MODULE – 5

LESSON CONTENTS:

Gauges: Classification of gauges, Taylor's principle, design of GO, NO GO gauges, wear allowance on gauges, types of gauges- plain plug gauges, ring gauges, snap gauge, limit gauge, simple problems.

Comparators: Introduction to comparators, classification, characteristics, systems of displacement amplification in mechanical comparators, Reed type, Sigma comparator, Zeiss ultra-optimeter, Solex air gauge, ultrasonic gauges, LVDT. **Angular Measurements**: Bevel protractor, sine bar, angular gauges, numerical on building of angles.

PLAIN GAUGES

- Gauges are **inspection tools without a scale** ***which serve to check the dimensions of the manufactured parts.***
- **Limit gauges ensure the size** of the component being inspected lies within its specified limits. They are *non-recording ·and do not determine the actual size of the part.*
- **Plain gauges** are used for checking plain (unthreaded) holes and shafts.

CLASSIFICATION OF PLAIN GAUGES

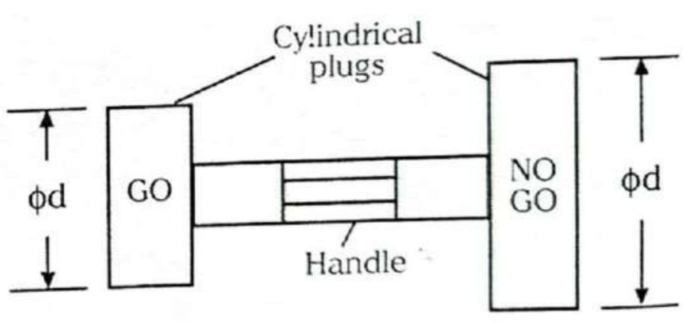
1) **According to their type :**
   a) Standard gauges
   b) Limit gauges
2) **According to their purpose**
   a) Workshop gauges
   b) Inspection gauges
   c) Reference or master gauges
3) **According to the form of the tested surface**
   a) Plug gauges for checking holes
   b) Snap and ring gauges for checking shafts
4) **According to their design**
   a) Single limit and double limit gauges
   b) Single ended and double ended gauges
   c) Fixed and adjustable gauges.

LIMIT GAUGING

- There are several methods available to determine the dimensions of components in a system of limits and fits.
- The method of measurement ***adopted for mass production of parts is called the system of limit gauging***. It has an advantage that it can be operated by unskilled persons.
- Instead of measuring actual dimensions, the conformance of product with tolerance specifications can be checked by a "GO" and "NOT GO" gauges. These gauges represent the limit sizes of the work piece, as per the specified product tolerances.
- A "GO" gauge represents the maximum material condition of the product (i.e. minimum hole size, or maximum shaft size) and conversely,
- A “NOT GO” or “NO-GO” gauge represents the minimum material condition (i.e. maximum hole size, or minimum shaft size)

PLUG GAUGES

- These are the limit gauges for a hole and consists of two cylindrical wear resisting steel plugs whose sizes are made to the limiting values of the hole dimension.
- The plug made to the lower limit of the hole is known as "GO" gauge, and this will obviously enter any hole which is not smaller than the lower limit allowed.
- The plug made to the upper limit is known as "NOT-GO" or "NO-GO" gauge, and will not enter any hole which is smaller than the upper limit allowed.
- GO and NO-GO plugs are arranged at either end of a common handle.



(a) Double ended plug guage

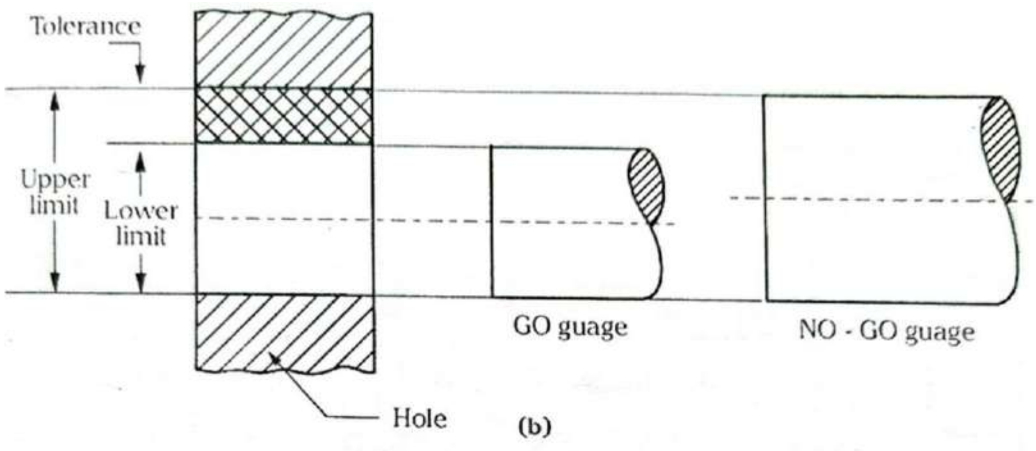


Fig. 1

- The handles of heavy plug gauges are made of any light metal alloys.
- While the handles of small plug gauges can be made of some non-metallic materials.
- The plug gauges are normally double ended for sizes upto 63 mm and for sizes above 63 mm they are single ended type as shown in the **Fig. 2**. below

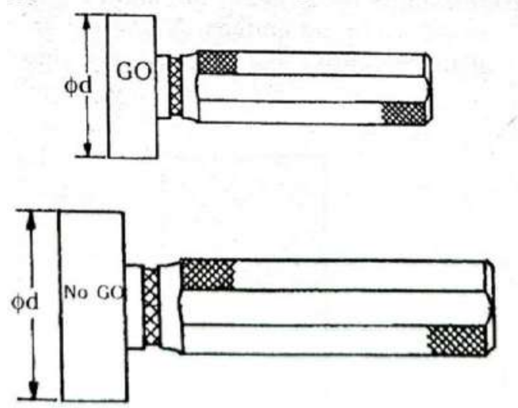


Fig. 2 Single Ended Plug Gauges

PROGRESSIVE FORM OF PLUG GAUGE

- For smaller through holes, a progressive form of plug gauge as shown in Fig. is used.
- In this both the GO and NOGO gauges are on the same side separated by a small distance.
- First the GO portion is inserted into the hole. Further entry will be obstructed by the portion if NOGO of the hole is within the tolerance limits.

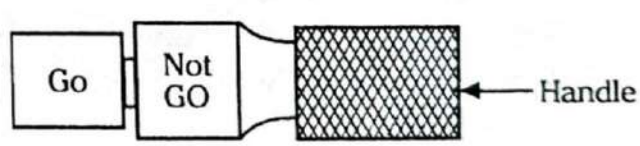


Fig. 3 Progressive Form of Plug Gauge

SHELL FORM OF PLUG GAUGE

- For dimensions over 100 mm and upto 250 mm a shell form of plug gauges as shown in the Fig. 4 are used.
- While for very large holes spherically ended gauges are used.

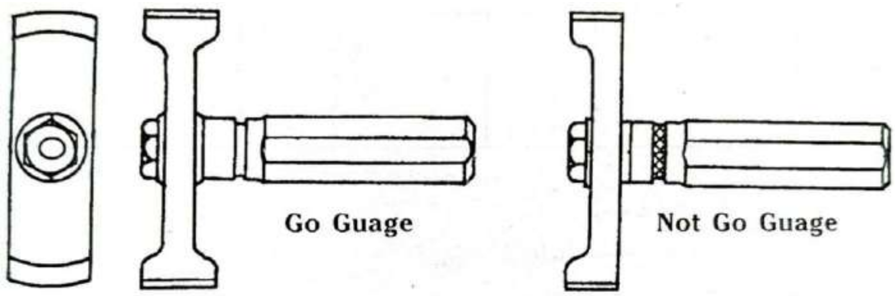


Fig. 4 Shell Form of Plug Gauges

RING GAUGES

- Ring gauges arc limit gauges for gauging the shafts, and are used in a similar manner to that of GO and NO-GO plug gauges.
- A ring gauge consists of a piece of metal in which a hole of the required size is bored as shown in the figure 5.

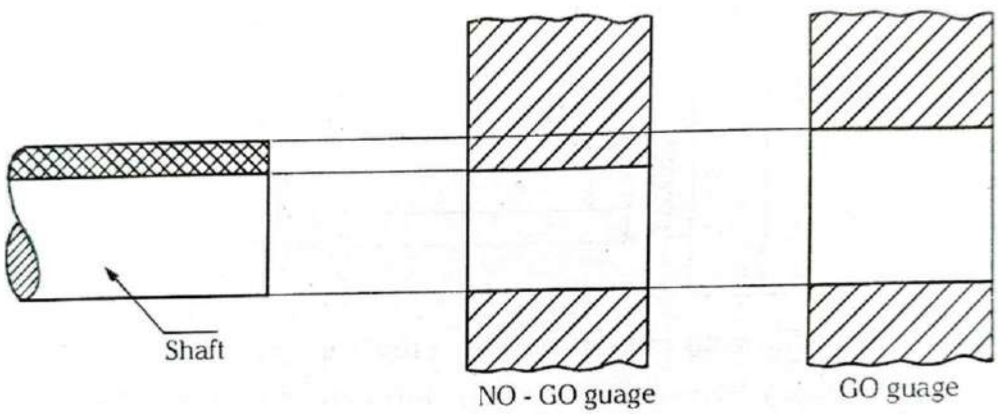
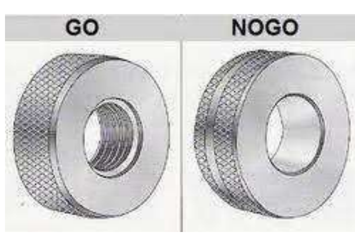


Fig. 5



- The general shapes of "GO" and “NO GO” gauges for the range 3mm to 70 mm in 10 steps **Fig. 6**.
- And for the range 70 to 250 mm in 17 steps are as shown in **Fig. 7**.

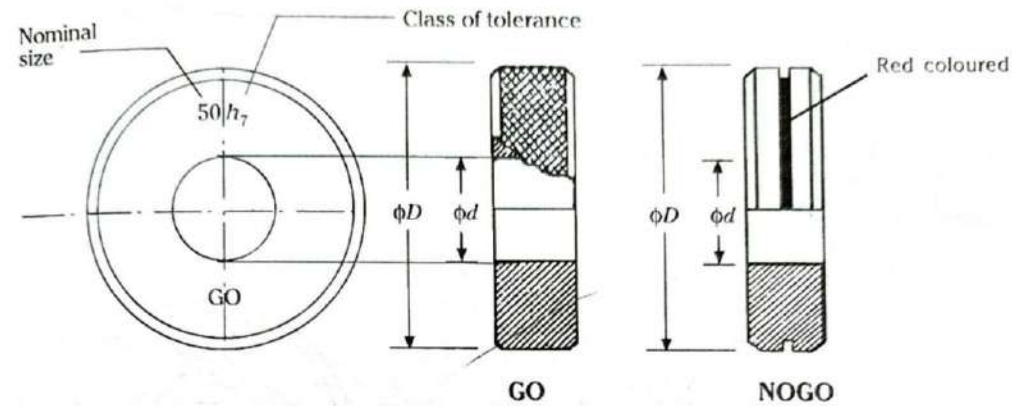


Fig. 6 GO and NO GO Ring Gauges for Dimensions 3 to 70 mm

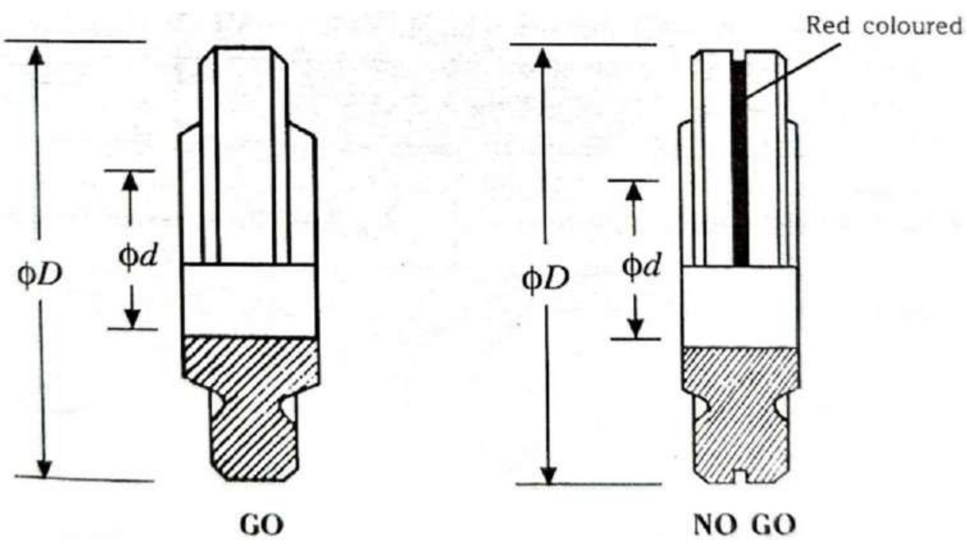


Fig 7 GO and NO GO Gauges for Dimensions 70 to 250 mm

SNAP GAUGES or GAP GAUGES

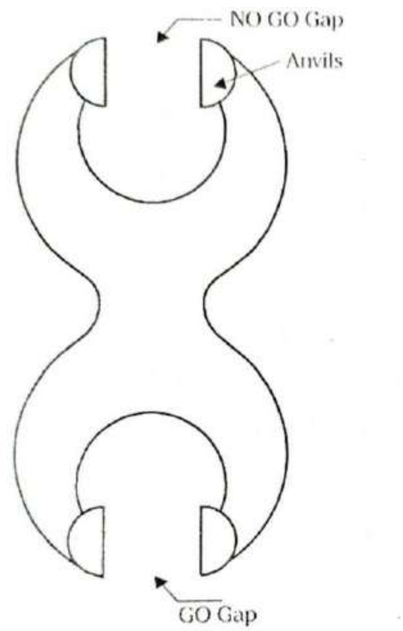


Fig 1 Double Ended Snap Gauge

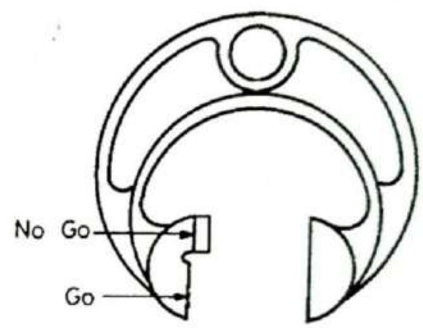


Fig 2 Progressive Type Snap Gauge

- A snap gauge usually consists of a plate or frame with a parallel faced gap of the required dimension as shown in the Fig. 1.
- In these gauges the gauging anvils can be adjusted endwise to suit any particular limit dimension required.
- Snap gauges are used for both cylindrical as well as non cylindrical work as compared to ring gauges which are conventionally used only for cylindrical work.
- Double ended snap gauges as shown in Fig. can be used for sizes ranging from 3 to 100 mm. For the sizes above 100 to 250mm a single ended progressive type snap gauge is used.

ADVANTAGES OF GAUGES

1. They are free from errors
2. They are portable and independent of power supply
3. They require no auxiliary equipment's and set up
4. Various dimensions can be checked
5. They are inexpensive
6. They provide uniform standards

DISADVANTAGES OF GAUGES

1. Some of the components which are within work tolerance limits may be rejected by the workshop gauges. Hence, they have to be checked again by inspection gauges and may be accepted after that.

2. Some components which are not within the work tolerance limits may be accepted when tested by inspection gauges.
3. The workshop and inspection gauges have to be made separately since their tolerance zones are different.

GAUGE MATERIALS

Essential considerations in the selection of materials for gauges

- Hardness to resist wear
- Stability to preserve size and shape
- Corrosion resistance
- Machinability for obtaining the required degree of accuracy
- Low coefficient of linear expansion to avoid temperature effect

MATERIALS USED FOR GAUGES

HIGH CARBON STEEL:

- Cast steel (0.8 to 1.0% C) either water or oil hardened is relatively inexpensive and most commonly used material for gauges.
- Bigger sizes of plug gauges are made from case-hardening steels.

MILD STEEL:

- These gauges are usually case hardened on the working surface.
- They are used for gauges of shapes which might cause cracking during hardening if made in other steels.
- Mild steel is easily machinable, stable and expensive.

CASE HARDENED STEEL:

- Low carbon case-hardening steel is used for majority of small and medium sized gauges. It has the advantages of good Machinability, stability and the ability to be surface hardened to varying depths at any required position.

OIL HARDENED STEEL:

- It is best suited where gauges are required in huge quantities.

CAST IRON:

- It is often employed for the bodies or frames of large gauges, whose working faces are hard inserts of tool steel or cemented carbides.

PLATING, AND HARD ALLOYS:

- Chromium plating have led to its increasing use for gauges. It renders the surface of the gauges very hard coupled with resistance to abrasion and corrosion.

- Chromium plating also proved a useful method of reclaiming the worn out gauges. Hard alloys of the tungsten carbide type are finding increasing applications in gauges.

I N VA R :

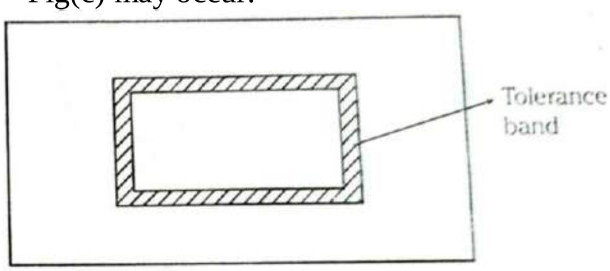
- Invar containing 36% nickel has low coefficient of expansion but is unsuitable over a long period.

G L A S S :

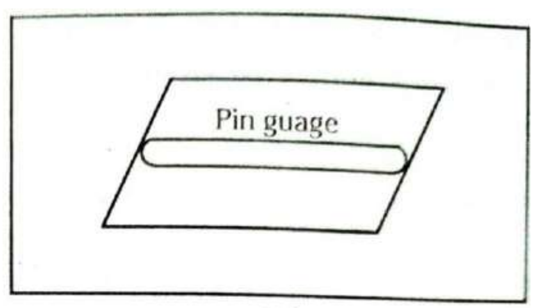
- Glass gauges in spite of their good wear qualities have not gained much popularity because if dropped or heavily knocked they may get damaged. Glass gauges have the advantage of eliminating the corrosive effects due to perspiration from hands.
- Their dimensions are not affected by temperature changes due to their low coefficient of expansion. Further when a glass gauge is scratched or chipped, no burn is left on the gauge.

TAYLOR'S PRINCIPLE OF GAUGE DESIGN

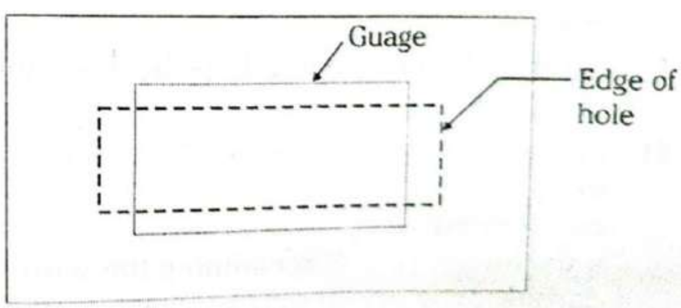
- It states that Go-gauges should be of full form, that is, they should check the shape as well as the size, whereas a NO-GO gauge should check only one dimension.
- This principle is as shown in the Fig(a) shows a rectangular slot in a component, with the tolerance band shaded.
- Pin gauges for the length and width, made to the lower limits for their respective dimensions may "GO" and thereby indicate that the slot is satisfactory although the corners may not be square, as shown in Fig(b).
- It is necessary for the GO gauge to be a rectangular plate, that is, to be a full-form gauge.
- The NO-GO gauge, however, must not be of full form, if it is so, the condition shown at Fig(c) may occur.



(a)



(b)



(c)

- Here the slot, shown by the dotted lines, has the correct width but its length is excessive.

- As seen in the Fig(c) the gauge will not go through the slot which is therefore passed as being satisfactory.
- The NO GO gauge must consists of two separate pin gauges, one for the length and the other for the width.

TAYLOR'S PRINCIPLE IN THE DESIGN OF LIMIT GAUGES

- According to Taylor "GO" and "NO GO" limit gauges should be designed to determine the **maximum and minimum metal limits.**

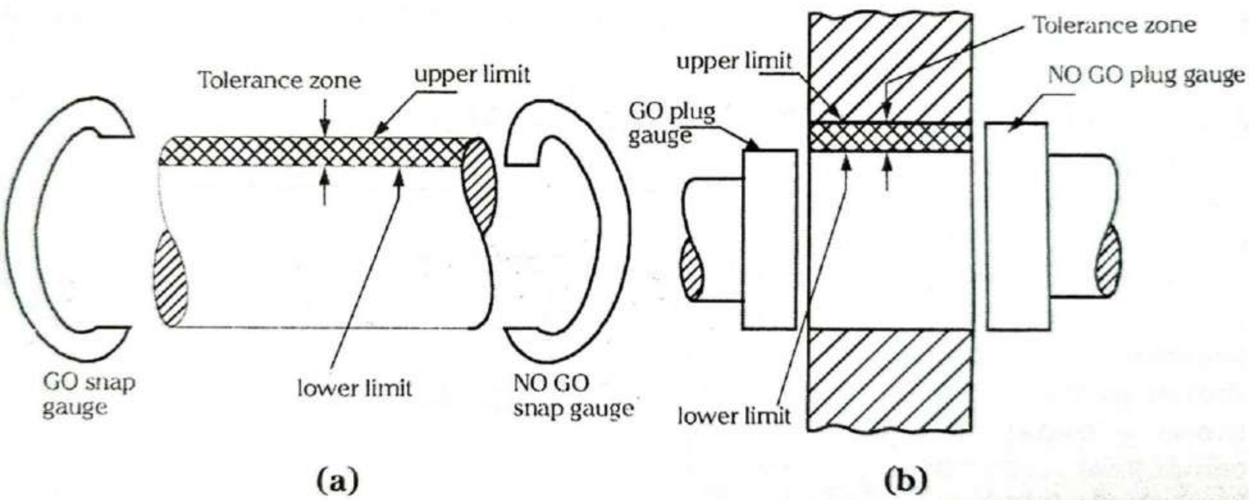


Fig. Illustration of Taylor's principle in the design of limit gauges

<u>GO LIMIT GAUGE</u> : A GO gauge corresponds to **maximum metal condition**. For example, upper limit of a shaft or lower limit of a hole as shown in Figures (a) and (b).

- **The *'GO' snap gauge* corresponds to *upper limit of the shaft*, while the *"GO" plug gauge* corresponds to *lower limit of the hole.***
- The "GO" gauges should check all the possible elements of dimensions at a time (roundness, location size etc).
- A GO plug gauge must be of corresponding mating section and preferably to the full length of the hole so that straightness of the hole can be checked.

<u>NO GO limit gauge</u>:

- A NOGO gauge corresponds to minimum metal condition.
- ***<u>For example</u>***, *lower limit of a shaft and the upper limit of a hole.*
- It should check only one feature of the component at a time.
- The ***NOGO snap gauge*** corresponds to lower limit of shaft while the ***NOGO plug gauge corresponds to upper limit of hole***

GAUGE TOLERANCE

- Gauges, like any other job requires a manufacturing tolerance.
- Therefore, the *theoretical gauge size as determined from the maximum and minimum metal limits of the component* needs some modification to allow for reasonable imperfections in the workmanship of the gauge maker.
- This, tolerance on the gauges allowed for the workmanship of a gauge maker is known as **Gauge maker's tolerances or gauge tolerances.**
- This tolerance should be kept as small as possible. However, it will have an impact on the cost of making the gauge.
- The tolerance on each gauge whether GO or NO-GO is **1/10** of the work tolerance.

METHODS OF GAUGE MAKER'S TOLERANCE

There are three methods of giving tolerance on snap and plug gauges.

1. First system (For Workshop and Inspection gauges)
2. Second System (Revised Gauge Limits)
3. Third System (Present British System)

1. FIRST SYSTEM (FOR WORKSHOP AND INSPECTION GAUGES)

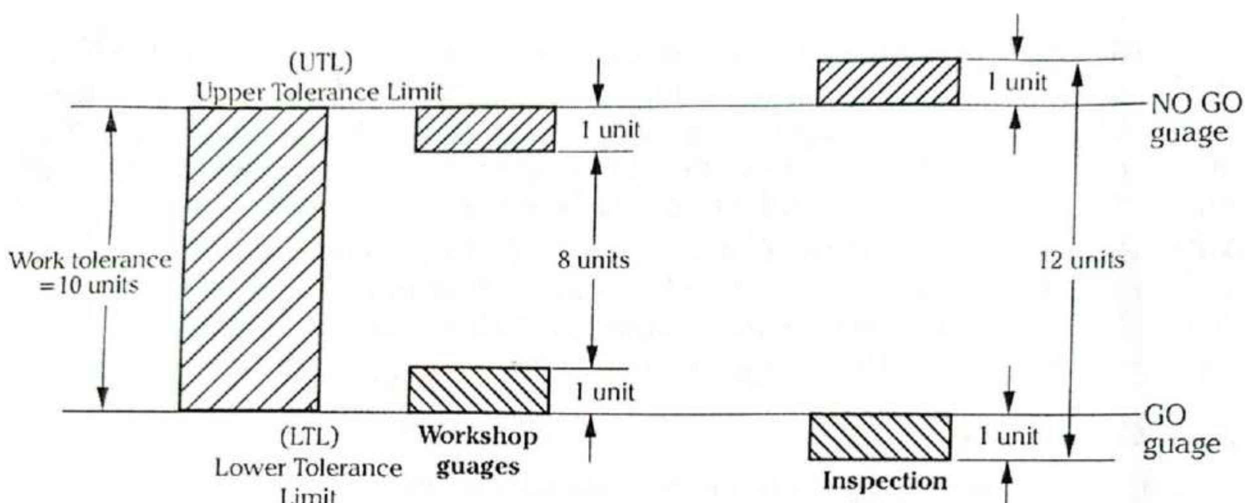


Fig.

- In this method, workshop and inspection gauges are made separately and their tolerance zones are different.

- According to this system the tolerances on the workshop gauges are arranged to fall within the work tolerance, while the inspection gauge tolerances fall outside the work tolerance as shown in Figure.
- Further in workshop gauges, "GO" gauge will consume 10% of work tolerance and similarly the tolerance on "NOGO" gauge will be 1/10 of work tolerance.
- So, if work tolerance is 10 units then only 8 units will be left on the workshop gauges. Since, the difference between the minimum of "NOGO" and maximum of "GO.", the tolerance on "GO" as well as "NOGO" gauges individually being, one unit each.
- **In inspection gauges, gauges are kept beyond work tolerance by 10% of its value.**

Disadvantages of Workshop and Inspection Gauges

1) Some of the components which are with in work tolerance limits may be rejected by the workshop gauges. Hence, they have to be checked again by inspection gauges and may be accepted after that.
2) Some components which are not with in the work tolerance limits *may be accepted when tested by inspection gauges.*
3) The ***workshop*** and ***inspection gauges*** have to be made **separately since their tolerance zones are different.**

2. SECOND SYSTEM (REVISED GAUGE LIMITS)

- In this system the disadvantages of inspection gauges are reduced by ***reducing the tolerance zone of inspection gauges***, while the workshop gauge tolerance remains the same.
- In this system, for "GO" and "NOGO" inspection gauges, the 110% of the range of work tolerance is covered instead of 120% in the first system as shown in the Fig.

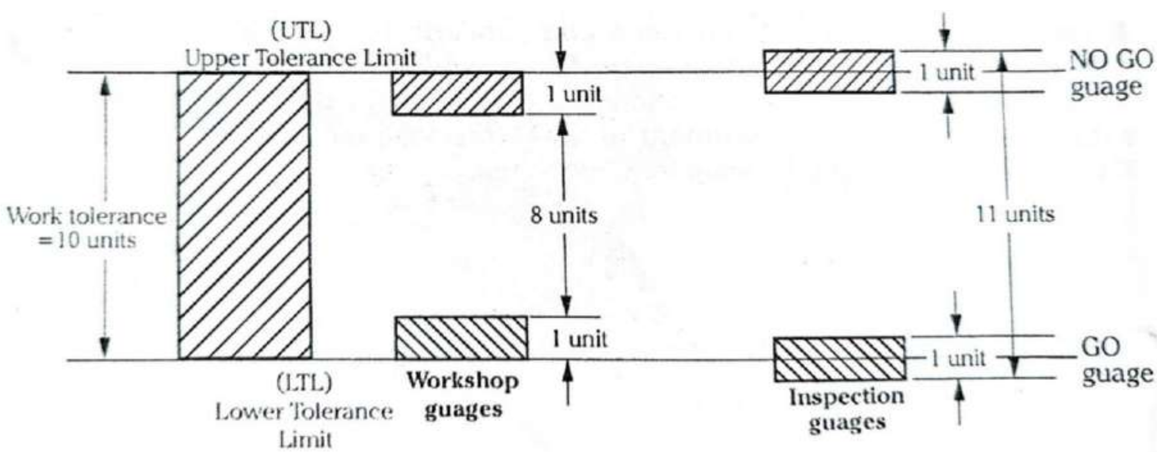
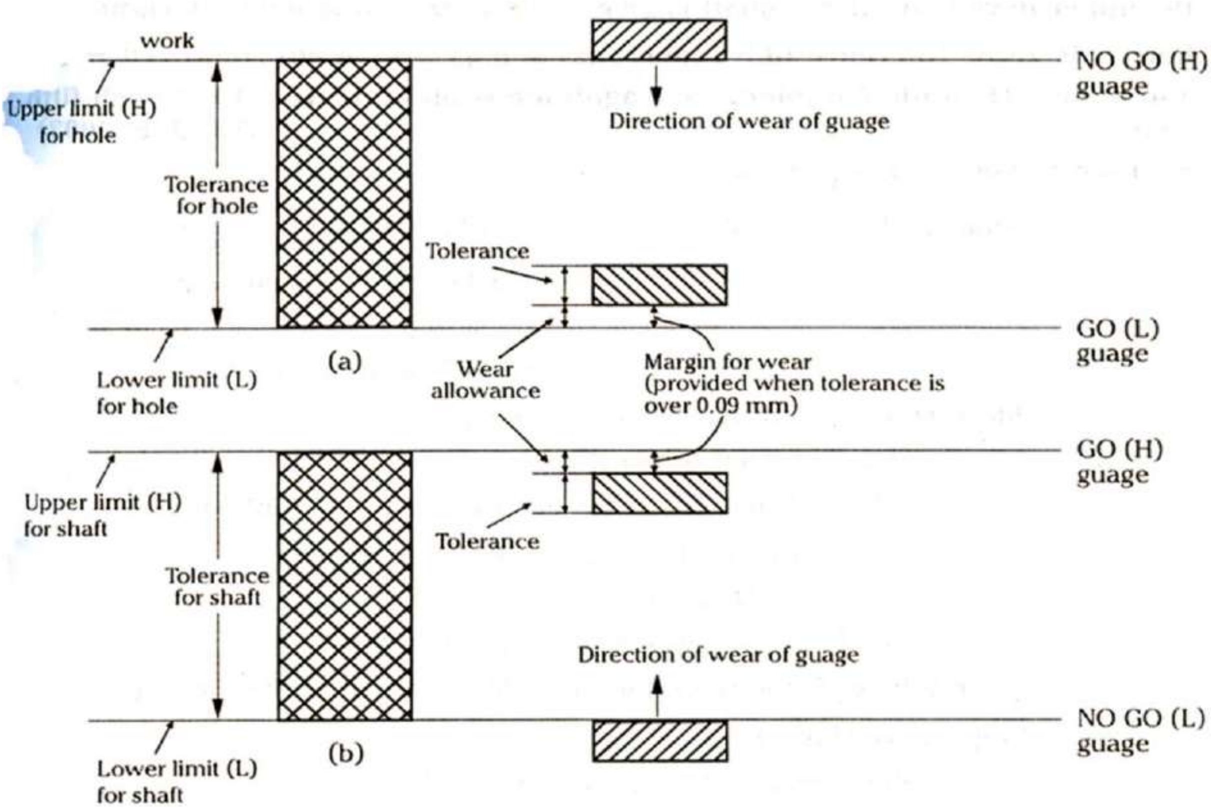


Fig.

THIRD SYSTEM (PRESENT BRITISH SYSTEM)

In this system, following principles are followed along with Taylor's principle.

1) Tolerance will be as wide as consistent *with satisfactory functioning, economical production and inspection.*
2) ***No component will be accepted*** which lies outside the drawing specified limits.



- This system gives the ***same tolerance limits*** *on* ***workshop and inspection gauges*** and the **same gauges can be used for both purposes.**
- The tolerance zone for the "GO" gauges will be placed within the work-limits while the tolerance zone for the "NOGO" gauges will be outside the work-limits as shown in Fig.
- Provision for wear of "GO" gauges is made by introducing a margin (called wear allowance) between the tolerance zone for the gauge and maximum metal limit of the work.
- Wear should not be permitted beyond the maximum metal limit of thew, when the limit is of critical importance.
- Its magnitude is **1/10** of the gauge tolerance. Thus, when work tolerance is less than 0.09

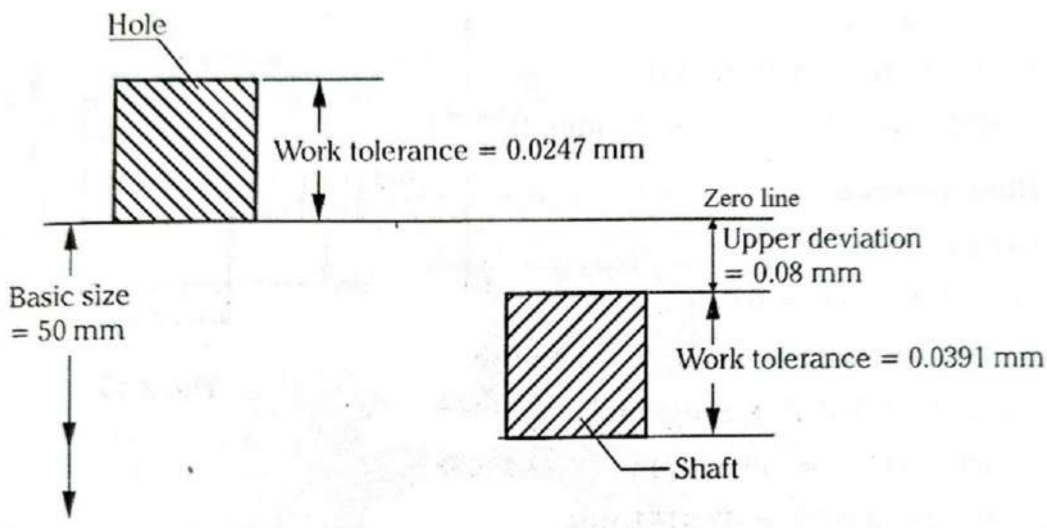
mm there is no need of giving allowance for wear.

- **If work tolerance is more than 0.09 mm then 10% gauge tolerance is given only on "GO" gauge for wear.**

WEAR ALLOWANCE CONSIDERATION ON GAUGES

- The measuring surfaces of ***"GO" gauges which constantly rub against the surfaces of the parts during inspection are consequently subjected to wear and lose their initial size.***
- Thus, due to wear, **the size of "GO" plug gauges is reduced**, *while that of* ***"GO" snap gauges is increased.***
- But it is **desirable to prolong the service life of gauges** and therefore a ***special allowance called wear allowance is added in a direction opposite to the wear.***
- **For this reason, *"GO' plug gauges are made with two positive deviations*** *and* ***"GO" snap gauges with two negative deviations from the nominal size.***

∴ Limits of 50 g_6 Shaft = □□ $^{-□.□□□}_{-□.□□□□}$ ***mm***



Design of Gauges:

(i) **Plug gauge design:**

According to new system, “GO” gauges are given 1/10 of work tolerance within the tolerance zone and “NOGO” gauges, outside it.

Note: If work tolerance < 0.09 mm, Neglect wear allowance on "GO" gauge

a) **GO gauge**

Work tolerance of Hole = 0.0247 mm

$$\therefore \textbf{Plug}\text{ Gauge tolerance} = \frac{\text{Work tolerance of Hole}}{10}$$

$$\therefore \textbf{Plug}\text{ Gauge tolerance} = \frac{0.0247}{10}$$

$\therefore$ **Plug** Gauge tolerance = **0.00247 mm**

$\therefore$ **Limits for “GO” plug gauge are**

50 + 0.0000 = **50.0000 mm**

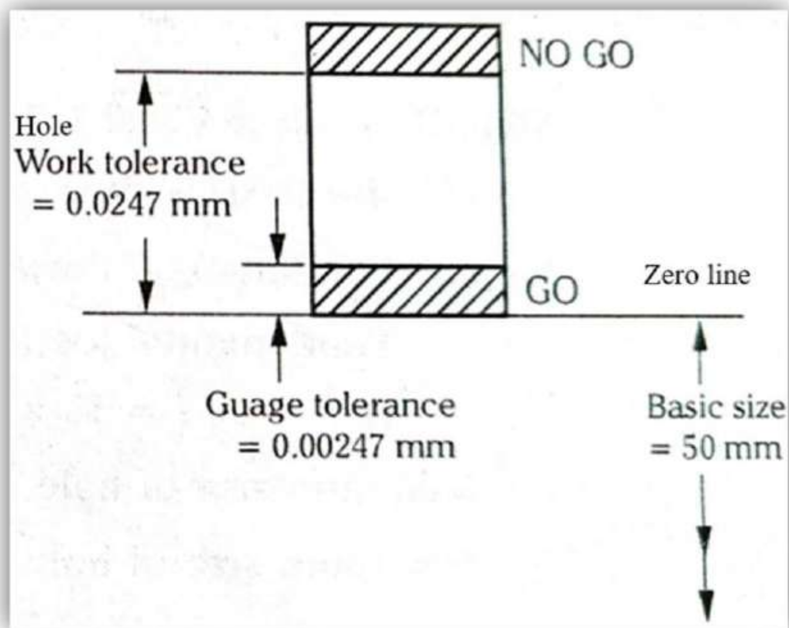
50 + 0.00247 = **50.00247 mm**

b) **NO GO gauge**

$\therefore$ **Limits for “NO GO” plug gauge are**

50 + 0.0247 mm = **50.0247 mm**

50.0247 + 0.00247 mm = **50.02717 mm**



ii. **RING GAUGE DESIGN:**

According to new system, "GO" gauges are given **1/10** of work tolerance within the tolerance zone and "NOGO" gauges, outside it.

Note: If work tolerance < 0.09 mm, Neglect wear allowance on "GO" gauge

a) **GO gauge**

Work tolerance of shaft = 0.0391 mm

∴ **Ring** Gauge tolerance $= \frac{\text{Work tolerance of Shaf}}{10}$

∴ **Ring** Gauge tolerance $= \frac{0.0391}{10}$

∴ **Ring** Gauge tolerance = 0.00391 mm

∴ **Limits for "GO" ring gauge are**

$50 - 0.08 =$ **49.92 mm**

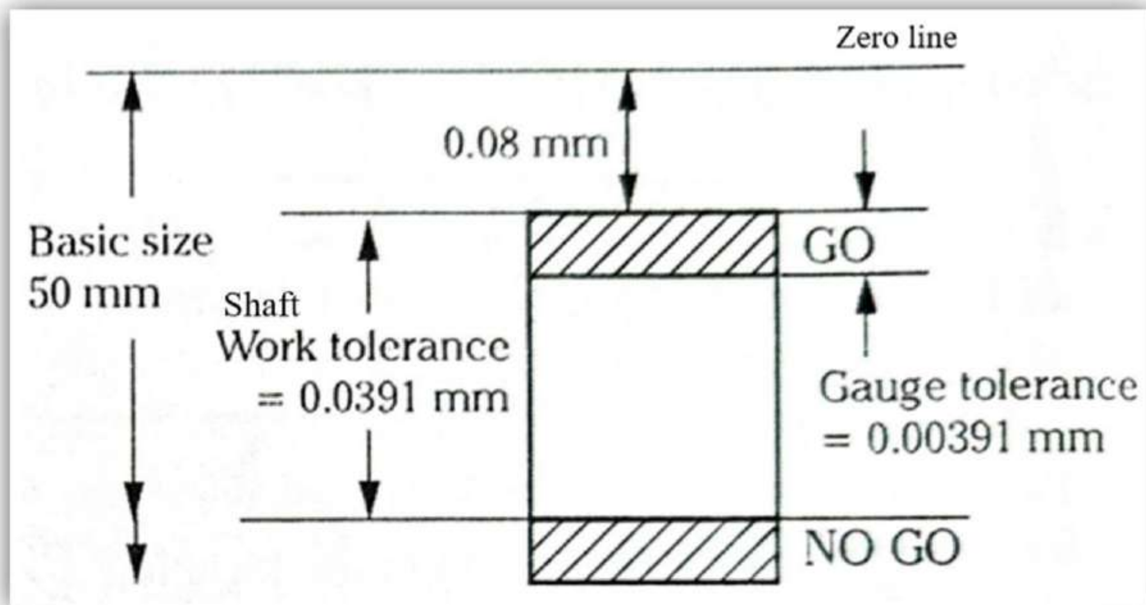
$49.92 - 0.00391 =$ **49.9161 mm**

b) **NO GO gauge**

∴ **Limits for "NO GO" ring gauge are**

50 – (0.08 + 0.0391) = **49.8809 mm**

$49.8809 - 0.00391 =$ **49.8770 mm**


Zero line
0.08 mm
Basic size
50 mm
Shaft
Work tolerance
= 0.0391 mm
GO
Gauge tolerance
= 0.00391 mm
NO GO

Design of Gauges: "GO" and "NOT GO" gauges for the component having 25 H_7 / f_8 fit

(i) **PLUG GAUGE DESIGN: (HOLE GAUGING)**

Note : Given data, Take wear allowance as 10% of the gauge tolerance (Note : Wear allowance is only for 'GO' gauge)

a) **<u>GO gauge</u>**

Work tolerance of Hole = 0.0209 mm

∴ **Plug** Gauge tolerance = $\frac{\text{Work tolerance of Hole}}{10}$

∴ **Plug Gauge tolerance** = $\frac{0.0209}{10}$

∴ **Plug Gauge tolerance = 0.00209 mm**

Given data, Take wear allowance as 10% of the gauge tolerance

∴ **Wear allowance on 'GO' gauge = 10% of (0.00209 mm)**

∴ **Wear allowance on 'GO' gauge = 0.000209 mm**

∴ **Limits for "GO" plug gauge are**

25 + 0.00209 + 0.000209 mm = **25.002299 mm** (Maximum)

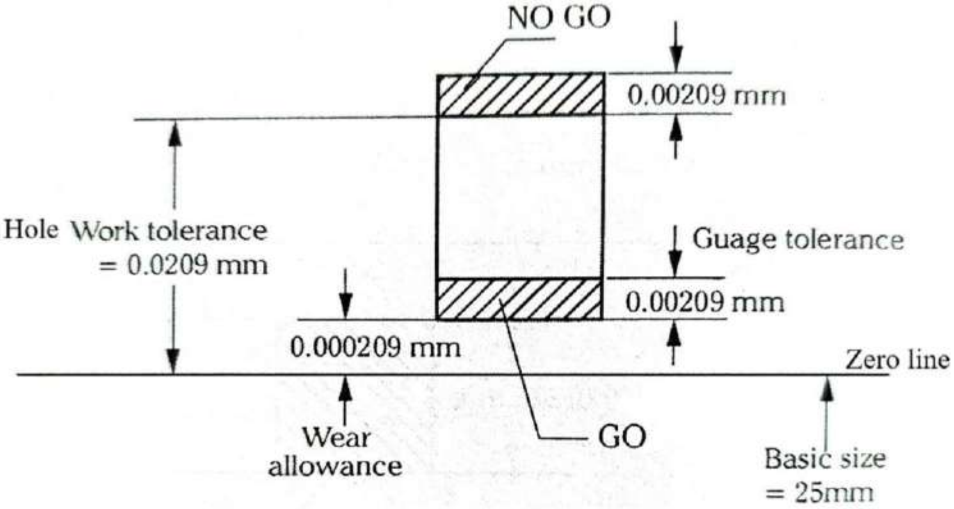
25 + 0.000209 mm = **25.000209 mm** (Minimum)

b) **NO GO gauge**

∴ **Limits for "NO GO" plug gauge are**

25 + 0.0209 + 0.00209 = **25.02299 mm** (Maximum)

25 + 0.0209 = **25.0209 mm** (Minimum)



ii. **RING GAUGE DESIGN: (SHAFT GAUGING)**

Note : Given data, Take wear allowance as 10% of the gauge tolerance (Note : Wear allowance is only for 'GO' gauge)

a) **GO gauge**

Work tolerance of shaft = 0.0327 mm

∴ **Ring** Gauge tolerance $= \frac{\text{Work tolerance of Shaft}}{10}$

∴ **Ring** Gauge tolerance $= \frac{0.0327}{10}$

∴ **Ring** Gauge tolerance = 0.00327 mm

Given data, Take wear allowance as 10% of the gauge tolerance

∴ **Wear allowance on 'GO' gauge = 10% of (0.00327 mm)**

∴ **Wear allowance on 'GO' gauge = 0.000327 mm**

∴ **Limits for "GO" ring gauge are**

25 – 0.0200 – 0.000327 mm = **24.979673 mm** (Maximum)

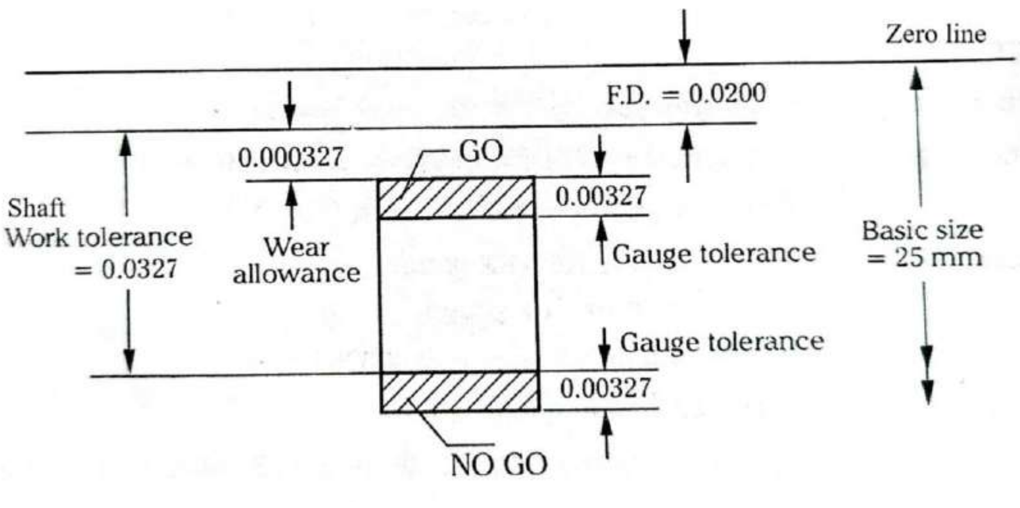
25 – 0.0200 – 0.000327 – 0.00327 mm = **24.976403 mm** (Minimum)

b) **NO GO gauge**

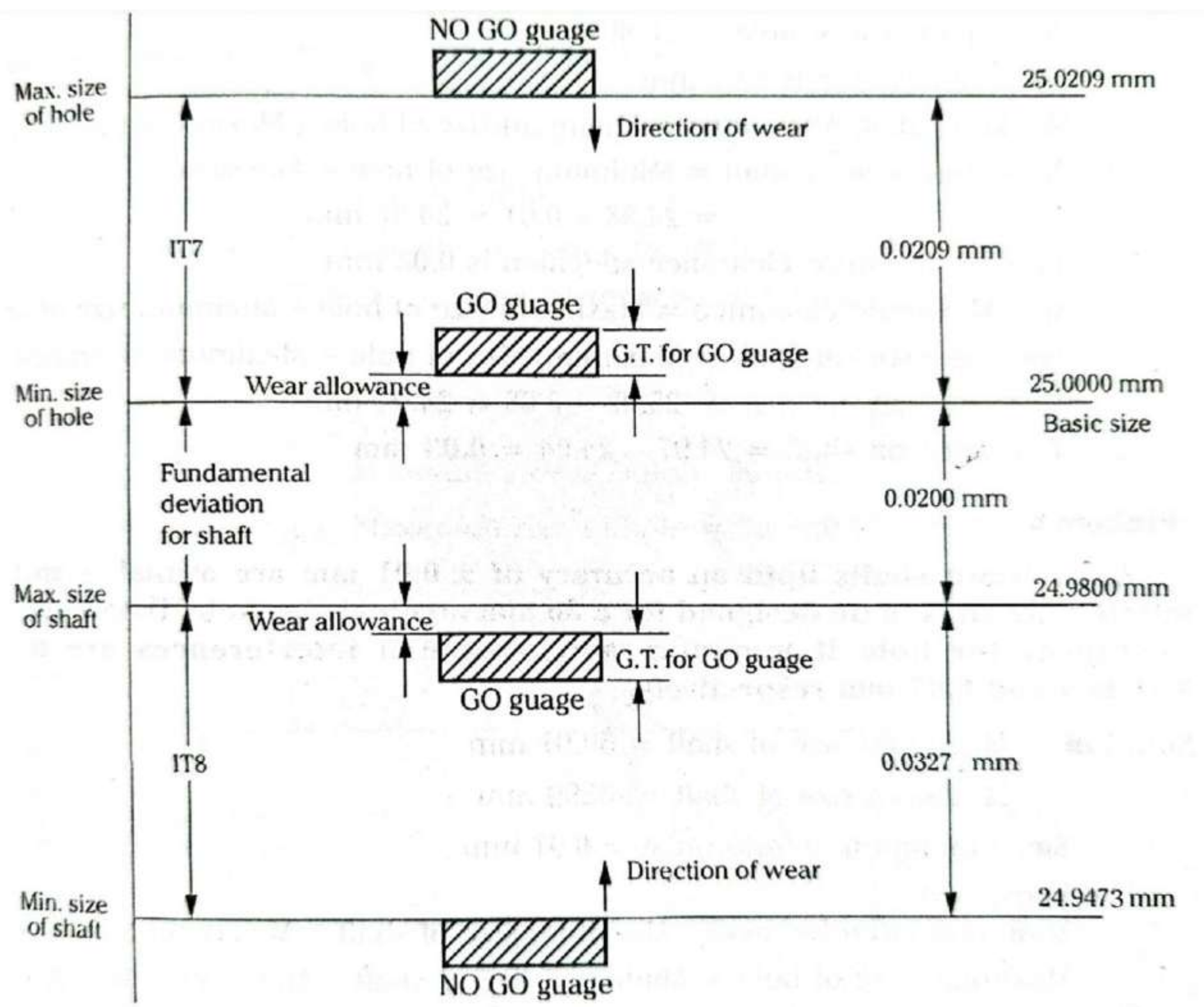
∴ **Limits for "NO GO" ring gauge are**

25 – 0.0200 – 0.0327 mm = **24.9473 mm** (Maximum)

25 – 0.0200 – 0.0327 – 0.00327 mm = **24.94403 mm** (Minimum)



Design of Gauges:



INTRODUCTION TO COMPARATORS

- All measuring instruments are ***comparators, ranging from a simple scale to a complex instrument.***
- A comparator works on relative measurement, i.e. it gives only dimensional differences in relation to a basic dimension
- A comparator is an instrument used for the ***measurement of lengths or diameters on gauges and components, using slip gauge as a standard.***
- The **general principle** of all these comparators is to *indicate differences in size between the standard and the work being measured by means of some form of pointer* on a scale at a magnification which is sufficient to read to the accuracy required

All comparators irrespective of their type, usually consists of three basic features.

1) A **sensing device** which faithfully senses the input signal.
2) A **magnifying** or **amplifying system** to increase the signal to a suitable magnitude. *Mechanical, optical, pneumatic, hydraulic and electronic methods are used for this purpose.*
3) A **display system** (usually a scale and pointer) which utilizes the amplified signal to provide a suitable read out.

NEED OF A COMPARATOR

1) Comparator is required in **mass production** and mass production would be impossible i f component parts could not be produced to close dimensional tolerances.
2) Use of line or end standards such as vernier calipers and micrometer requires a considerable degree of skill, if consistent results are to be obtained.
3) Where dimension must be checked with high degree of precision and speed in the mass production. **Example : Piston**
4) When many dimensions are to be checked, in a very short time.
5) For inspecting the newly purchased gauges

CHARACTERISTICS OR BASIC REQUIREMENTS OF COMPARATORS

1) The instrument must be of robust design and construction so as to withstand the effect of ordinary usage without impairing its measuring accuracy.
2) The indicating devices must be such that readings are obtained in least possible time.
3) The system should be free from backlash, wear effects and the inertia should be minimum. (*In Mechanics, backlash is the free tolerance available [lash] or* play, *a certain type of void space between machining.),*
4) Provision for maximum compensation to temperature effects.
5) The scale must be linear and must have straight line characteristics.
6) The instrument must be versatile, i.e., its design must be such that it can be used for a wide range of measurements.
7) The measuring pressure should be low and constant.
8) The indicator (pointer, liquid column etc,) should be clear and free from oscillations.

CLASSIFICATION OF COMPARATORS

Based on the design used for amplifying and recording the variations, the comparators are classified as

1. **Mechanical comparators**
2. **Optical comparators**
3. **Electrical and Electronic comparators**
4. **Pneumatic comparators**
5. **Fluid displacement comparators**

Further the combination of magnifying principles has resulted in the development of following comparators

a) **Mechanical - Optical comparators**
b) **Electro - Mechanical comparators**
c) **Multi - check comparators**

In addition, comparators of high sensitivity and magnification are as follows

1) **The Brookes level comparator**
2) **The Eden - Rolt "millionth" comparator**

MECHANICAL COMPARATORS

- In mechanical comparators, the required magnification is obtained by using mechanical linkages, levers, gearing and other mechanical devices.
- Example of mechanical type of comparators:
    - ✓ Dial gauge
    - ✓ Reed type comparator
    - ✓ Johansson Mikrokator
    - ✓ Sigma comparator
    - ✓ Eden-Rolt millionth comparator etc.,

System of displacement amplifications used in Mechanical Comparators

1) Rack and pinion: Measuring spindle integral with the rack, engages a pinion which amplifies the movement of plunger through a gear train.
2) Cam and gear train: In this case the measuring spindle acts on a cam which transmits the motion to the amplifying gear train
3) Lever with toothed sector: Here the lever with a toothed sector at its end engages a pinion in the hub of a crown gear sector which further meshes with a final pinion to produce the indication
4) Compound levers: In this type the lever forming a couple with compound action are connected through segments and pinion to produce the final pointer movement
5) Twisted taut strip: The movement of the measuring spindle t ilts the knee causing straining which further causes the twisted taut band to rotate proportionally.
6) Lever combined with band wound around drum: In this case the movement of the measuring spindle tilts the hinged block, causing the swing of the fork which induces the rotation of the drum

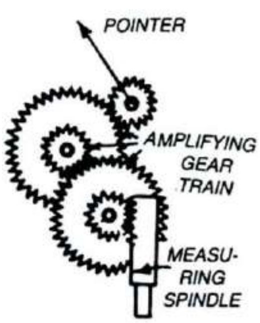


Fig. 5.1. Rack and pinion.

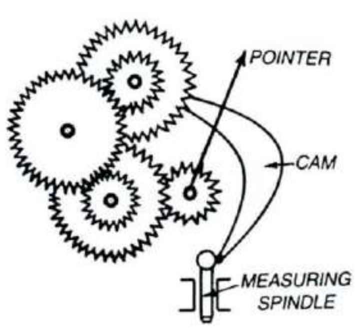


Fig. 5.2. Cam and gear train.

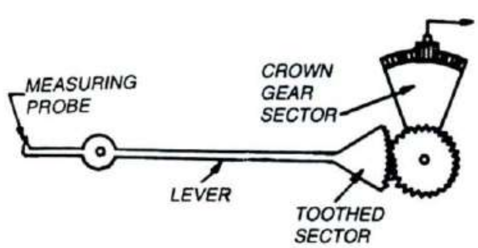


Fig. 5.3. Lever with toothed gear.

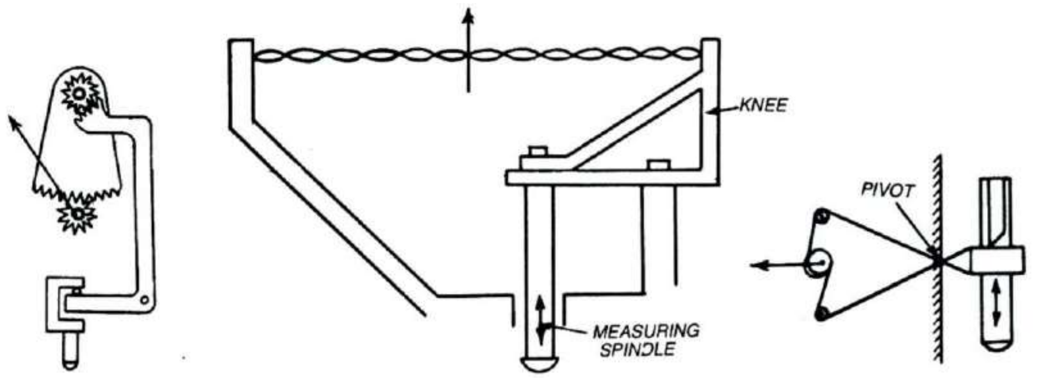


Fig. 5.4. Compound levers. Fig. 5.5. Twisted taut strip. Fig. 5.6. Lever combined

REED TYPE MECHANICAL COMPARATOR

- Figure shows the basic principle involved in amplifying linkages used in Reed type mechanical comparator.

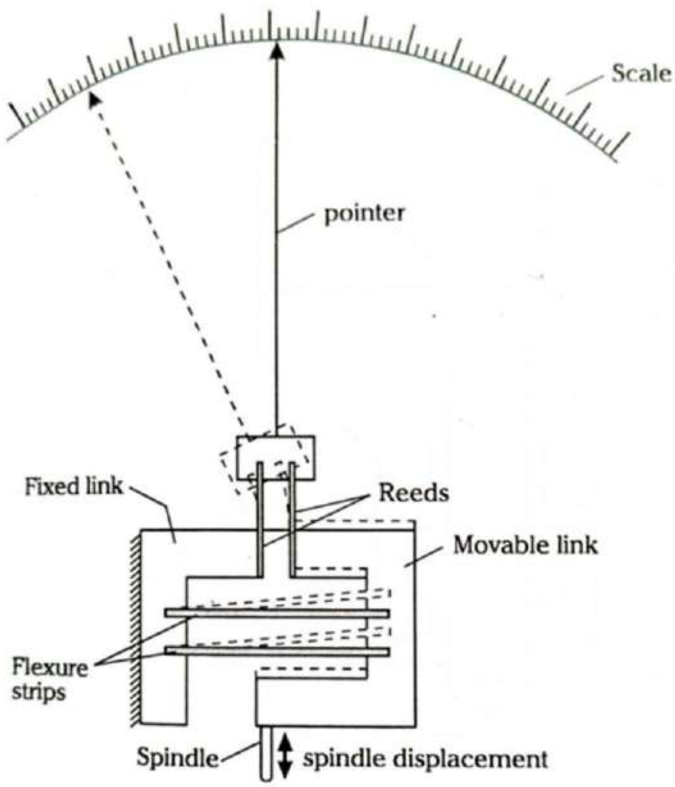


Fig. Schematic of Amplifying Mechanism used in Reed Type Mechanical Comparator

- Movable link is constrained by thin metal flexure strips to move vertically relative to the fixed link, which is, attached to the housing.
- Because of their orientation relative to the motion, reeds provide a large angular movement of the pointer·. The scale may be calibrated to indicate any deviation from an initial setting.
- The most commonly used mechanical comparator for height measurement is shown in photograph

JOHANSSON MIKROKATOR (ABRAMSON'S MOVEMENT)

- This comparator uses the simplest and most smart method of obtaining the mechanical magnifications designed by H. Abramson.
- It works on the principle of a button spinning on a loop of string.
- A twisted thin metal strip carries a very light pointer made of thin glass at the centre of its length.

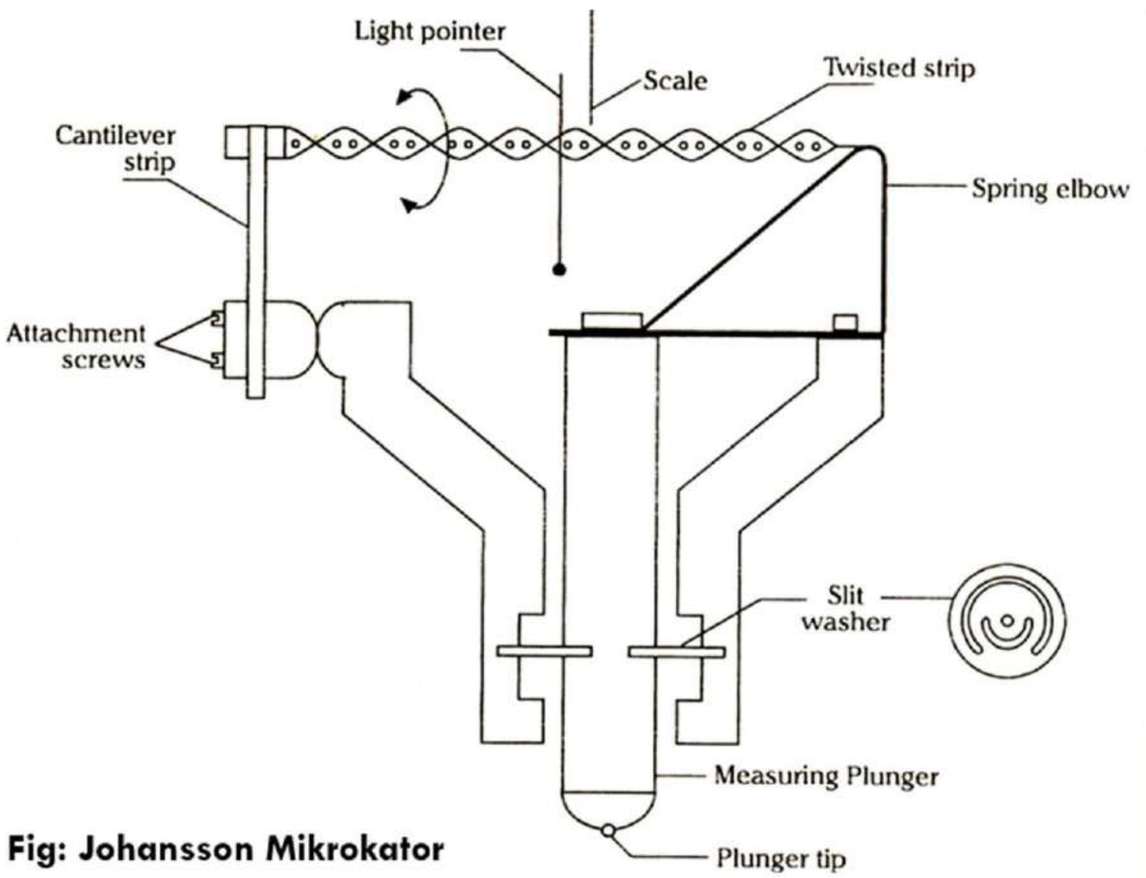


Fig: Johansson Mikrokator

- The two halves of the strip from the centre are twisted in opposite directions so that any pull on the strip will cause the centre to rotate.
- One end of the strip is fixed to an adjustable cantilever strip and the other end is anchored to the spring elbow, one arm of which is carried on the measuring plunger.
- As the measuring plunger moves either upwards or downwards, the elbow acts as bell crank lever and causes twisted strip to change its length thus making it further twist or untwist.
- Thus, the pointer at the centre of the twisted strip rotates by an amount proportional to the change in length of the strip and hence proportional to the plunger movement.
- The spring elbow is formed of flexible strips with a diagonal which is relatively stiff.
- The length of cantilever can be varied to adjust the magnification of the instrument.
- Since the centre line of the strip is straight even when twisted, therefore it is directly stretched by the tension applied to the strip.
- In order to prevent excessive stress on the central portion, the strip is perforated along the centre line.
- A slit washer is used for lower mounting of the plunger.

The amplification of this comparator is given by,

$$\frac{\square\square}{\square\square} = \frac{\square}{\square^{2}\square}$$

where,

- θ - is the twist at mid-point of the strip with respect to the ends
- L - is the length of twisted strip measured along its neutral axis
- □ -is the width of the twisted strip and
- *n* - is the number of turns

In order to increase the amplification of the instrument, a very long thin rectangular strip must be used.

The magnification of this instrument is of the order of 5000.

SIGMA COMPARATOR

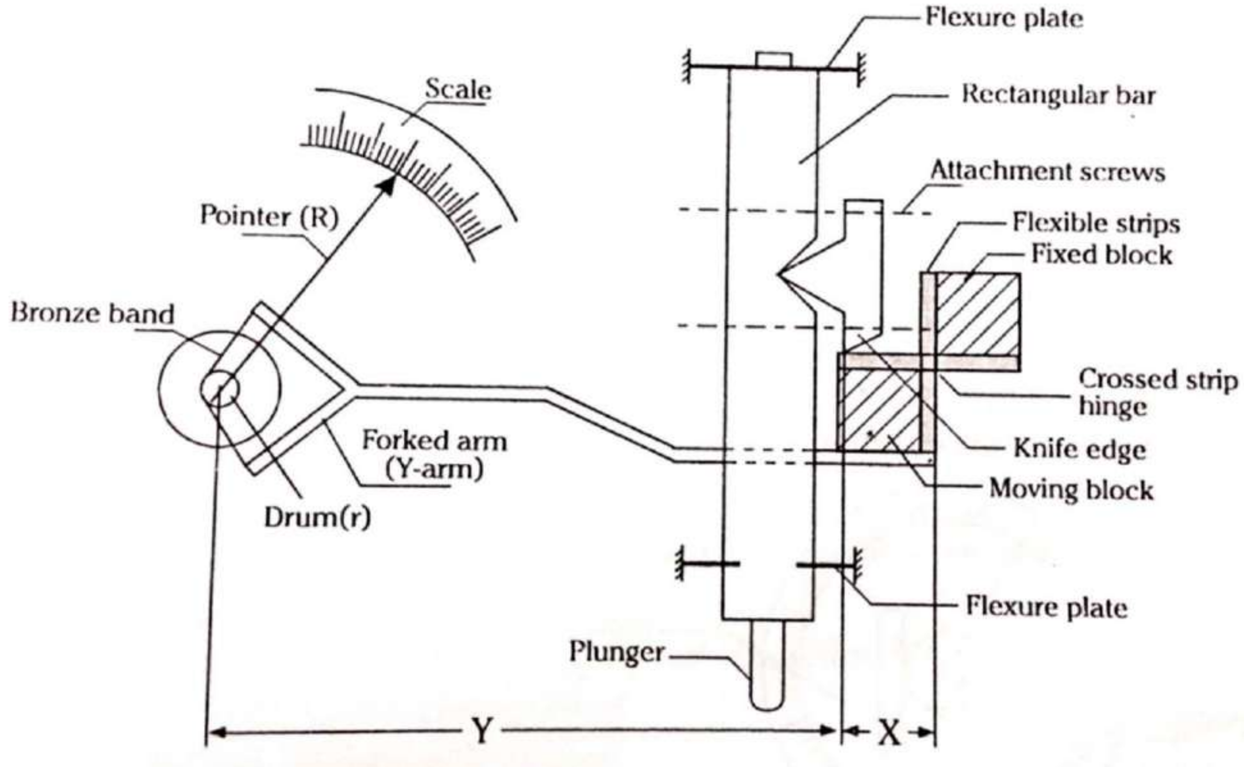


Fig: Mechanism of Sigma Comparator

- Sigma comparator is an example of a mechanical comparator with magnifications in the range of 300 to 5000.
- The plunger is attached to a rectangular bar which is supported at its upper and lower ends by flexure plates.
- A knife edge is fixed to the side of the rectangular bar which stands on a moving block.
- The moving block and the fixed block are connected by flexible strips at right angles to each other.
- If an external force is applied to the moving block, it would pivot about the line of intersection of the strips.
- This hinge is suitably pre-tensioned to allow it to rotate within the range of the instrument scale.
- A forked arm or Y-arm attached to the moving block transmits rotary motion to the indicator driving drum through a bronze band wrapped around the drum.

- Magnification: If Y is the length of the forked arm and "X" is the distance from the knife edge to the hinge, then the first stage magnification is $\frac{\square}{\square}$

- If the pointer length is "R" and radius of the drum is "*r*" then the second stage of magnification is □/□
- Hence the total magnification is given by

$$□ = \frac{□}{□} \times \frac{□}{□}$$

- The magnification preset by the manufacturer may be varied by adjusting the knife edge attachment screws.
- And another way to produce instrument of different magnification is to use drum of different radii "*r*" with a suitable strip.

DIAL INDICATOR

- It consists of a robust base whose surface is perfectly flat and a pillar carrying a bracket in which is incorporated a spindle fitted with a pinion and a dial scale.

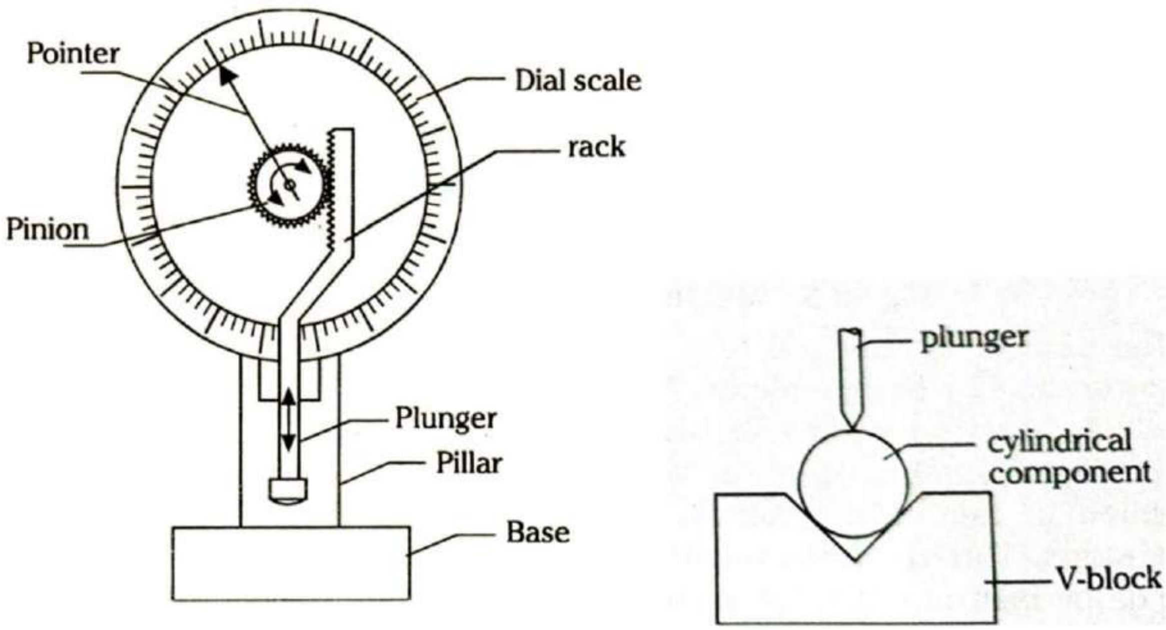


Fig: Schematic of a Simple dial indicator

- The linear movement of the plunger is magnified by means of a rack and pinion train into sizable rotation of the pointer on the dial scale.
- The dial scale is set to zero by the use of slip gauges representing the basic size of the part.
- This is generally used for inspection of small precision machined parts.
- This type of comparator can be used with various attachments so that it may be used for large number of works.

- For example, with a V-block attachment, it can be used for checking out-of-roundness of a cylindrical component. As shown in figure below.

ADVANTAGES OF MECHANICAL COMPARATORS

1) Mechanical comparators are usually cheaper when compared to other amplifying devices.
2) Mechanical comparators do not require any external sources such as electricity or air and as such the variations in outside supplies do not affect the accuracy.
3) Usually the mechanical comparators have linear scale.
4) They are robust and easy to handle.

DISADVANTAGES OF MECHANICAL COMPARATORS

- Mechanical comparators have more moving linkages, due to which the friction is more and hence the accuracy is low.
- Any slackness in moving parts reduces the accuracy considerably.
- The mechanisms used in mechanical comparators have more inertia and this may cause them to be sensitive to vibrations.
- Any wear, play, backlash or dimensional faults in the mechanical devices used will also be magnified.
- The range of these instruments is limited, because the pointer moves over a fixed scale.
- It is very difficult to incorporate an arrangement for adjusting the magnification.

OPTICAL COMPARATORS

- There are no pure optical comparators but the instruments classed as Optical Comparators
- These obtain large magnifications by the use of optical principles.
- All optical comparators works on one of the following two main principles
  - ✓ The use of the optical lever
  - ✓ The use of enlarged image
- Optical comparators are capable of giving high degree of measuring precision.
- Due to the reduction of moving members they ***possess better wear resistance qualities, than mechanical types.***
- Also the inherent disadvantages found with the mechanical comparators, such as weight, bending properties, friction etc., ***are overcome by optical comparators.***

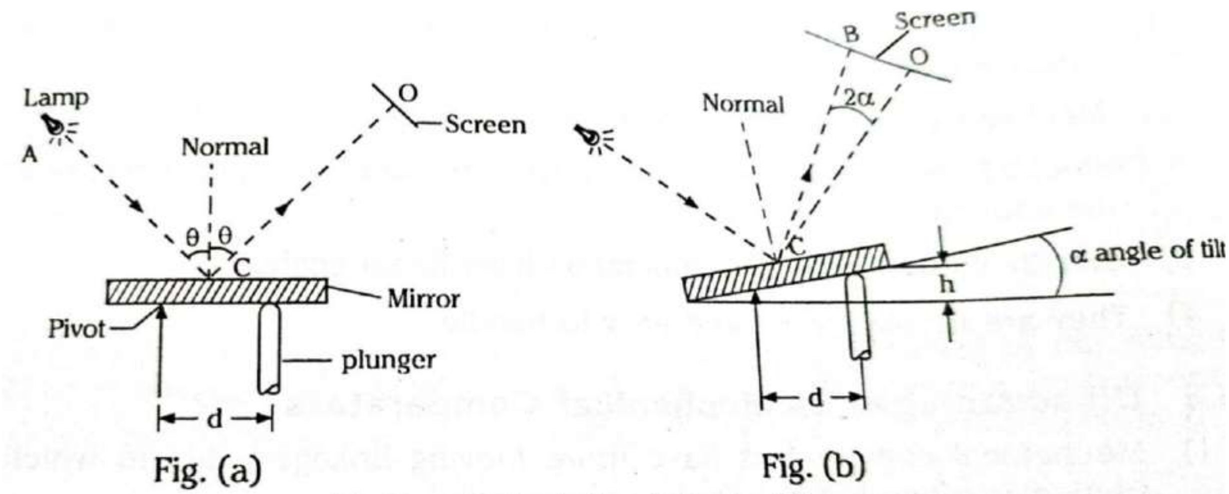


Fig. Principle of Optical Lever

- If a ***beam of light (AC)*** is directed on to a mirror as shown Fig. (a), it will be reflected onto the screen at **O** as a dot.
- The angle θ at which the beam strikes the mirror is equal to the angle θ at which the beam is reflected from the mirror.
- When the plunger moves upwards vertically, causing the mirror to tilt by an angle 'α' as shown Fig. (b).
- Then the ***reflected light beam moves through an angle "2α"*** which is twice the angle of tilt produced by the plunger movement.

PRINCIPLE OF MECHANICAL - OPTICAL COMPARATOR

- In mechanical - optical comparators as shown, small displacements of the measuring plunger are amplified first by a **mechanical lever.**
- The amplified mechanical movement is further amplified by an optical system involving the projection of an image.
- The mechanical lever causes the mirror to tilt about mirror pivot and the image of the index is projected on a scale on the inner surface of a glass screen.
- By lever principle, the mechanical amplification $= \frac{\square\square}{\square\square}$
- If the plunger movement has an effect on turning the mirror by an angle **Θ**, then the reflected ray (D) will be turned through an angle **2Θ**.
- Therefor optical amplification = $2 \times \frac{\square\square}{\square\square}$
- **The overall magnification of this system** = $\frac{\square\square}{\square\square} \times 2 \times \frac{\square\square}{\square\square}$

- **The overall magnification of this system** = $2 \times \frac{[illegible]}{[illegible]} \times \frac{[illegible]}{[illegible]}$

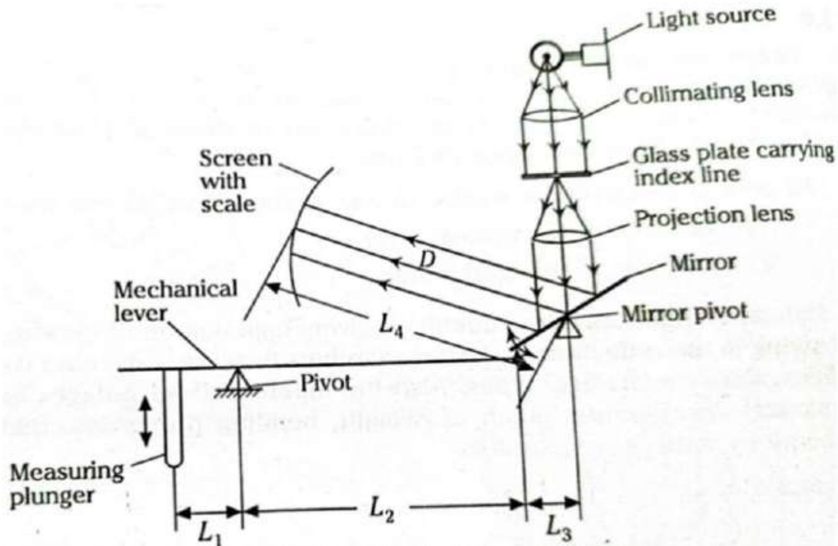


Fig. Mechanical-optical Comparator

ZEISS ULTRA – OPTIMETER

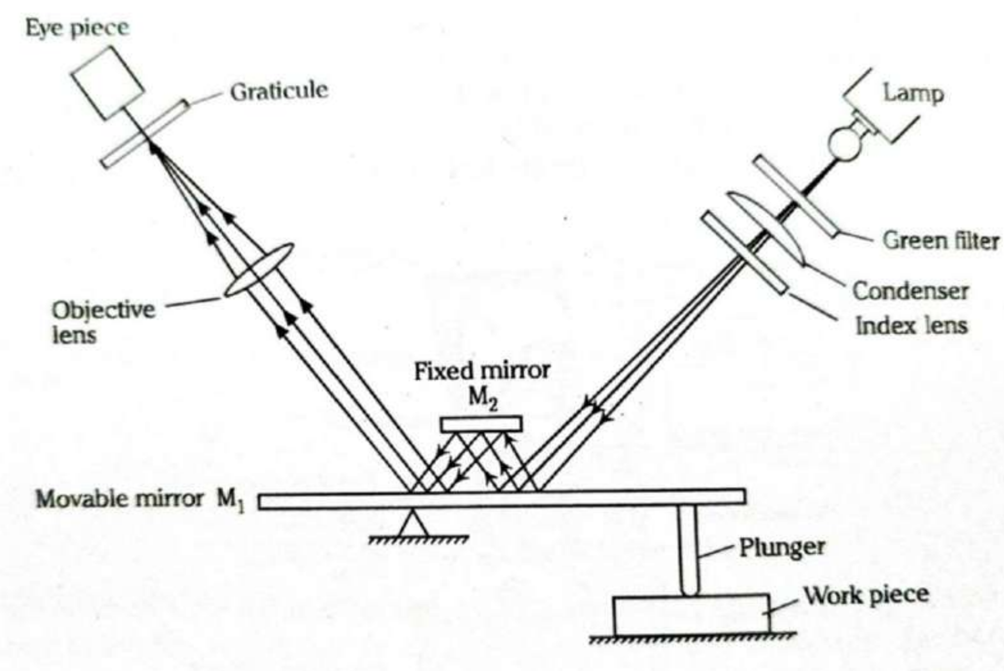


Fig. Principle of Zeiss Ultra-optimeter

- The optical system of this instrument involves double reflection of light and thus gives **higher degree of magnification.**

- A lamp sends light rays through green filter to filter all rays except green light, which causes less fatigue to eye.
- **The green light** then passes through a condenser which via an index mark projects it on to a movable mirror $\mathbf{M_1}$.
- It is then reflected to another fixed mirror $\mathbf{M_2}$ and back again to the first movable mirror $\mathbf{M_1}$.
- The objective lens **brings the reflected beam from the movable mirror to a focus at a transparent graticule containing a precise scale which is viewed by the eye-piece.**
- The projected image of the index line on the graticule can be adjusted by means of a screw in order to set the **initial zero reading.**
- When correctly adjusted, **the image of the index line is seen against that of the graticule scale.**
- The end of the contact plunger rests against the other end of the first movable mirror so that any vertical movement of the plunger will tilt the mirror.
- This causes a shift in the position of the reflected index line on the eye piece **graticule scale**, which in turn measures the displacement of the plunger.

ADVANTAGES OF OPTICAL COMPARATORS

- Optical comparators have **few moving linkages** and hence are not subjected to friction and consequent wear and tear. *This results in high accuracy of measurement.*
- The scale can be made to move past a datum line and thus have high range of measurements and ***no parallax error.***
- The **magnification is usually high**.
- Optical lever is **weightless**

DISADVANTAGES OF OPTICAL COMPARATORS

- Heat from the source of light, transformers etc., may cause the setting to drift.
- An **electric supply is necessary** to operate these type of comparators.
- The size of these comparators are large, and **costly.**
- Since the scale is projected on a screen, it is essential to use these **instruments in dark room in order to take the readings easily**.
- Some comparators in which the scale is viewed through an **eye piece of a microscope are not convenient for continuous use.**

PNEUMATIC COMPARATORS

- In pneumatic comparators ***air is used as a means of magnification***.
- Pneumatic comparators works on the principle of an ***air jet***.
- When ***air jet*** is in close proximity with a surface, the flow of air out of that jet will be restricted.
- This will result in a change of pressure in the system, supplying the jet.

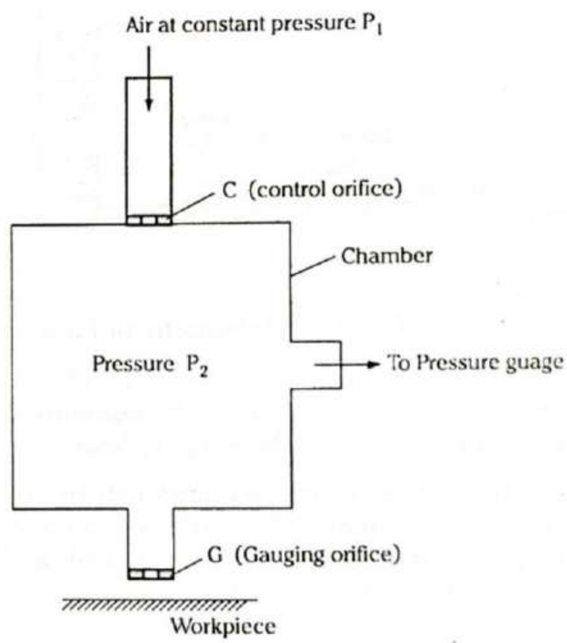


Fig. Principle of Pneumatic Comparator

- As shown in the Figure, a chamber is fitted with ***control orifice C*** and a ***gauging orifice G***, through which the air flows from a supply at ***constant pressure P_1***
- If the size of the ***control orifice C*** remains constant, any variation in the size of the ***gauging orifice G*** will cause an alteration in the ***pressure P_2*** in the chamber.
- This pressure variation is measured by a pressure gauge of suitable sensitivity, which may be a manometer, Bourdon-type gauge or bellows, and graduated to read in linear units.
- The size of ***gauging orifice (G)*** varies as the distance of the workpiece from the gauging orifice ***(G)*** alters.

SYSTEMS OF PNEUMATIC COMPARATORS

Based on the physical phenomenon on which the pneumatic comparators works, they are classified as,

1) Flow or velocity type
2) Back pressure type

FLOW OR VELOCITY TYPE COMPARATOR

- Flow or velocity type of pneumatic comparators operate ***by sensing and indicating the momentary rate of air flow.***
- In this case the *compressed air* after the filtering and pressure regulating unit flows through a glass tube containing a ***small metal float***.
- The compressed air then flows through a plastic tube to the gauge head having two diametrically opposite orifices for the air to escape.

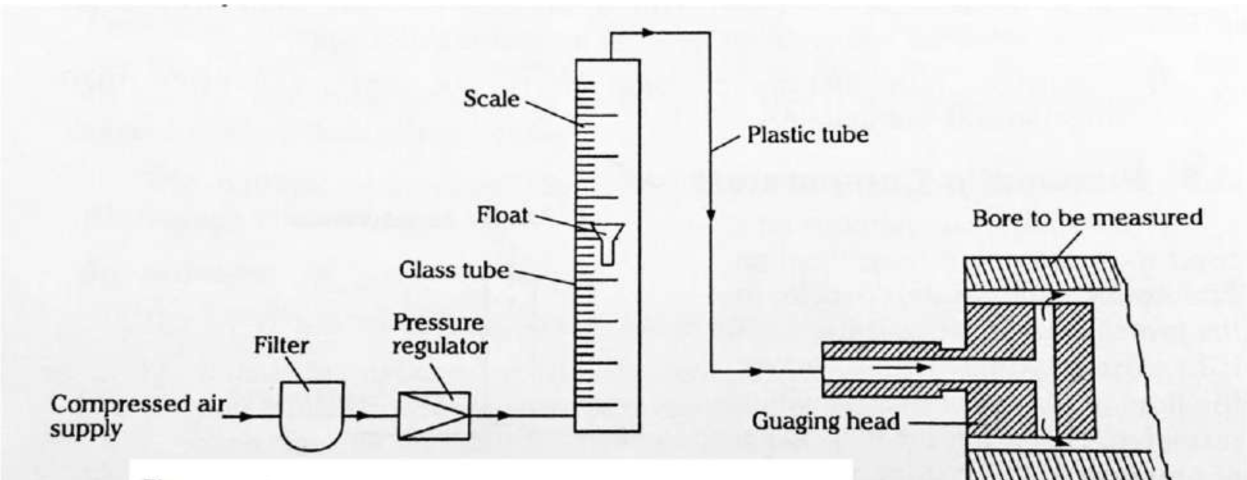


Fig. Schematic of Flow or Velocity type Comparator

- The position of the float depends upon the amount of air flowing through the gauge head, which in turn depends upon the clearance between the bore to be measured and the gauging head.
- These type of comparators can be assembled together side by side and thus multiple inter-related dimensions can be seen at a time.
- This method of measuring multiple dimensioning with great ease, accuracy and speed is the great advantage of these type of comparators.

BACK PRESSURE TYPE PNEUMATIC COMPARATORS

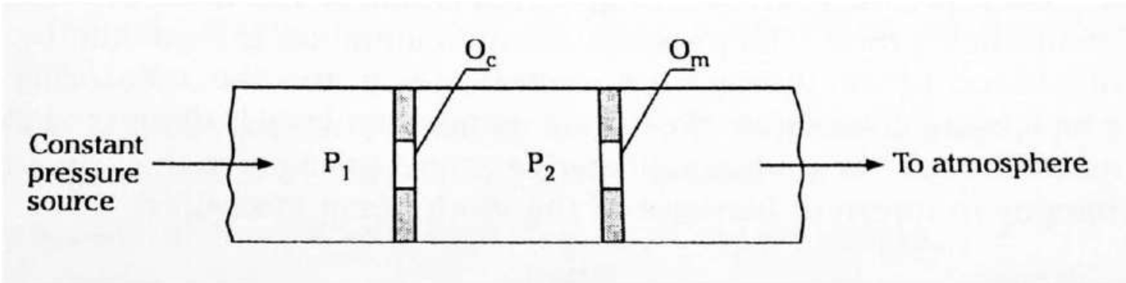


Fig. Principle of Back Pressure type Pneumatic Comparator

- The principle of pneumatic gauging in the back pressure type comparator is as follows
- Air from a constant pressure source flows to the atmosphere through two orifices ***O_c*** and ***O_m*** as shown in the figure.
- ***P_1*** is the pressure on the upstream of the first orifice and ***P_2 is the pressure between the two orifices.***
- The relationship between P_1 and P_2 depends upon the relative sizes of the two orifices.
- ***P_2*** becomes equal to ***P_1*** when ***O_m*** is blocked and tends to zero as ***O_m*** is increased indefinitely.

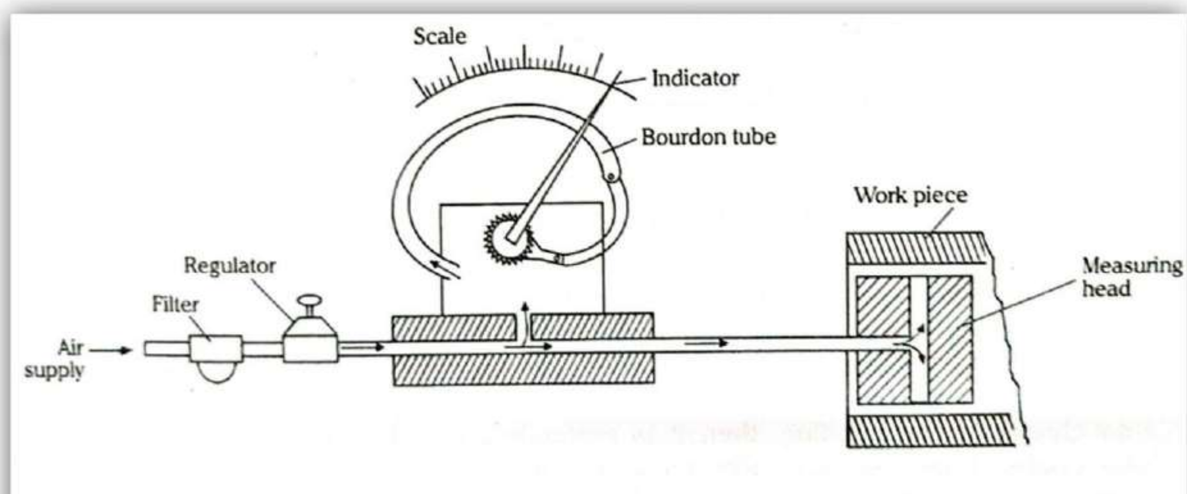


Fig. Back Pressure Circuit

- In the basic ***back pressure circuit*** shown a bourdon tube, bellows or a diaphragm deflects according to the back pressure changes built up in the circuit when the workpiece is placed over the measuring head.
- The deflection is amplified by a lever and gear arrangement and indicated on a dial.

SOLEX PNEUMATIC GAUGE or (SOLEX AIR GAUGE)

- The solex company has marketed a device employing a water manometer for the indication of back pressure. The solex apparatus is as shown in Figure.

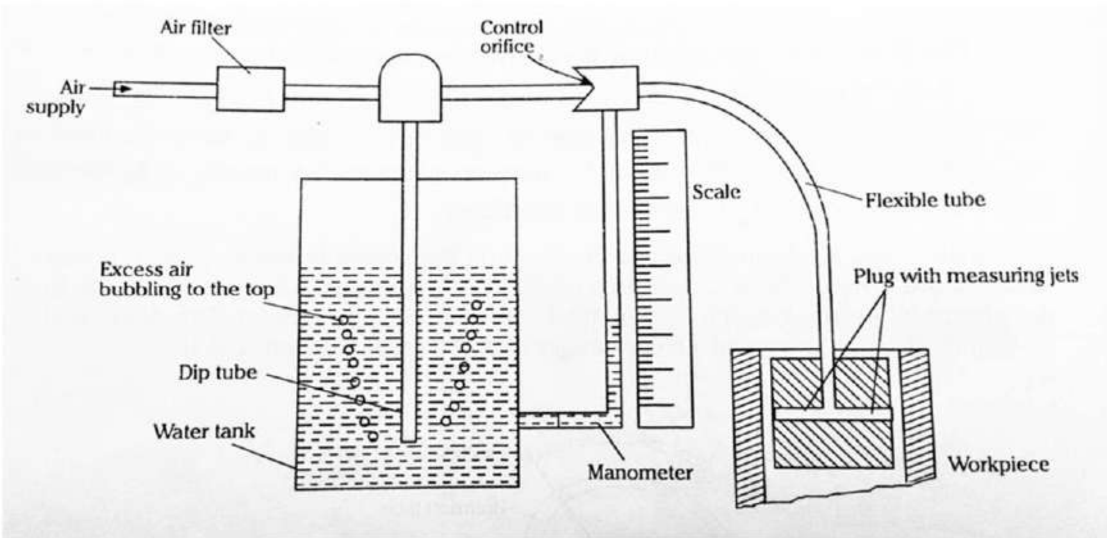


Fig. 1 Solex Pneumatic Gauge

- It consists of a water tank in which water is filled upto a certain level and a ***dip tube*** is immersed into it upto a depth corresponding to the air pressure required.
- Since ***air*** is sent at high pressures than the required, some *air will escape from the dip tube* and bubbles to the top of the water tank.
- Thus, the *air moving towards the control orifice will be at the desired constant pressure.*
- Then, the ***air at this pressure passes through the control orifice and escapes from the measuring jets***.
- The ***back pressure*** in the circuit is indicated by the head of ***water displaced in the manometer tube.***
- The pressure in the manometer is regulated by the relative rates of escape of air through the control orifice and the measuring jets.
- If the measuring jets are completely closed, the manometer level is depressed to the bottom of the tube.
- The tube is graduated linearly to show changes in the ***pressures resulting from changes in internal diameter of the work being measured.***
- It is very obvious from the **Fig. 1** that the diameter being measured at any instant is corresponding to the portion against two jets.

- ***To find the concentricity***, the workpiece may be revolved around the measuring gauge.
- If there is ***no change in the reading***, ***then it is perfectly a concentric hole***.
- Similarly, the diameter can be noted at several places along the length of the bore and thus tapering of the hole can be determined.
- This method is therefore best suited for *measuring roundness and taperness of cylinder bores and gun barrel bores etc*.
- This method is therefore best suited for measuring roundness and taperness of cylinder bores and gun barrel bores etc.

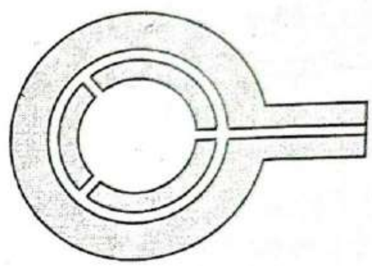


Fig.2 **Three jets measuring head for external gauging**

- By having ***suitable measuring head these gauges can be used for external gauging as shown in the Figure 2.***
- It is also possible to have arrangement to *measure the length of slip gauges by having a flat table and one jet at the top.*

Advantages of Pneumatic Comparators

- The gauging member does not come in contact with the part to be measured and hence practically **no wear takes place on the gauging member.**
- It has very less number of moving parts and thus the **accuracy is more due to the absence of friction and lower inertia.**
- It is possible to have a very high degree of magnification.
- It is a suitable device for measuring diameter of holes where the diameter is small compared with the length.
- It is the best method for determining **the quality and taperness of the circular holes.**
- Measuring pressure is very small and the jet of air helps in cleaning the dust, if any, from the part to be measured.

Disadvantages of Pneumatic Comparators

- It requires elaborate auxiliary equipment's ***such as accurate pressure regulator, compressor etc.,***
- The scale is generally *not linear.*
- When indicating **device is glass tube**, then ***high magnification is necessary*** in order ***to avoid the parallax errors.***
- The apparatus ***is not easily portable*** and is rather elaborate for many industrial applications.

ULTRASONIC GAUGES

- Ultrasonic gauges are non-destructive testing devices used to measure the thickness of materials, particularly metals, and detect flaws.
- These devices use high-frequency sound waves to determine the thickness of the material and locate any internal defects.
- Ultrasonic gauges are essential tools in quality control and maintenance, ensuring the integrity and safety of various structures and components.
- In the figure below, the reflected signal strength is displayed versus the time from signal generation, when a echo was received.
- Signal travel time can be directly related to the distance. From the signal, information about the reflector location, size, orientation and other features can sometimes be gained.

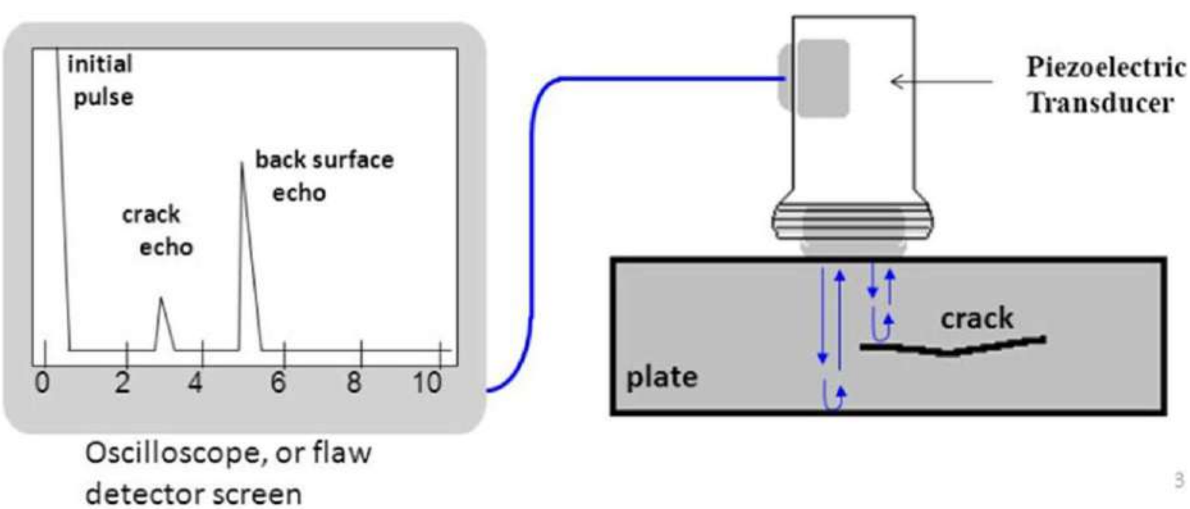


Fig. Basic Principle of Ultrasonic Testing

How Ultrasonic Gauges Work

1. **Transducer**: The device uses a transducer to generate ultrasonic waves. When the transducer is placed on the material's surface, it sends ultrasonic pulses into the material.
2. **Propagation**: The sound waves travel through the material. The speed of these waves depends on the material's properties.
3. **Reflection**: When the ultrasonic waves encounter a boundary (e.g., the back wall of the material or an internal flaw), they reflect back towards the transducer.
4. **Reception**: The transducer also acts as a receiver, detecting the reflected waves.
5. **Calculation**: The device measures the time it takes for the waves to travel to the boundary and return. Using the known speed of sound in the material, the device calculates the thickness of the material or identifies the location of flaws.

Components of an Ultrasonic Gauge

1. **Transducer**: Generates and receives ultrasonic waves.
2. **Couplant**: A gel or liquid applied to the material's surface to facilitate sound wave transmission.
3. **Display Unit**: Shows the thickness measurement or defect location.
4. **Control Unit**: Processes the received signals and calculates the thickness or identifies flaws.

Applications

- **Thickness Measurement**: Used in industries like manufacturing, aerospace, and automotive to measure the thickness of metal sheets, pipes, and other components.
- **Flaw Detection**: Helps in detecting internal defects such as cracks, voids, and inclusions in materials.

LINEAR VARIABLE DIFFERENTIAL TRANSFORMER (LVDT)

- Linear variable differential transformer is the most popular electro-mechanical device **used to convert mechanical displacement into electrical signal.**
- In effect, it is a differential transformer ***consisting of three symmetrically spaced coils.***
- It works on the principle of mutual inductance.

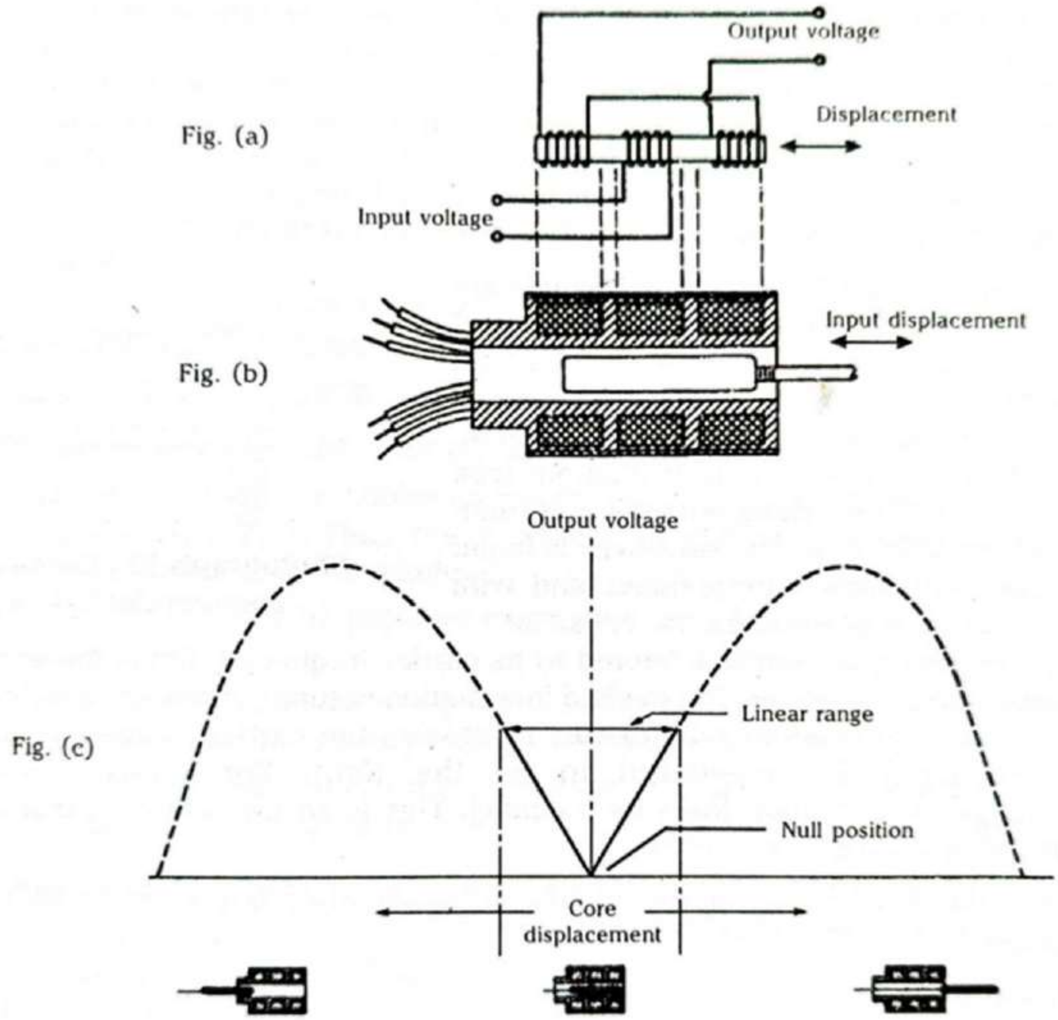


Fig. 3.11 LVDT (a) Schematic arrangement (b) Section through a typical transformer (c) Typical Differential Transformer Performance Characteristics

- A differential transformer is one of the most useful variable inductance transducer, i t provides an A.C ***voltage output proportional to the displacement of a core passing through the windings.***
- It is a mutual inductance device making use of 3 coils arranged as shown in Figs. 3. 11 (a) and (b).
- The centre coil is energized from an external A.C power source and the two end coils are connected together in phase opposition which in turn are used as pick up coils.
- The output amplitude and **phas** e depends on the relative coupling between the two pick up coils and the power coil.
- The **relative coupling is inturn depends upon the position of the core.**

- Theoretically there should be a *core position, for which the voltage induced in each of the pick up coils will be of the same magnitude.*
- When they are connected in ***phase opposition the*** *two voltages cancels giving a resultant output of zero magnitude*.
- This position is known as the null position and it is difficult to attain in practice.
- Fig.3.11(c) shows typical differential transformer characteristics obtained by plotting the output voltages Vs core displacements.
- Within the limits on either side of the null position, the core displacements results in a proportional output.
- The **linear range depends upon the length of the secondary coils**.
- Beyond the proportionality limit the output increases at a decreasing rate until it reaches a maximum from, which it *drops again to the balance condition*
- While, the output voltages are ideally the same for equal core displacements on either side of the null position, the phase relation between the input voltage and output voltage changes by 180° through the null position.
- By the use of phase sensitive arrangements it is possible to **distinguish between the outputs resulting from displacements on each side of the null position.**
- All commercial differential transformers are designed to operate only in the linear range and are known as linear variable differential transformers (LVDTs).
- LVDTs operate on a supply voltage of **6. 3volts** at **60 cps** this voltage can be easily obtained with the help of filament type transformer.
- LVDTs are designed for a maximum displacement of 25 mm. The sensitivity is found to increase with higher frequencies and with increased number of turns on the coils.
- The exciting frequency, sometimes referred to as carrier frequency, limits the dynamic response of the transformer.

ADVANTAGES OF LVDT

- It can be used as a primary detector transducer, **since it converts a mechanical displacement into electrical voltage.** It does not require the assistance of another element just **like a strain gauge.**
- LVDT can't be over loaded mechanically since the core is completely separable from the rest of the equipment.
- It is relatively insensitive to high or low temperatures and to temperature changes.
- It provides a comparatively high output which can be used without intermediate amplification.
- It is reusable and of reasonable cost.

DISADVANTAGES OF LVDT

- It can't be widely used in the area of dynamic measurement since the core is of appreciable mass compared with the mass of a strain gauge.
- If 60 cps supply voltage is used then it becomes a limiting factor as for as dynamic measurement is concerned.
- If the direction from the null point is to be indicated then the advantage of sample circuit arrangement is lost.

ANGULAR MEASUREMENTS

- The angle is defined as the opening between two lines which meet at a point.
- If one line is moved around a point in an arc, a complete circle can be formed and it is from this circle the units of angle are derived. If a circle is divided into 360 parts, then each part is called a degree (˚).
- An angle is one which requires no absolute standard, and it is the precision with which a circle can be divided to get the correct measure of angle.
- Each degree is further divided into ***sixty parts called minutes*** (') and ***each minute is further subdivided into 60 parts called seconds (").***



- Angular measurement is generally concerned with the ***measurement of individual angles on gauges, tools as well as small angular changes and deflections etc.***
- An alternative method of defining angle is based on the relationship between the radius and arc of a circle.
- This unit is called **radian** and is defined as the angle subtended by an arc of a circle of length equal to the radius.

The following instruments are used to measure the angles of the parts:

1. Bevel protractor
2. Sine bar
3. Sine center
4. Angle gauges
5. Clinometers

SINE BAR

- Sine bars are made from high carbon, high chromium, corrosion resistant steels which can be hardened, ground and stabilized.
- Two cylinders of equal diameter are attached at the ends as shown.
- The axes of these ***two cylinders are mutually parallel to each other and also parallel to and at equal distance from the upper surface of the sine bar.***
- The distance between the axes of the two cylinders will be 100, 200 & 300 mm in metric system.
- Depending on the accuracy of the centre distance, sine bars are graded as ***A*** **grade (accurate up to 0.01 mm/m of length)** and ***B*** **grade (accurate up to 0.02 mm/m)**

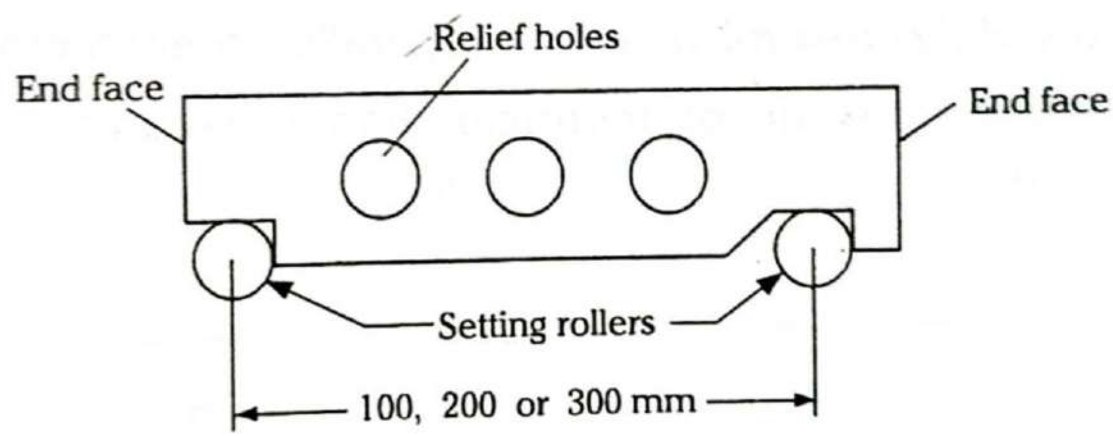


Fig. Sine Bar

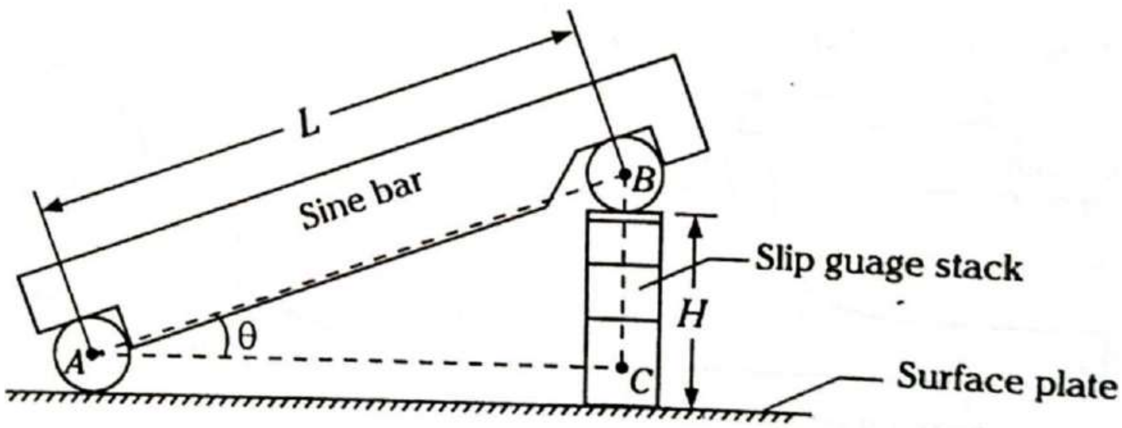
PRINCIPLE OF SINE-BAR

- The sine bar is designed basically for the precise setting out of angles and is generally used in conjunction with slip gauges and surface plate. **The principle of operation of the sine bar relies upon the application of trigonometry.**
- **In** the right angled triangle *ABC* as shown in the Fig, the ratio of the length *BC* to that of hypotenuse *AB* is referred to as the sine of the angle θ.

i.e., $\sin\theta = \frac{BC}{AB}$

- Using the above principle *it is possible to set out precisely any angle by using a standard length of side AB and marking off the length of side BC equal to AB multiplied by the sine of the angle.*
- The sine bar is placed on a surface plate with slip gauges of the required height *(H)* under one roller and opposite to the angle θ as shown in the Fig. Then the angle θ is given by

$$\theta = \sin^{-1}\frac{H}{L}$$



ACCURACY REQUIREMENTS OF A SINE BAR

1. The axes of the rollers must be parallel to each other and the centre distance *L*, must be precisely known.
2. The top surface of the sine bar must be flat and parallel to a plane connecting the axes of the rollers.
3. The axes of the two rollers must be parallel to each other.
4. The rollers must be of identical diameters and round to within a close tolerance

USE OF SINE BAR

1) Measuring known angles or locating any work to a given angle
2) Checking of unknown angles of small components
3) Checking of unknown angles of heavy component

1. MEASURING KNOWN ANGLES OR LOCATING ANY WORK TO A GIVEN ANGLE

- For this purpose, the surface plate is assumed to be having a perfectly flat surface, so that its surface could be treated as horizontal (Fig.)

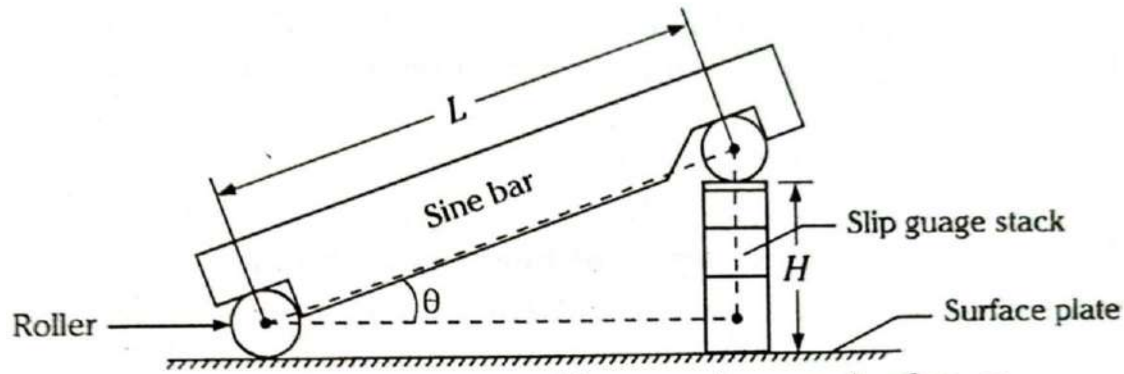


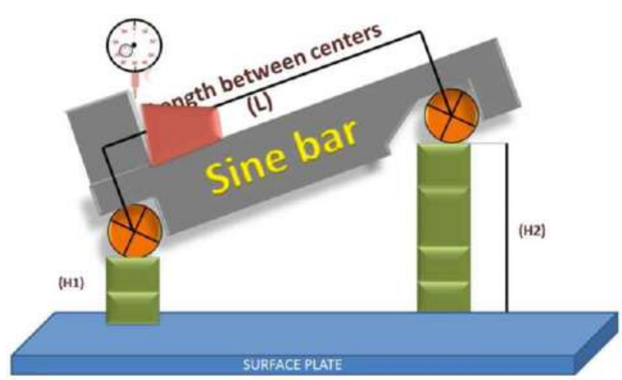
Fig. Use of Sine Bar to Measure known Angles or Locating any Angle to a given Angle

- One roller of the sine bar is placed on the surface plate and the other roller is placed on the slip gauges of height ***H.*** Let the sine bar be set at an angle □.

$$\text{i.e., } \sin □ = \frac{H}{L}$$

- where ***L*** is the centre distance between the rollers. Thus knowing □, H can be found out and any work can be set at this angle as the top face of sine bar is inclined at angle □ to the surface plate.
- Angle plates and clamps can be used in case of heavy components. For better results, both the rollers should be placed on slip gauges of height □1 & □2 respectively.

$$\text{Then, } \sin □ = \frac{(H_2 – H_1)}{L}$$



2. CHECKING OF UNKNOWN ANGLES OF SMALL COMPONENTS

- When an angle of a component to be checked is unknown.
- It is necessary to first find the angle approximately with the help of a bevel protractor.
- If the angle is □, then the sine bar is set at an ***angle*** □ with the help of slip gauges and clamped to an angle plate as shown in the Figure.

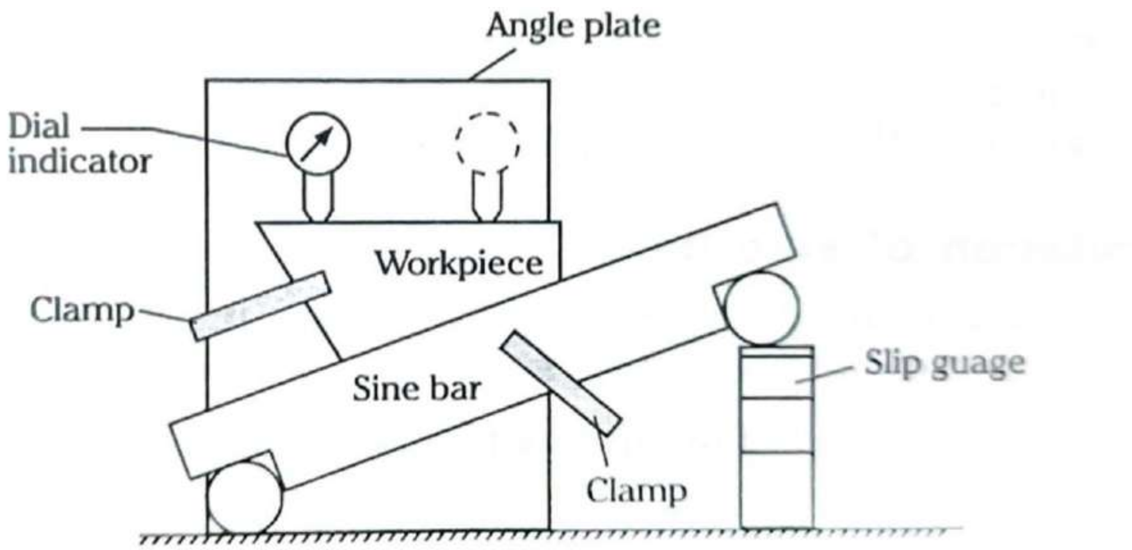


Fig. Use of Sine Bar to Measure unknown Angles

- A dial indicator is set at one end of the work and moved to the other end and the deviation is noted.
- Again slip gauges are so adjusted (according to this deviation) such that dial indicator reads zero as it moves from one end to the other end of the workpiece.
- If deviation noted down by the dial indicator is ΔH over a length l_1 of work, then height of slip gauges by which it should be adjusted is equal to

$$\Delta H \times \frac{l}{l_1}$$

3. CHECKING OF UNKNOWN ANGLES OF HEAVY COMPONENT

- When components are heavy and can't be mounted on the sine bar, then sine bar is mounted on the component as shown in the Figure below.
- The height over the rollers can be measured by a vernier height gauge using a dial gauge mounted on the anvil of the height gauge with the fiducial indicator to ensure constant measuring pressure.
- **Figure** shows the use of height gauge for obtaining two readings over the two rollers of the sine bar.
- The difference in the two readings of height gauge divided by the centre distance of sine bar gives the sine angle of the component to be measured.

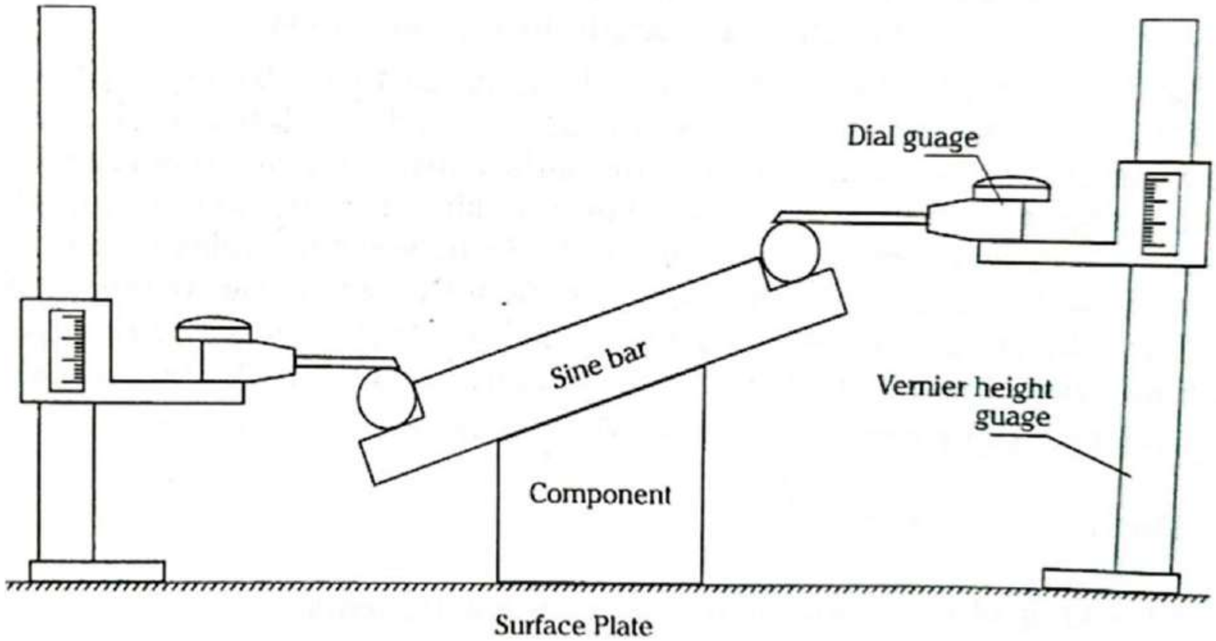


Fig. Use of Sine Bar to Measure unknown Angle of Heavy Component

LIMITATIONS OF SINE BAR

- *The accuracy* of sine bars is limited by the measurement of *centre distance of two precision rollers.*
- The geometrical condition involved in measuring the exact, *effective centre distance between the two rollers of a sine bar to a fraction of a is an infinitely complex problem*.
- Limitation in the *use of sine bar as a primary standard of angle.*
- Measurements using *sine principle are fairly reliable at angles less than 15°, but become increasingly inaccurate as the angle increases.*
- **The sine bars inherently become impractical and inaccurate as the angle exceeds 45° because of following reasons:**
  - ✓ The sine bar is physically clumsy to hold in position especially circular objects.
  - ✓ The body of the sine bar obstructs the gauge block stack, even if relieved.
  - ✓ Slight errors of the sine bar causes large angular errors.
  - ✓ Long gauge stacks are not nearly as accurate as shorter gauge blocks.
  - ✓ A difference in deformation occurs at the point of roller contact supporting the surface and to the gauge blocks, because at higher angles, the load is shifted more toward the fulcrum roller.

SOURCES OF ERROR IN SINE BARS

- *The slip gauge combination which is required to generate any particular angle is given by* **i.e.,** $\sin\theta = \frac{H}{L}$,
- where, H ➔ length of the slip gauge combination
- L ➔ centre distance between the sine bar rollers

The relationship between the angular setting accuracy ($d\theta$) and any error which may be present in the slip gauge combination (dH) or the spacing of the rollers (dL) can be determined by differentiating the equation $\sin\theta = \frac{H}{L}$

Thus, $$\cos\theta\, d\theta = \frac{LdH - HdL}{L^2}$$

$$= \frac{dH}{L} - \frac{HdL}{L^2}$$

$$= dH\left(\frac{1}{L}\right) - \left(\frac{H}{L}\right)\frac{dL}{L} \qquad \left(\because \frac{H}{L} = \sin\theta, \text{ and } \frac{1}{L} = \frac{\sin\theta}{H}\right)$$

$$= \frac{dH}{H}\sin\theta - \frac{dL}{L}\sin\theta$$

$$\therefore d\theta = \tan\theta\left(\frac{dH}{H} - \frac{dL}{L}\right)$$

From the above equation it can be seen that the effect of errors in either the spacing of the rollers (L) or the height of the slip gauge combination (H) is a function of the tangent of the angle θ.

It is also obvious that maximum error occurs when H and L are of opposite sign.

Fig. shows the possible effects of a combined tolerance for a 100 mm sine bar in which the distance between the rollers is in error of - 0.0025 mm and the slip gauge accumulated tolerance is + 0.0005 mm.

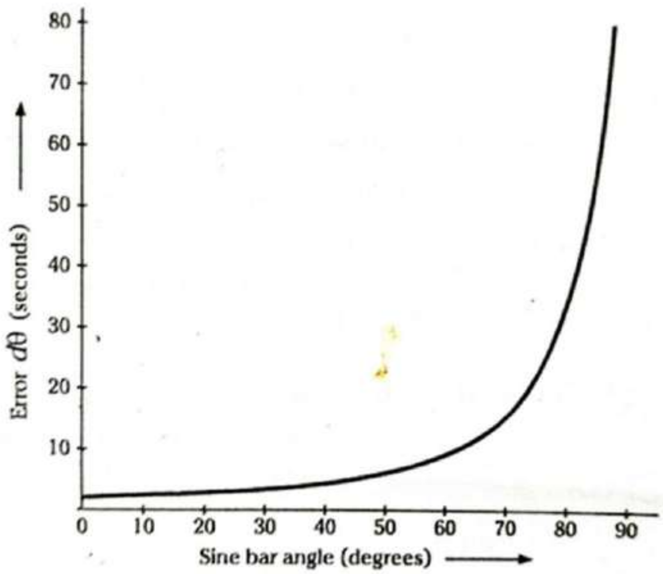


Fig. 3.27 Effect of Combined Centre Distance Error and Block Gage Accumulated Tolerance Error

It can be observed from the curve that as the angle increases, the error also increases progressively. For angles less than 45° the effect is small. However, the effect becomes progressively more significant when the angle is greater than 45°. In general it is preferable not to use the sine bar for generating angles larger than 45° if high accuracy is required.

SINE CENTER

- The ***conical workpiece*** is mounted between the centers of the sine centre.
- Then to make the top conical surface horizontal, the sine centre has to be titled through an angle 'θ' by building the slip gauge stack of height *'H'*. This slip gauge height *'H'* can be found by the sine formula as in sine bar.
- The procedure followed for sine center is as same as that of the sine bar
-

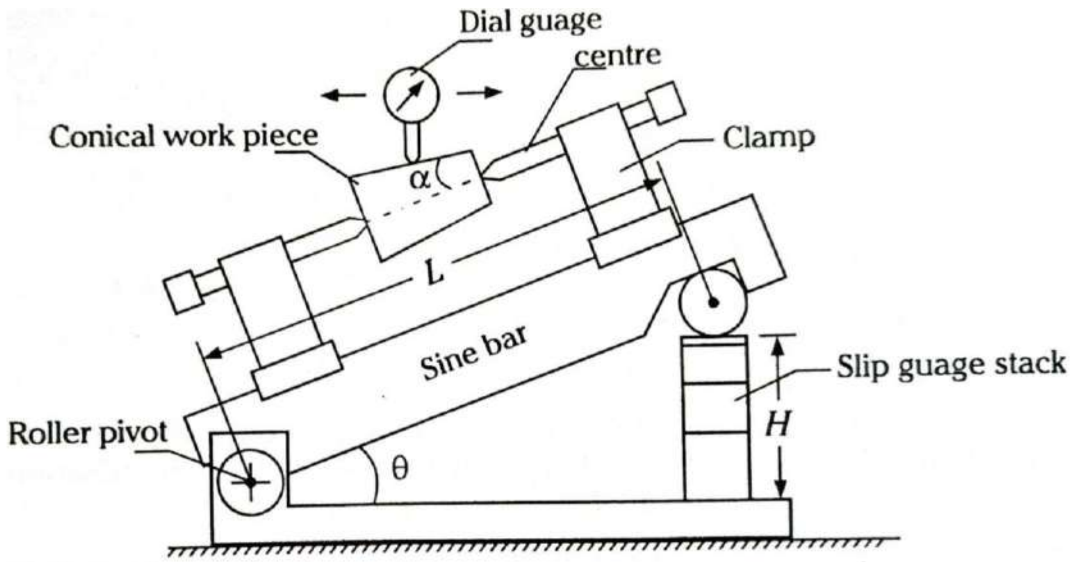
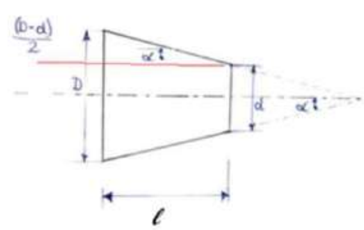


Fig. Sine Centre

To measure semi cone angle (α), initially the small end diameter (*d*), large end diameter (*D*) and the axial length (*l*) of the conical workpiece are measured using vernier calipers. Then the semi cone angle 'α' is calculated by using the formula.

$$\tan\alpha = \left(\frac{\frac{D-d}{2}}{l}\right)$$



$$\alpha = \tan^{-1}\left[\frac{D-d}{2l}\right]$$

Sine centres as shown in photograph 15 are used for mounting conical work pieces, which cannot be held on a conventional sine bar. Sine centre consists of a self contained sine bar, hinged at one roller and mounted on its own datum surface. The top surface of the bar is provided with a pair of clamps and centres for holding the work as shown in Fig. 3.28. To measure semi cone angle (α), initially the small end diameter (d), large end diameter (D) and the axial length (l) of the conical workpiece are measured using vernier calipers. Then the semi cone angle 'α' is calculated by using the formula.

$$\alpha = \tan^{-1}\left[\frac{D-d}{2l}\right]$$

The conical workpiece is mounted between the centres of the sine centre. Then to make the top conical surface horizontal, the sine centre has to be titled through an angle 'θ' by building the slip gauge stack of height 'H'. This slip gauge height 'H' can be found by the following sine formula.

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

where, L is the distance between the sine centre rollers.

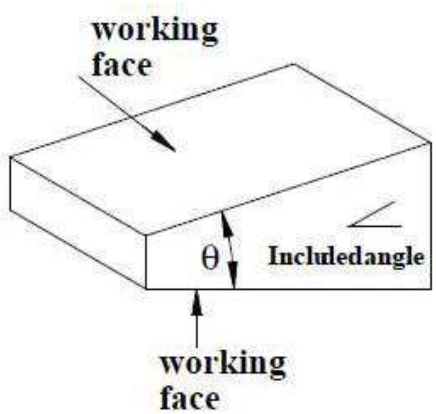
$$\therefore \quad H = L \cdot \sin\theta.$$

Finally, the plunger of the dial gauge is moved along the top conical surface. If any deviation is indicated by the dial gauge, then slip gauge height can be suitably adjusted to get zero deviation. Then the accurate semi cone angle of the workpiece can be found by using the formula.

$$\alpha = \theta = \sin^{-1}\left(\frac{H}{L}\right)$$

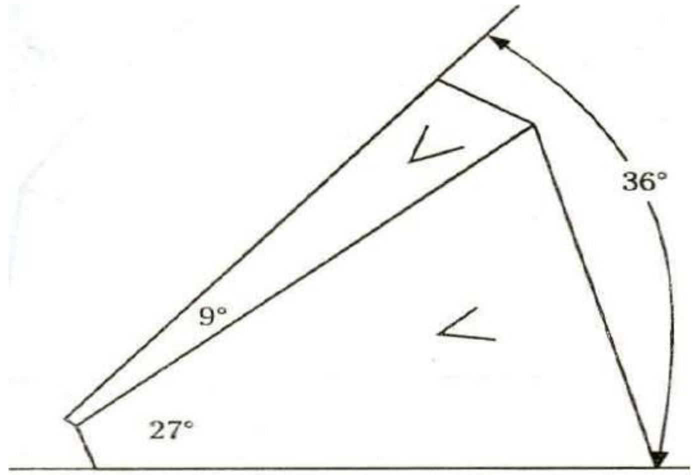
ANGLE GAUGES

- These are developed by Dr.Tomlinson in 1939.
- They are ***hardened steel*** blocks of approximately 75 mm long and 16 mm wide which has two lapped flat working faces lying at a very precise angle to each other.
- The engraved symbol ‘ < ’ indicates the direction of the included angle.
- They are supplied in ***13 pieces set*** (see table) and ***can be wrung together to build the desired angles.***
- (First series with 1˚,3 ˚,9 ˚,27 ˚, and 41˚ and the second series with 1’,3’,9’, and 27’ along with 3’’,6’’,18’’ and 30’’ – total 13 pieces)
- These gauges together with a square block, enable any angle between 0˚ and 360˚ to be constructed to within ***1.5 seconds*** of the nominal value by a suitable combination of gauges.



Degrees	1	3	9	27	41
Minutes	1	3	9	27	-
Fraction of minute	0.05	0.1	0.3	0.5	-
(or seconds)	3	6	18	30	-

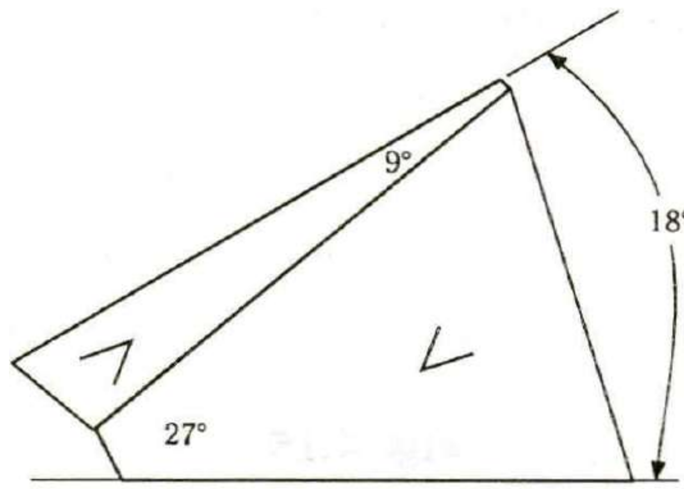
- Each angle gauge is a wedge, thus two gauges with their narrow ends together provide an angle which is the sum of the angles of the individual gauges.
- The engravings '< ' in addition are all in the same direction as shown.



(a) Angle addition

Fig. Combination of Angle Gauges

- Subtraction of angles are obtained when the narrow ends are opposed as shown in the (b) and the engravings ' < ' are in the opposite direction.



(b) Angle subtraction

Fig. Combination of Angle Gauges

NUMERICAL ON BUILDING OF ANGLES

Example 1:

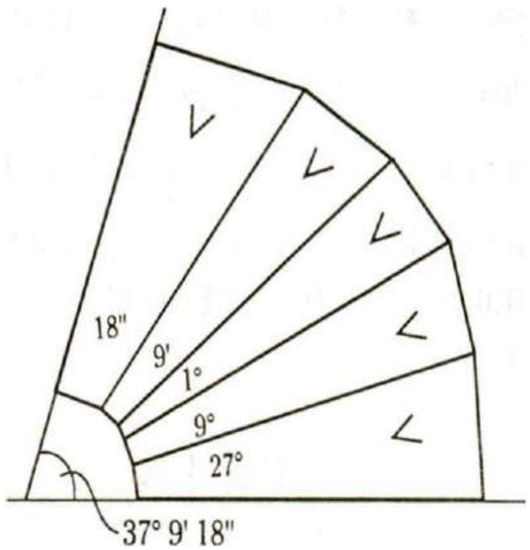
Select the size of angle gauges required to build the **37˚ 9' 18''** . Also sketch the arrangement.

Solution:

From the table of angle gauges

Degrees	1	3	9	27	41
Minutes	1	3	9	27	-
Fraction of minute	0.05	0.1	0.3	0.5	-
(or seconds)	3	6	18	30	-

- First the degree is obtained: **37˚ = 27˚+9˚+1˚**
- Then the minutes: **9' = 9'**
- Fraction of minutes (or seconds) **: 18'' = 18'' (0.3 minutes)**
- **A total of 6 gauges**

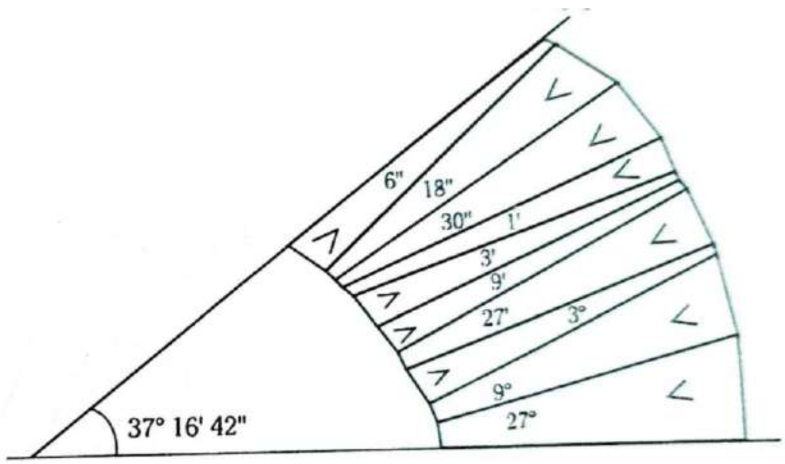


Example 2:

Select the size of angle gauges required to build the **33˚ 16' 42''** . Also sketch the arrangement.

Solution: From the table of angle gauges (need to draw table of angle gauges)

- First the degree is obtained: **33˚ = 27˚+ 9˚- 3˚**
- Then the minutes: **16' = 27' - 9' - 3' + 1'**
- Fraction of minutes (or seconds) **: 42'' = (30'') + (18'') - (6'')**
- **= 0.5 + 0.3 - 0.1 = 42''**
- **A total of 10 gauges**

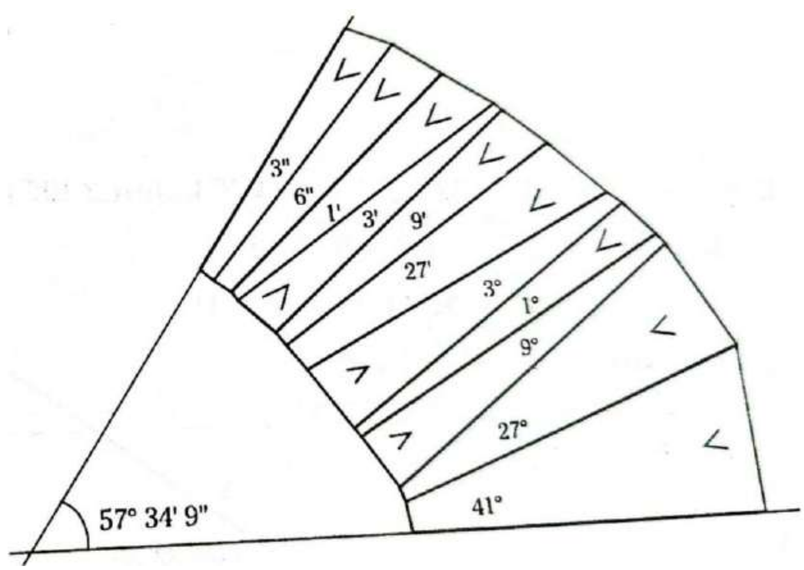


Example 3:

Select the size of angle gauges required to build the **57˚ 34' 9''** . Also sketch the arrangement.

Solution: From the table of angle gauges (need to draw table of angle gauges)

- First the degree is obtained: **57˚ = 41˚+ 27˚- 9˚+ 3˚- 1˚**
- Then the minutes: **34' = 27' + 9' - 3' + 1'**
- Fraction of minutes (or seconds) **:9''** = **(6'') + (3'')**
- **= 0.1 + 0.05 = 9''**
- **A total of 11 gauges**

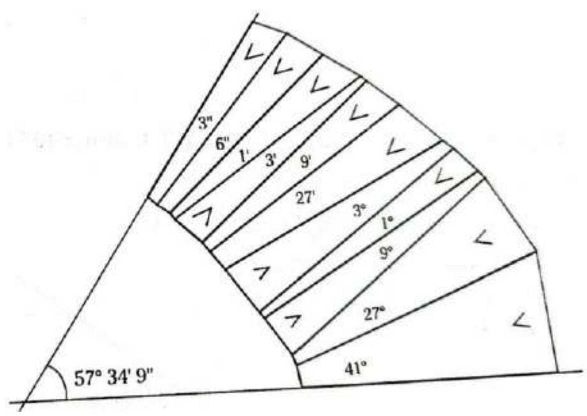


Example 4:

Select the size of angle gauges required to build the **37° 16' 42''** . Also sketch the arrangement.

Solution: From the table of angle gauges (need to draw table of angle gauges)

Degree	$27^\circ + 9^\circ + 1^\circ = 37^\circ$
Minutes	$27' - 9' - 3' + 1' = 16'$
Fraction of minutes (sec)	$0.5 + 0.3 - 0.1 = 42''$ $(30'' + 18'' - 6'')$

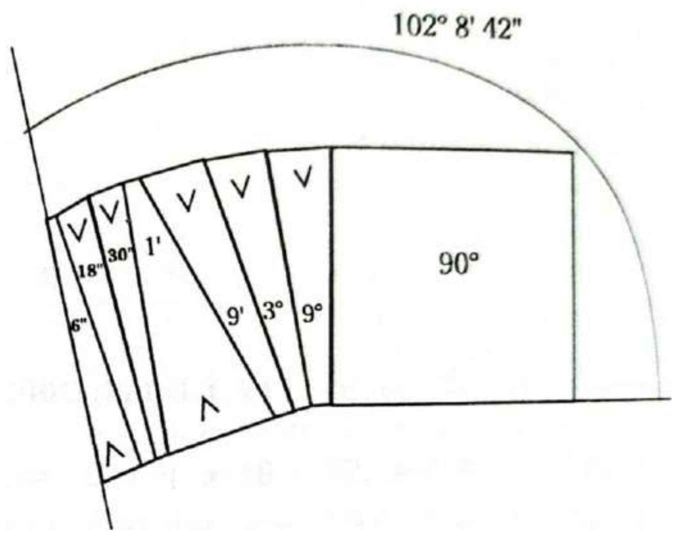


Example 5:

Select the size of angle gauges required to build the **102° 8' 42''** . Also sketch the arrangement.

Solution: From the table of angle gauges (need to draw table of angle gauges)

Degree	$90^\circ + 9^\circ + 3^\circ = 102^\circ$
Minutes	$9' - 1' = 8'$
Seconds	$30'' + 18'' - 6'' = 42''$



Example 6:

Select the size of angle gauges required to build the **35˚ 32' 36''**. Also sketch the arrangement.

Solution: From the table of angle gauges (need to draw table of angle gauges)

Degree $35° = 41° - 9° + 3°$

Minutes $32' = 27' + 9' - 3' - 1'$

Seconds $36'' = 30'' + 6''$

Vernier Bevel Protractor: (Universal Bevel Protractor)

- It is a simplest instrument for measuring the angle between two faces of a component.
- As shown in **figure.**
- It consists of a base plate attached to the main body, and an adjustable blade which is attached to a circular plate containing vernier scale.
- The adjustable blade is capable of sliding freely along the groove provided on it and can be clamped at any convenient length.
- The adjustable blade is along with the circular plate containing the vernier scale can rotate freely about the centre of the main scale engraved on the body of the instrument and can be locked in any position with the help of knob.
- An acute angle attachment is provided for the purpose of measuring acute angles.
- The base plate is made flat so that it can laid flat upon the work and any type of angle can be measured. (i.e., from 0˚ to 360˚)

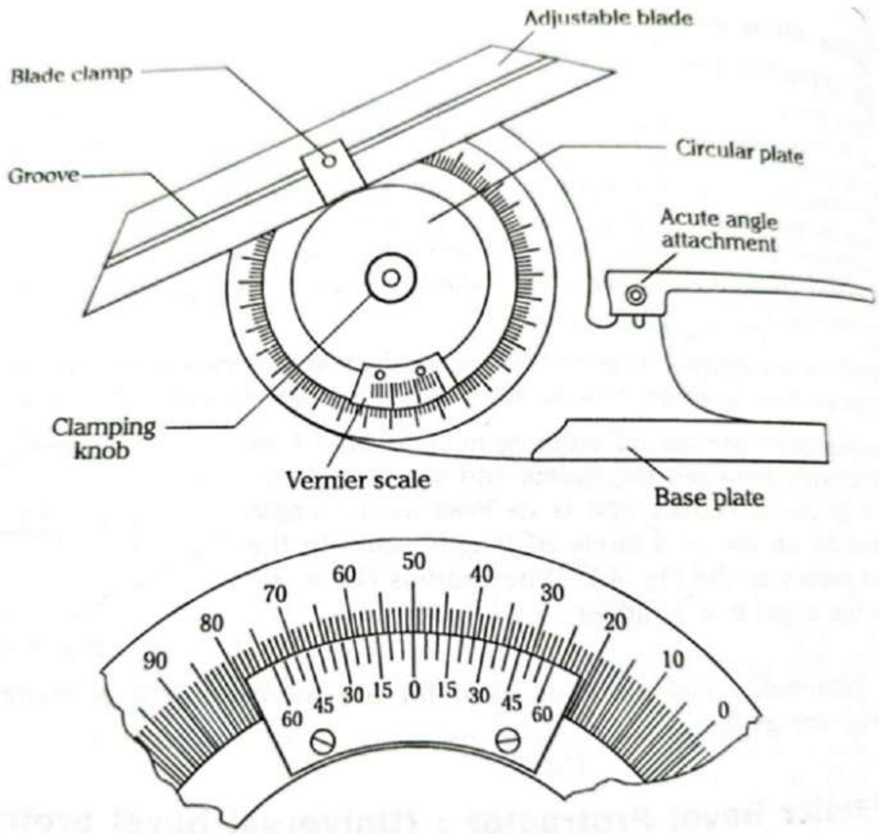


Fig. Schematic of Vernier Bevel Protractor

The main scale is graduated in degrees of arc. The vernier scale has 12 divisions on either side of the centre zero. They are marked 0-60 minutes of arc, so that each division is 1/12 of 60 minutes, that is 5 minutes of arc.

These 12 divisions occupy the same space as 23 degrees on the main scale. Therefore, each division of the vernier is equal to

$$\frac{1}{12} \text{ of } 23^\circ \text{ or } 1\frac{11^\circ}{12}$$

If the zero graduation on the vernier scale coincides with a graduation on the main scale, the reading is in exact degrees, but if some other graduation on the vernier scale coincides with a main scale graduation, the number of vernier graduations multiplied by 5 minutes must be added to the number of degrees read between the zeros on the main scale and the vernier scale.

OPTICAL BEVEL PROTRACTOR

- A recent development of the **vernier bevel protractor** is an ***optical bevel protractor*** as shown in the figure.

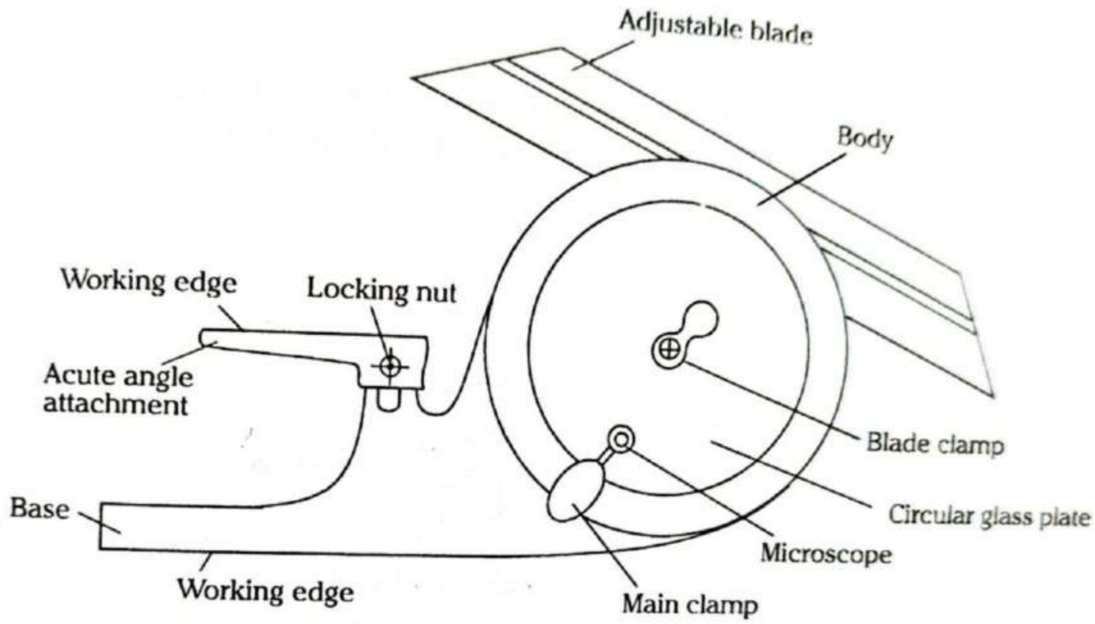


Fig. Schematic of Optical Bevel Protractor

- In this instrument, a circular glass plate divided at ***10minutes*** intervals throughout *the whole 360˚ is fitted inside the main body*.
- ***A small microscope*** is fitted through which the circular graduations can be viewed.
- The readings are taken against a ***vernier scale with the help of a microscope.***
- The adjustable blade is clamped to a ***rotating member which carries the microscope.***
- With the help of ***microscope, it is possible to read to about 2 minutes.***

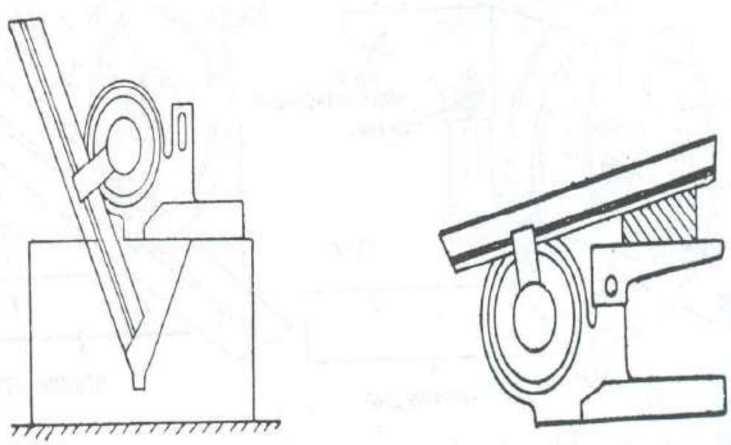


Fig. 8.7. Use of bevel protractor for checking of vee block.

Fig. 8.8. Use of Vernier protractor for measuring acute angle.