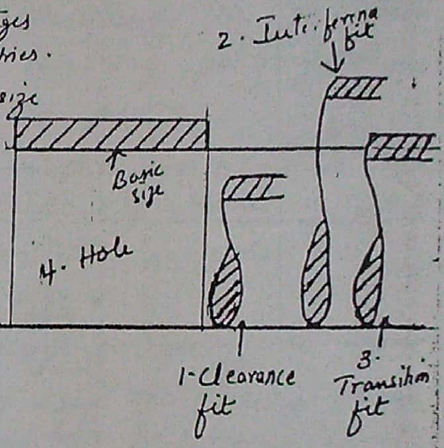
→ System of limits and fits are classified in two types based on series of standard allowance and tolerance to suit specific ranges of basic size when properly selected to ensure a class of fit.

1. **Hole basis system** :- In this system, the design size of hole whose lower deviation (i.e fundamental deviation) is zero of H hole is assumed as basic size and inorder to obtain different class of fit the size of shaft varies.

(or) you can say that in this system the size of hole is kept constant and size of shaft is varying to obtain the necessary fit.

Hole basis system is having many advantages because of which it is preferred in industries.

1. It is easy to manufacture a hole of constant size with the help of standard drills & reamers.
2. Gauging of constant size of hole is easier.
3. To vary the shaft size is also convinient because grinding and turning operations are external one.
4. Gauging of different size of shaft is also easier.
5. Production rate is increased hence reducing the production cost.



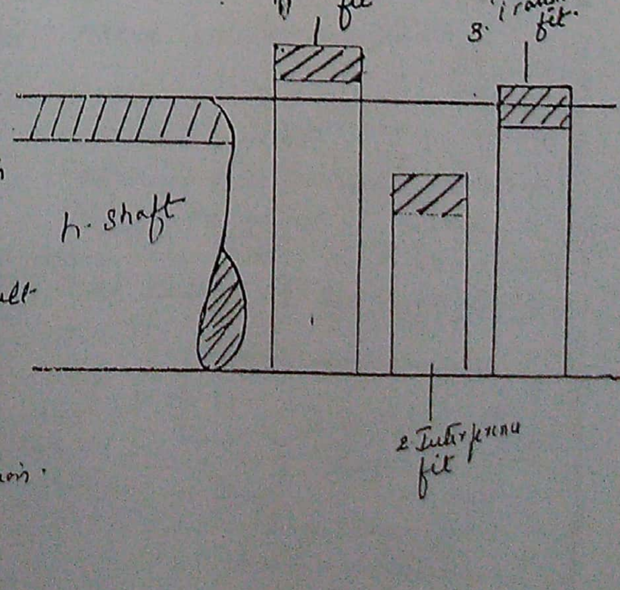
2. **Shaft basis system** :- In this system the design size of shaft whose upper deviation (i.e fundamental deviation) is zero of h-shaft is assumed as basic size and inorder to obtain different class of fit the size of hole varies.

(or) you can say that in this system the size of shaft is kept constant and size of the hole is varying to obtain the necessary fit.

The only advantage of this system is when on a single shaft it has to carry more than one accessory having different fits such as pulleys, gears, bearing & coupling.

It is not preferred in mass production because inorder to vary hole size drills, reamers, punches can not be adjusted, also gauging is difficult for different size of hole, being internal dimensions.

Production rate is decreased hence increasing cost of production.



a. What are limit gauges. Explain the principle of Go-Gauge and No-Go Gauge

→ In mass production it is very time consuming to measure the dimension of each part, therefore instead of measuring actual dimension of each part the conformance of each part with tolerance specification is checked by devices known as limit gauge. It is scaleless inspection tool of rigid design used to check dimensions, form and position of surface of parts. Limit gauges doesn't measure the actual size of part but only confirm whether the object lies within the tolerance limits or not. Limit gauges are having two ends one Go-Gauge and another No-Go Gauge. The difference in between the size of Go-Gauge and No-Go Gauge is equal to tolerance provided on parts. Limit Gauge for shaft is Ring or snap Gauge, for hole it is plug gauge.

Go-Gauge :- Go-Gauge is designed always considering the maximum metal condition of work piece. or you can say go-gauge always checks the maximum metal condition of a part.

In case of shaft the maximum metal condition is when the shaft is manufactured to its high limit of size and in hole the maximum metal condition is when the hole is manufactured to its low limit of size.

No-Go-Gauge :- No-Go gauge is designed always considering the minimum metal condition of work piece (or) you can say No-Go-Gauge always checks the minimum metal condition of a part

In case of shaft the minimum metal condition is when the shaft is manufactured to its low limit of size and in hole the minimum metal condition is when the hole is manufactured to its high limit of size.

NOTE - How to USE & CONCLUSIONS

for shaft :-

i) when the shaft is entering both the Go-Gauge and No-Go-Gauge then you can say the shaft is undersize and it is rejected.

ii) when the shaft is not entering both the Go-Gauge and No-Go-Gauge then you can say the shaft is oversize and it is rejected.

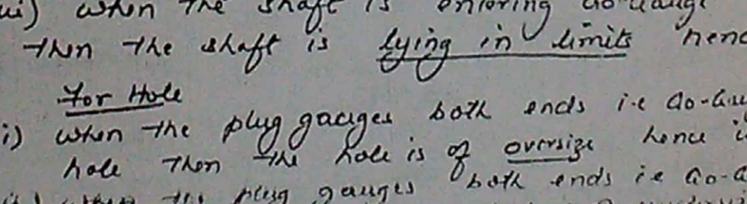
iii) when the shaft is entering Go-Gauge and not entering No-Go-Gauge then the shaft is lying in limits hence it is accepted.

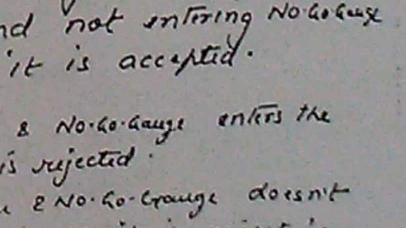
For Hole

i) when the plug gauges both ends i.e Go-Gauge & No-Go-Gauge enters the hole then the hole is of oversize hence it is rejected.

ii) when the plug gauges both ends i.e Go-Gauge & No-Go-Gauge doesn't enters the hole then the hole is of undersize hence it is rejected.

iii) when the Go Gauge of plug gauge enters the hole and No-Go-Gauge of plug gauge doesn't enters then the hole is of lying in limits hence the hole is accepted.





→ Explain Taylor's principle as applied to design of limit gauges.

A→ **Taylor's principle:-** It states that Go-Gauge should be of full form means it should check shape as well as size of the part where as No-Go gauge should check only one dimension of part at a time.

Explanation of principle:- Consider a part having rectangular hole. Now a plug gauge's Go-end enter the hole even if the corners are not square and depth of the hole is not as per requirement. Therefore to eliminate such sort of problem while using Go-Gauges Taylor's said that Go-Gauge should be of full form it means it should be geometrical equivalent to that of mating part.

No-Go end of plug gauge doesn't enter the hole even if one dimension either length or width is not correct, but after the product is rejected the operator doesn't understood where to work and what corrections has to be made. Therefore he says that there should be separate NO-GO gauges for measuring Length, width and depth. Here we can understand which dimension of the part is correct which one is not correct.

→ What is Gauge Makers Tolerance?

→ In order to manufacture a Gauge of exact size we require sophisticated machines, skilled operator and more time which is costly. Hence some tolerance is required at the time of manufacturing of Gauges. This tolerance is known as Gauge Makers Tolerance. Logically it is said to provide Gauge makers Tolerance as small as possible but this will increase cost of manufacturing. Therefore in General cases Gauge makers tolerance is 1/10 of work tolerance.

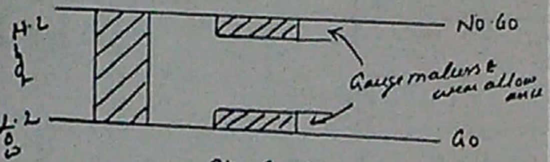
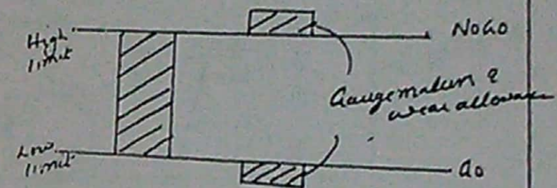
ex. $25^{+0.2}_{-0.2}$ in this case work tolerance is 0.4 mm

∴ 1/10 of 0.4mm = 0.04 mm is Gauge Makers Tolerance.

→ State why and how wear allowance are considered in Gauge designs.

→ When the gauges are put in service its measuring surface after coming in contact with objects surface rub constantly, which results in wearing of measuring surface of gauge. Due to which the gauge will lose its initial dimension. It means the size of Go plug gauge is reduced and size of Go ring gauge is increased. Hence a wear allowance is provided in opposite direction to that of wear. In General type of Gauges for Go-Gauge wear allowance is added for plug gauge and in ring or gap gauges it is substracted. Wear allowance is normally not considered for No-Go Gauges

Differentiate between workshop Gauges and Inspection Gauges.

Workshop Gauge	Inspection Gauge
1. Workshop gauges are used by the operators during manufacture of parts in shops.	Inspection gauges are used by inspectors for final inspection of manufactured parts.
2. The tolerance on the workshop gauge is arranged to fall inside the work tolerance.  Plug Gauge	The tolerance on inspection gauge is arranged to fall outside the work tolerance.  Plug Gauge
3. Some parts which are in work-tolerance limits may be rejected under workshop gauges	Some parts which are not in work tolerance may be accepted when tested by inspection gauges

How holes, shaft and fits are designated. Explain with suitable example –

→ A hole is designated by Capital letter while shaft by small letter. Basic hole by 'H' and basic shaft by 'h'

Ex
20 H7 f6 — 20mm is the basic size for both hole and shaft with tolerance grade 7.

H7 – Hole basis system

f6 – Shaft with tolerance grade 6

fit is clearance. because f-shaft is less than 20 mm and H7 hole is of 20mm. ∴ Therefore clearance is there in two mating parts.

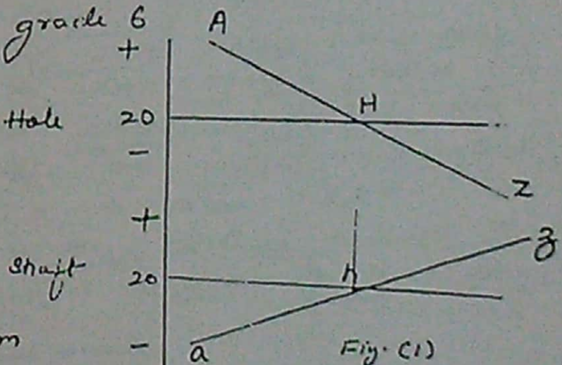


Fig. (1)

From fig (1) size of hole decreases from A – Z and size of shaft increases from a – z

therefore for deciding fits it has to be studied carefully.

Tolerance Grades are 18 i.e. IT01, IT0, IT1 – IT16.

H7 f6 – clearance fit

H7 g6 – Transition fit

Z7 g6 – Interference fit

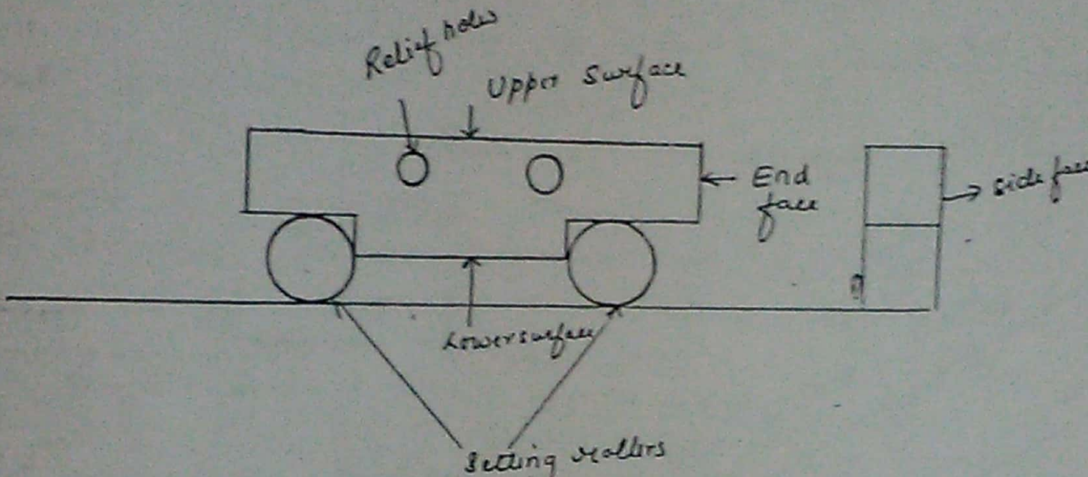
Measuring Instrument	Gauge
1. A device which is used to measure the actual dimension of part	A device which is used to confirm whether the object lies within limits or not
2. It is calibrated one	It is not calibrated one.
3. Time required is more	Time required is less.
4. Skilled operator is reqd.	Skilled operator is not reqd.
5. Not preferred in mass production	Preferred in mass production.

ANGULAR MEASUREMENT

The various instruments used for measurement of angles are as follows-

1. Sine bar
2. Angle Gauges
3. Bevel Protractor
4. Clinometer
5. Auto-collimator
6. Angle Dekkor

→ What is Sine bar and how sine bar is used to measure the angle of Component when it is i) Small ii) Large.



Sine Bar is a precision instrument used to measure or set an angle in combination with slipgauge. It consist of a horizontal steel bar made up of high carbon, high chromium corrosion resistant steel. First it is heated to about 760°c then quenched in water for suitably hardening, later on similarly by heating and cooling process is carried out and it is ground and stabilised. Two rollers of equal size is attached to the bar at each end. Relief holes are present in the bar due to which clamping devices can be engaged to support the object placed on sine bar. All the surfaces of sine bar and of roller are lapped and polished to a high degree of accuracy, with a Ra value 0.2 μm.

Length/Size of sine bar is equal to the distance between the axes of rollers. Normally sine bar is available in three lengths of 100mm, 200mm & 300mm.

Sine bar is available in two grades.

Grade A — Accuracy of 0.01 mm/m in length

Grade B — Accuracy of 0.02 mm/m in length

i) Use of Sinebar for measuring the angle of component when it is small.

In order to measure the angle of component when it is small place the component on sine bar and clamp it. Then place the sine bar on the surface plate with rollers in contact. Now place the combination of slip gauge below one roller till the upper surface of component comes parallel to the upper surface of surface plate, this is to be tested with the help of dial gauge indicator. when the upper surface is truly parallel then the pointer of dial gauge indicator remains constant when moving the dial gauge from one end to another.

Stop inserting any more slip gauge. The angle of the component is then given by relation (See fig (1))

$$\sin\theta = \frac{h}{L} \quad \therefore \theta = \sin^{-1}\frac{h}{L}$$

where h – (height of Combination of slip gauge)
L – (Length of sine bar i.e distance between axes of two rollers)

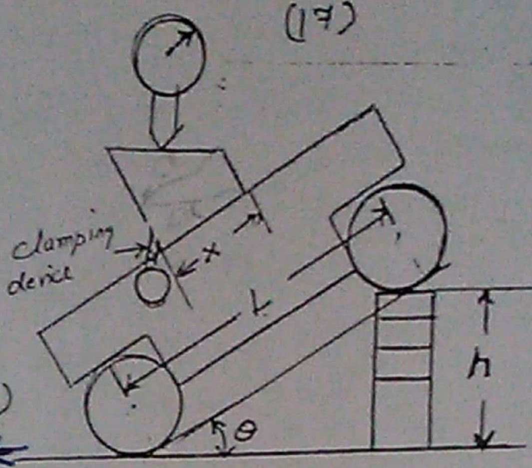


Fig (1)

→ But practically it is time consuming to bring upper surface of component truly parallel to that of surface plate. Hence to overcome this situation whenever you feel that after inserting slip guages below roller there is minimum variation when dial gauge indicator is moving over the surface of component stop .... inserting slip gauges note down the variation as 'dx' over length of component 'x'.

$$\therefore \text{Variation in angle } d\theta = \sin^{-1}\frac{dx}{x}$$

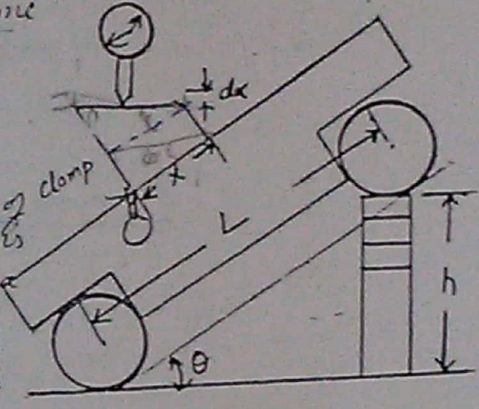


Fig (2)

Hence Actual Angle now becomes

$$\theta \pm d\theta = \sin^{-1}\frac{h}{L} \pm \sin^{-1}\frac{dx}{x}$$

$$\theta \pm d\theta = \sin^{-1}\left(\frac{h}{L} \pm \frac{dx}{x}\right)$$

ii) Use of sine bar when the component is of large size

To measure the angle of component when it is of large size. first place the component on surface plate now place the sine bar on the Component so that one of the roller is resting on component and insert combination of slip gauges under second roller; till you see that there is minimum variation of pointer of dial gauges indicator which is moving on the upper surface of sine bar. Let the variation be 'dh' over a length 'L' of sine bar

So the actual angle from fig (3)

$\theta \pm d\theta$ is given by

$$= \sin^{-1}\left(\frac{h}{l} \pm \frac{dh}{l}\right)$$

$$= \sin^{-1}\left(\frac{h \pm dh}{L}\right)$$

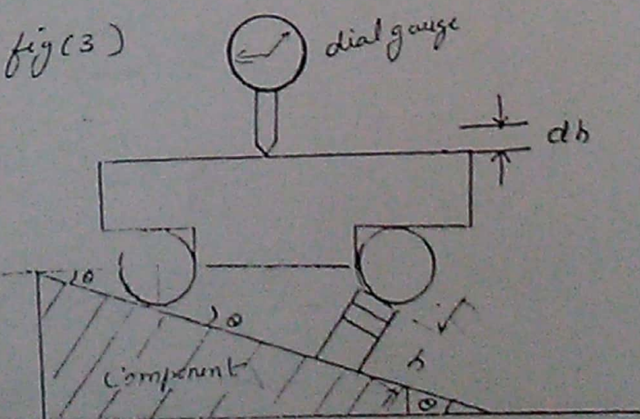


Fig (3)

→ What are the factors on which accuracy of sine bar depends

→ The accuracy of sine bar depends upon following factors

1) Two rollers should be of equal size and truly cylindrical in shape.
2) Roller axes should be parallel to each other.
3) Parallelism of roller axes to upper surface of sine bar
4) Flatness of upper surface of bar
5) When placed on surface plate the upper surface of sine bar should be parallel to upper surface of surface plate.

If any of the above factors are not taken into consideration the error will be introduced in measurement with sine bar

→ Explain why it is not preferred to use sine bar for measuring angle greater than 45°.

→ The slip gauge combination (h) required to set an angle (θ) is given by.

$$h = L \sin\theta$$

partial differentiation of above equation w.r.t. θ.

$$\frac{dh}{d\theta} = \frac{d}{d\theta}(L\sin\theta)$$

$$= L\frac{d}{d\theta}(\sin\theta) + \sin\theta \cdot \frac{d}{d\theta}(L)$$

$$\frac{dh}{d\theta} = L\cos\theta + \sin\theta \cdot \frac{dL}{d\theta}$$

$$dh = d\theta\left(L\cos\theta + \sin\theta \cdot \frac{dL}{d\theta}\right)$$

$$dh = L\cos\theta\, d\theta + \sin\theta \cdot \frac{dL}{d\theta} \times d\theta$$

$$L\cos\theta\, d\theta = dh - \sin\theta\, dL$$

$$d\theta = \frac{(dh - \sin\theta\, dL)}{L\cos\theta}$$

$$d\theta = \frac{dh}{L\cos\theta} - \frac{\sin\theta}{\cos\theta}\frac{dL}{L}$$

divide & multiply by sin θ

$$d\theta = \frac{dh\cdot\sin\theta}{L\cos\theta\cdot\sin\theta} - \frac{\sin\theta}{\cos\theta}\cdot\frac{dL}{L}$$

$$= \frac{dh\tan\theta}{L\sin\theta} - \tan\theta\cdot\frac{dL}{L}$$

$$= \tan\theta\left(\frac{dh}{L\sin\theta} - \frac{dL}{L}\right) \quad \because L\sin\theta = h$$

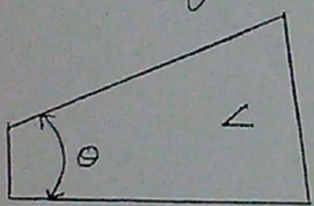
$$d\theta = \tan\theta\left(\frac{dh}{h} - \frac{dL}{L}\right) \rightarrow (1)$$

Error 'dθ' is function of tan θ and also error in slip gauge combination and roller spacing. From eqn (1) it is clear that value of tan θ increases from 0°–45° i.e from 0 – 1, but from 45° onwards the value of tan θ increases above unity, which results in increase of error dθ.
Hence sine bar is not preferred above 45°.

Write a short note on angle gauges.

→ **Angle Gauges:** Dr Tomlinson developed angle gauges in 1941 which is made up of high grade steel. Steel is first heated to about 760°c Then it is quenched in water to resist wear. Then it is stabilised by simultaneously heating and cooling. Now the pieces are being cut which is lapped and polished to a high degree of accuracy and flatness on its measuring surfaces. It is a wedge and it is 75mm long and 16mm wide. Angle gauges are available in two sets due to which any angle canbe set to the nearest of 3" or 6". Each angle gauge is accurate to within one-second. On every angle gauge V is marked which indicates the direction of included angle. Angle is added when both the 'V' is in same direction as in fig (1) and subtracted when 'V' is in opposite direction as in fig (2)

These angle gauges together with square block can be so wrung that any angle between 0° to 360° Can be set but the block prepared by the Combination of these square block and angle gauges is bulky because of which angle gauges are used as reference along with other measuring device.



ANGLE GAUGE

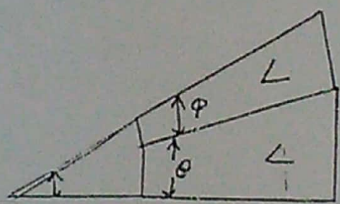


fig (1)
(θ+φ)
Addition

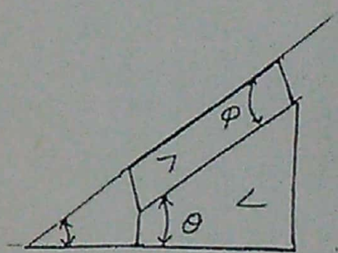


fig (2)
(θ − φ)
Substraction

USES:- Generally the angle gauges are used in industries for quick measurement of angles between two surfaces to check whether the components angle is within its tolerance

Two sets of Angle Gauges is as under:-

1 set consists of 12 pieces and a square block.

1° 3° 9° 27° 41° (degrees)

1' 3' 9' 27' (minutes)

6" 18" 30" (Seconds)

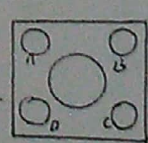
To Remember
1° = 60'
1' = 60"

2nd set consists of 13 pieces and a square block.

1° 3° 9° 27° 41°

1' 3' 9' 27'

3" 6" 18" 30"



Square block.

NOTE:- While constructing any angle we have to use minimum number of angle gauges, first we have to construct degrees, then minutes and seconds but while constructing degrees if minutes can be taken into consideration that is much better and so on.