

METROLOGY

(PR 401)

UNIT V

COMPARATORS

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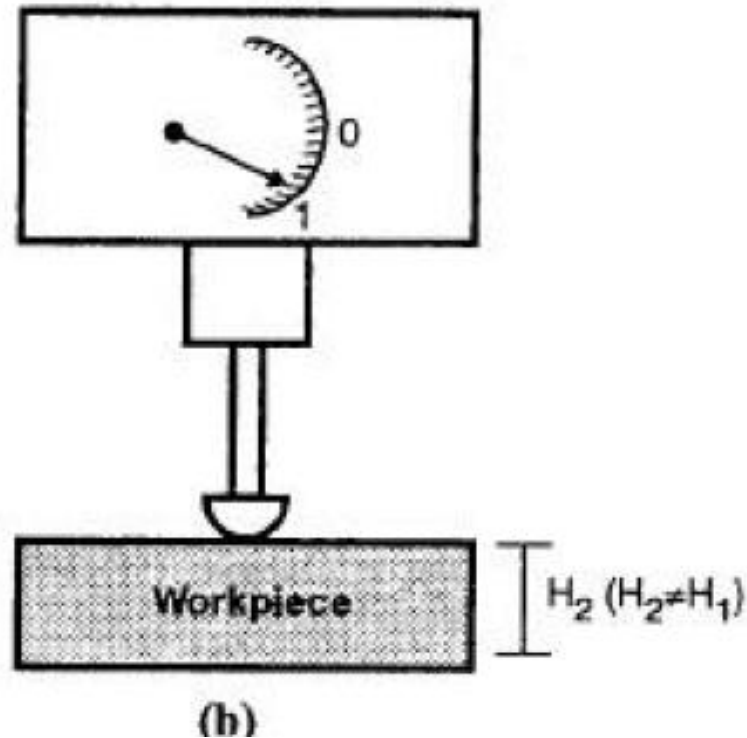
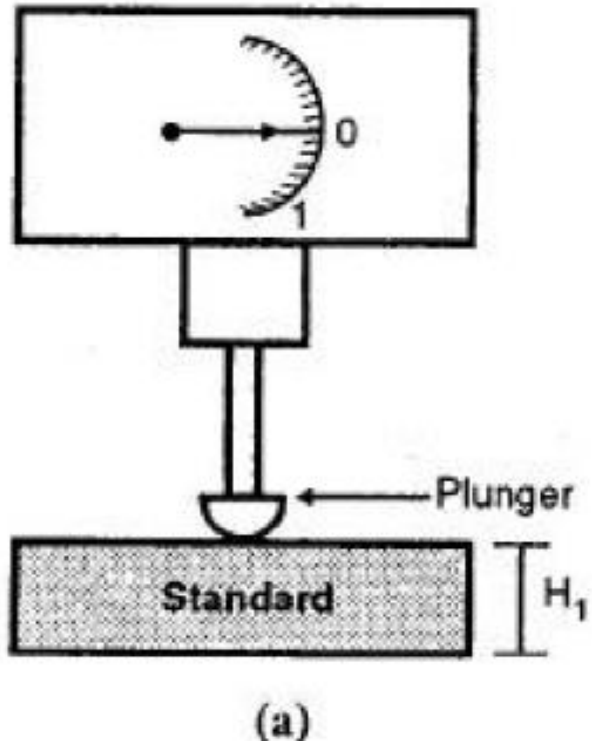
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Introduction

- Precision instrument
- Indirect measurement method
- indicate the small difference between the standard and the work piece being measured
- can be used for direct linear measurement within its range of operation
- The purpose of a comparator is to detect, magnify and display the small differences after between the unknown dimensions and the standard

Working principle

- The general principle of comparator is to indicate the difference in size between the standard and work being measured by means of some pointer on the scale with sufficient magnification.



Need for a comparator

- A comparator is used in mass production to inspect the components to close tolerance with high degree of precision and speed
- Use of line standards such as vernier caliper and micrometer required considerable skill
- Many dimensions can be checked in a very short time.

Uses of comparator

- To check the components and newly purchased gauges.
- As laboratory standards to set working or inspection gauges.
- As a final inspection gauge.

Essential Characteristics of Comparator:

- 1. Robust design and construction:** The design and construction of the instrument should be robust so that it can withstand the effects of ordinary uses without affecting its measuring accuracy.
- 2. Linear characteristics of scale:** Recording or measuring scale should be linear and uniform (straight line characteristic) and its indications should be clear.
- 3. High magnification:** The magnification of the instrument should be such that a smallest deviation in size of component can be easily detected.
- 4. Quick in results:** The indicating system should be such that the readings are obtained least possible time.
- 5. Versatility:** Instrument should be so designed that it can be used for wide range of measurement.

- 6.** Measuring plunger should have the hardened steel, or diamond contact to minimise wear and contact pressure should be low and uniform.
- 7.** The pointer should come rapidly to rest and should be free from oscillations.
- 8.** System should be free from back lash and unnecessary friction and it should have a minimum inertia.
- 9.** Indicator should be provided with maximum compensation for temperature effects.
- 10.** Indicator should return to its initial zero position every time.

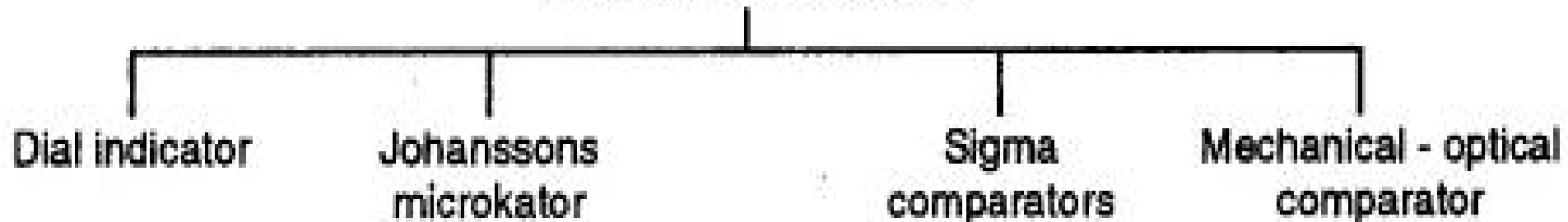
Classification

1. Mechanical Comparator: It works on gears pinions, linkages, levers, springs etc.
2. Pneumatic Comparator: Pneumatic comparator works by using high pressure air, valves, back pressure etc.
3. Optical Comparator: Optical comparator works by using lens, mirrors, light source etc.
4. Electrical Comparator: Works by using step up, step down transformers.
5. Electronic Comparator: It works by using amplifier, digital signal etc.
6. Combined Comparator: The combination of any two of the above types can give the best result.

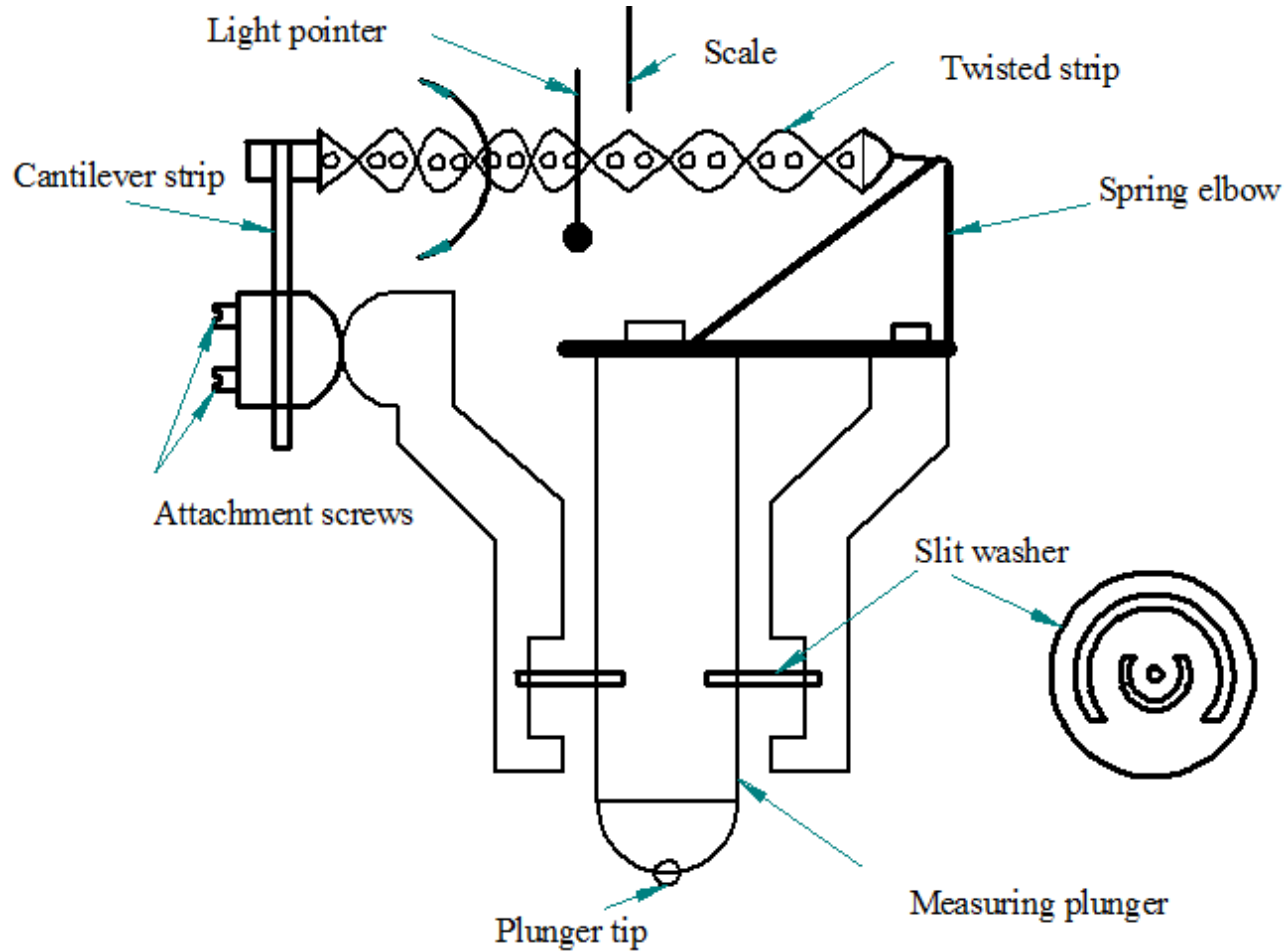
Mechanical Comparators

- It is self controlled and no power or any other form of energy is required.
- It employs mechanical means for magnifying the small movement of the measuring stylus.
- The movement is due to the difference between the standard and the actual dimension being checked
- The method for magnifying the small stylus movement in all the mechanical comparators is by means of levers, gear trains or combination of these.
- They are available of different make and each has it's own characteristic.

Mechanical comparator

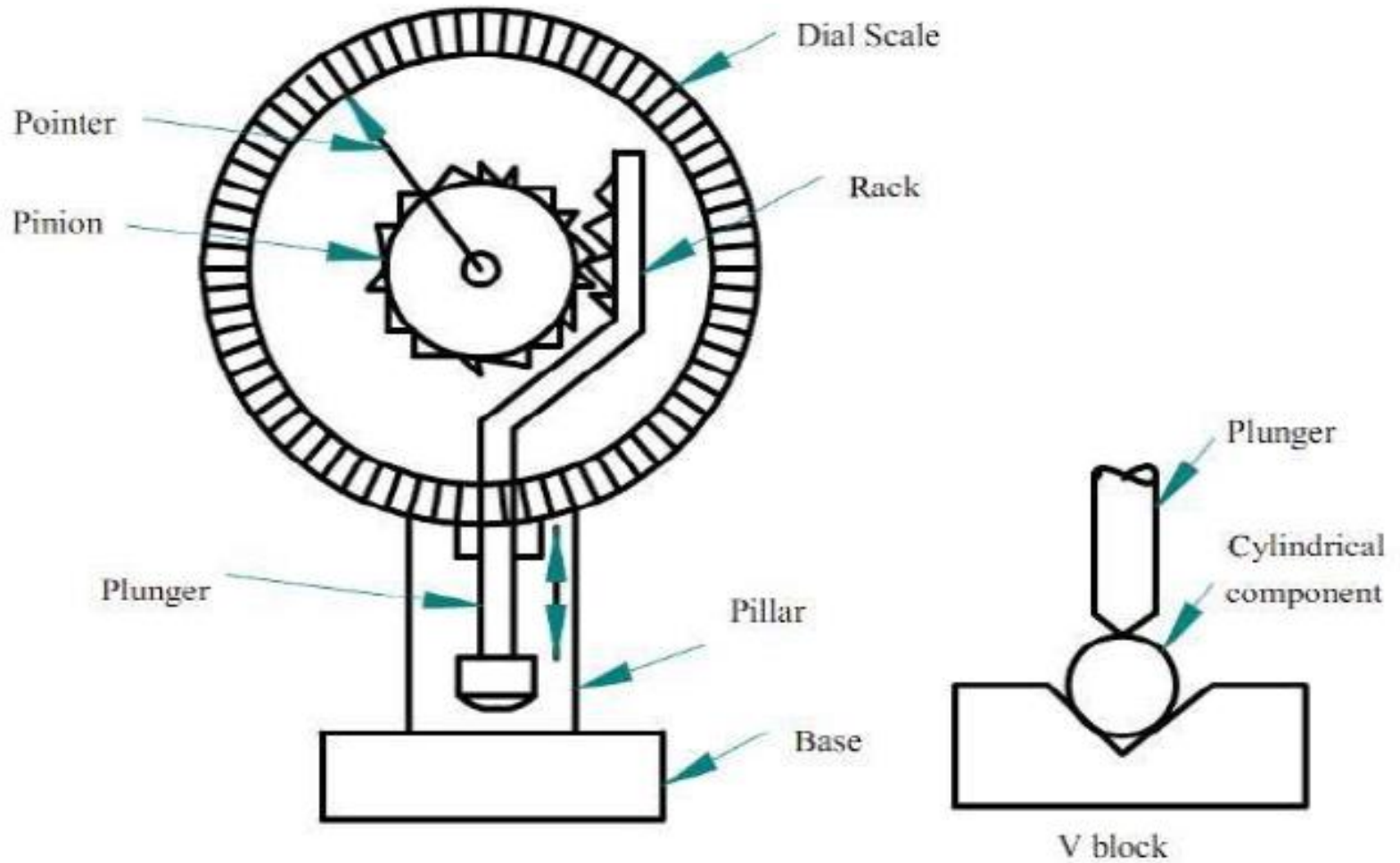


JOHANSSON “MIKROKATOR”:



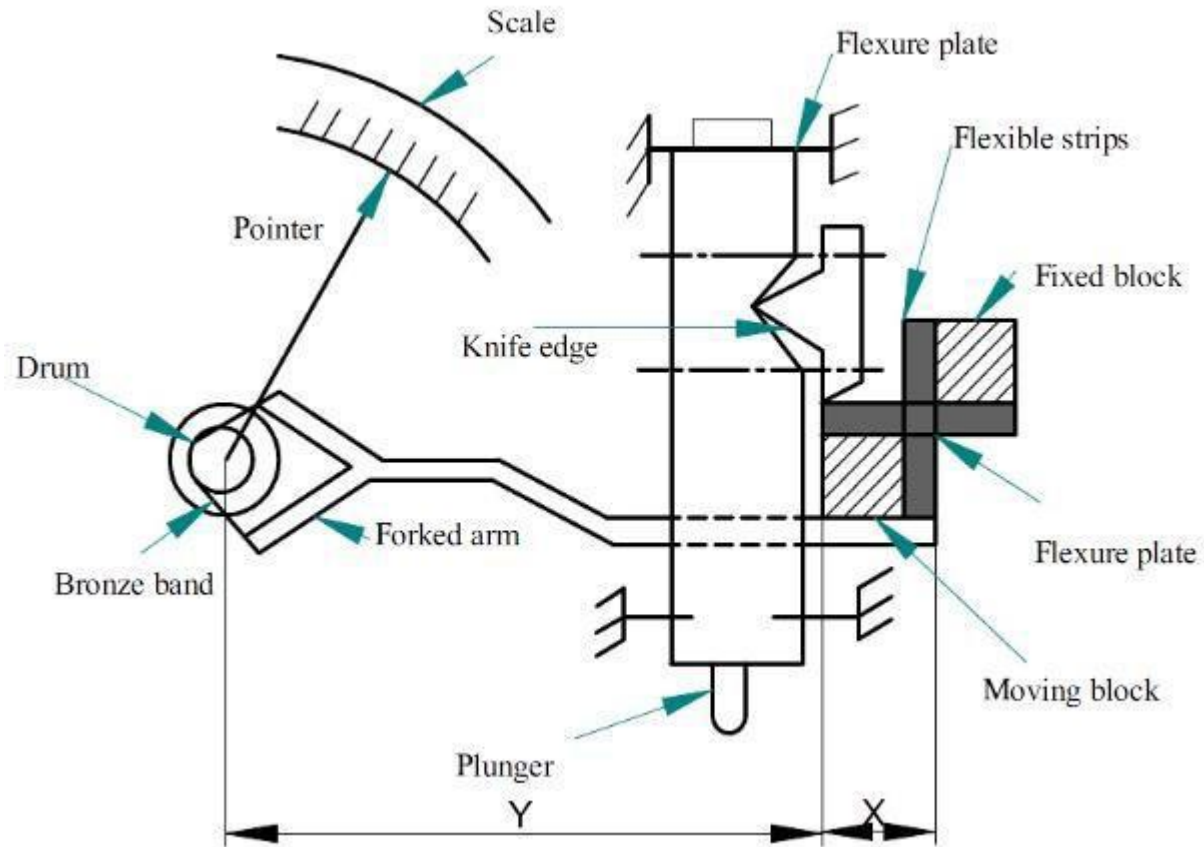
- Johansson “Mikrokator” is a mechanical comparators having magnification of about 5000.
- It works on the principle of a button spinning on a loop of string.
- The instrument consists of a plunger, twisted thin metal strip, spring elbow, pointer, etc.
- A very light glass pointer is attached to the Centre of the twisted strip.
- The two halves of the strip from the Centre are twisted in opposite directions, so that any pull in the strip causes the Centre and hence the pointer to rotate.
- One end of the strip is fixed to an adjustable cantilever strip and other end is attached to an arm of spring elbow.
- The measuring plunger is mounted on a flexible diaphragm. Its inner end is attached to the other arm of spring elbow.
- Thus the vertical movement of the plunger transmitted to the metal strip through the elbow.
- Any vertical movements of the plunger make it to twist or untwist.
- This will cause the pointer to rotate by an amount proportional to the change in the length of the strip
- Magnification of the instrument depends upon the length, width and number of twists of the twisted strip.
- It can be varied by changing the length of the strip with screws provided on adjustable cantilever strip.

DIAL INDICATOR:



- Dial indicator is a small indicating device using mechanical means such as gears, pinions for magnification.
- The usual magnification is about 250 to 1000.
- It consists of a plunger which slides in bearing and carries a rack at its inner end. The rack meshes with a pinion, which drives another gear and pinions.
- 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 plunger is kept in its normal extended position by means of a light coil spring. The linear movement of the plunger is magnified by the gear train and transmitted to the pointer on the dial scale.
- The dial scale is set to zero by use of slip gauges representing the basic size of the part to be measured.
- Dial indicators are compact and robust in construction.
- They are portable, easy to handle and can be set very quickly.
- This type of comparator can be used with various attachments so that it may be used for larger number of works.
- They are used for inspection of small precision machined parts testing alignment, roundness, parallelism of work pieces, etc.

SIGMA COMPARATOR



- This is a mechanical comparator providing magnification in 300 to 5000.
- It consists of a plunger mounted on two steel strings (slit diaphragms). This provides a frictionless linear movement for the plunger.
- The plunger carries a knife-edge, which bears upon the face of the moving block of a cross-strip hinge.
- The cross-strip hinge is formed by pieces of flat steel springs arranged at right angles and is a very efficient pivot for smaller angular movements.
- The moving block carries light metal Y-forked arms. A thin phosphor bronze ribbon is fastened to the ends of the forked arms and wrapped around a small drum, mounted on a spindle carrying the pointer.
- Any vertical displacement of measuring plunger and hence that of the knife edge makes the moving block of the cross-strip hinge to pivot.
- This causes the rotation of the Y-arms. The metallic band attached to the arms makes the driving drum and hence the pointer to rotate.
- The ratio of the effective length (L) of the arm and the distance (X) of the knife edge from the pivot gives the first stage magnification
- The ratio of pointer length (R) and radius r of the driving drum gives second stage magnification of the instrument.
- Total magnification of the instrument is thus $(L/X \times R/r)$.
- The magnification of the instrument can be varied by changing the distance (X) of knife-edge by tightening or slackening of the adjusting screws.

Advantages of Mechanical Comparators

- They are cheaper compared to other amplifying devices.
- Do not required electricity or air and such the variations in the outside sources do not affect the accuracy.
- They have a linear scale robust and easy to handle.
- It is suitable for ordinary workshop and also easily portable.

Disadvantages of Mechanical Comparators

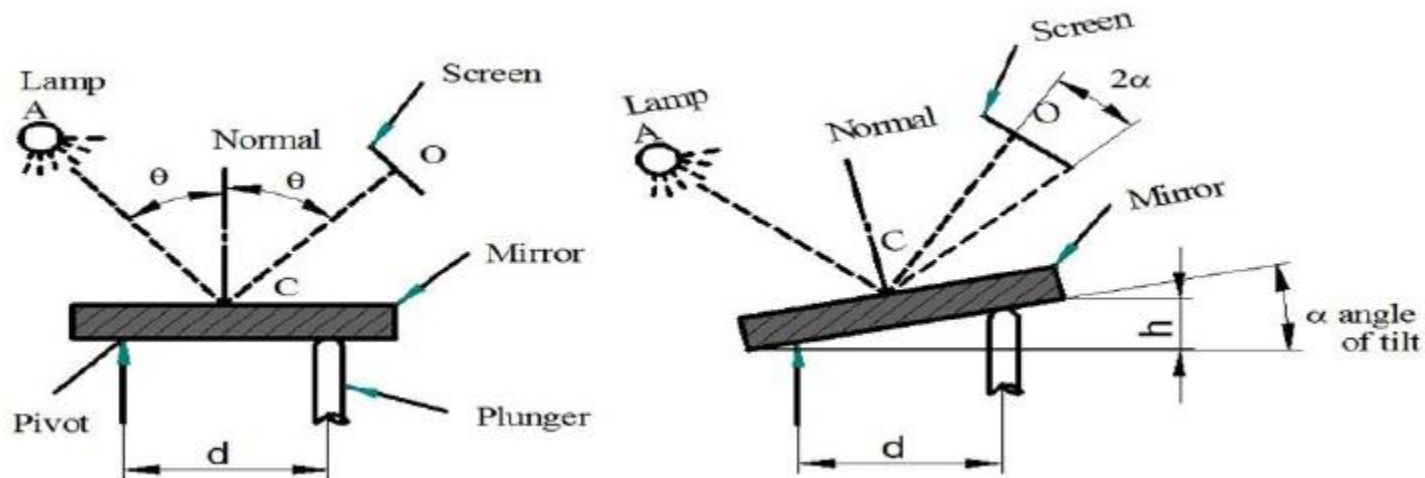
- They have more moving linkages, due to which friction is more and accuracy is low.
- Any wear, dimensional faults in the mechanical devices used will also be magnified.
- The range of the instrument is limited, because the pointer moves over a fixed scale

OPTICAL COMPARATOR

- **Introduction**
- There are no pure optical comparators but the instruments classed as optical comparators obtain large magnification in these instruments contributes principles though mechanical magnification
- All optical comparators are capable of giving high degree of measuring precision.
- **Working principle of Optical comparators:**
- Operating principle of this type, of comparator is based on the laws of light reflection and refraction. Magnification system depends on the tilting of a mirror, deflects a beam of light, thus providing an optical lever.

Principle of optical lever

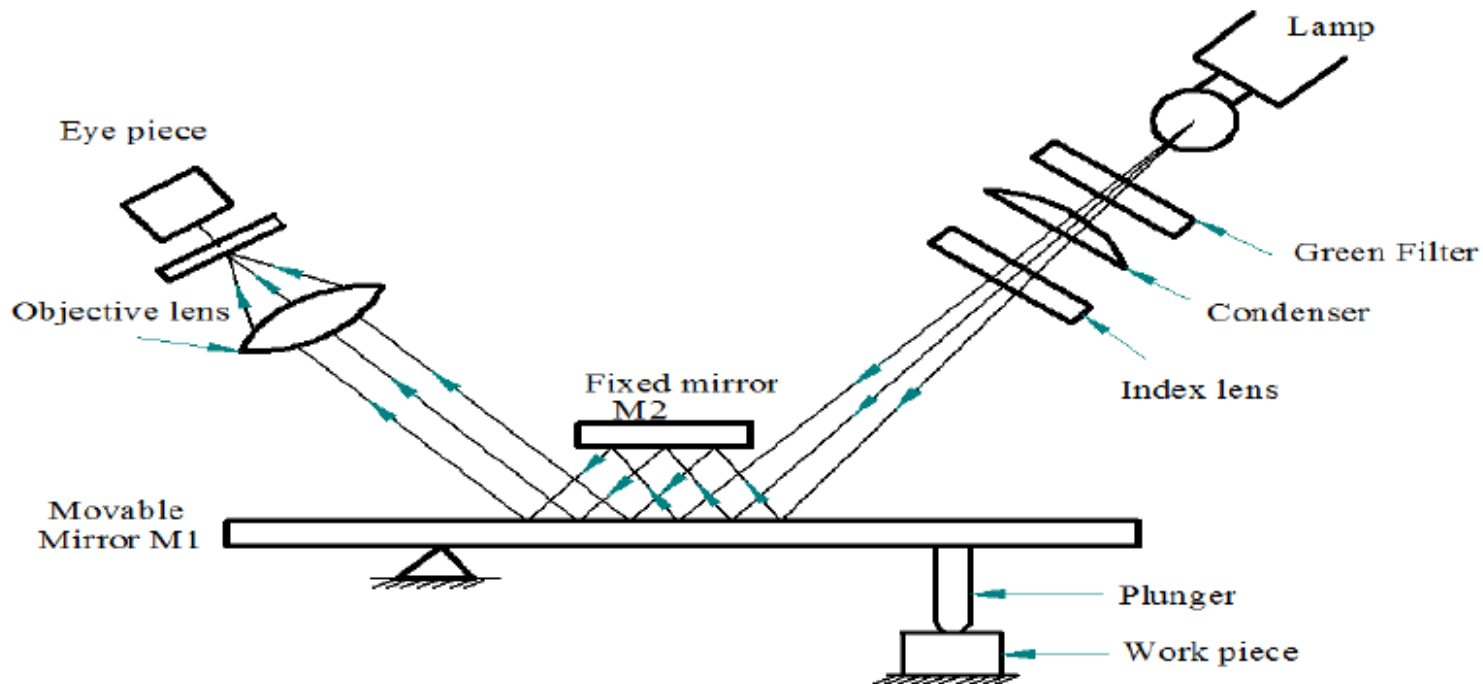
- If a beam of light AC is directed on to a mirror as shown in figure, it will be reflected onto the screen at O as a dot.
- The angle θ at which the beam strikes the mirror is equal to the angle θ at which the beam is reflected from mirror.
- When the plunger moves upwards vertically, causing the mirror to tilt by an angle „ α “ as shown in figure.
- Then the reflected light beam moves through an angle “ 2α ” which is twice the angle of tilt produced by the plunger movement.
- The illuminated dot moves to “B” thus a linear movement “h” of the plunger produces a movement of the dot equivalent to the distance OB on the screen.
- It also clear that as the distance (OC) of the screen from tilting mirror increases, greater will be the magnification and is called principle of enlarge image.



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 M1. It is then reflected to another fixed mirror M2 and back again to first movable mirror.
- 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 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

- Optical comparators have few moving linkages and hence are not subjected to friction, wear and tear.
- High accuracy of measurement.
- The magnification is usually high.

Disadvantages

- An electrical supply is necessary to operate these types of comparators.
- The size of these comparators are highly, 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.

Electrical comparator

Introduction

- Electrical comparators are also called as electromechanical measuring systems.
- This is because they use an electro-mechanical device that converts a mechanical displacement into an electrical signal.
- LVDT - Linear Variable Differential Transformer (LVDT) is the most popular electro mechanical device used to convert mechanical displacement into electrical signal. It is used to measure displacement.

Working principle of Electrical comparators:

- These instruments are based on the theory of Wheatstone A.C. Bridge. When the bridge is electrically balanced, no current will flow through the galvanometer connected to the bridge and pointer will not deflect. Any upset in inductances of the arms will produce unbalance and cause deflection of the pointer.

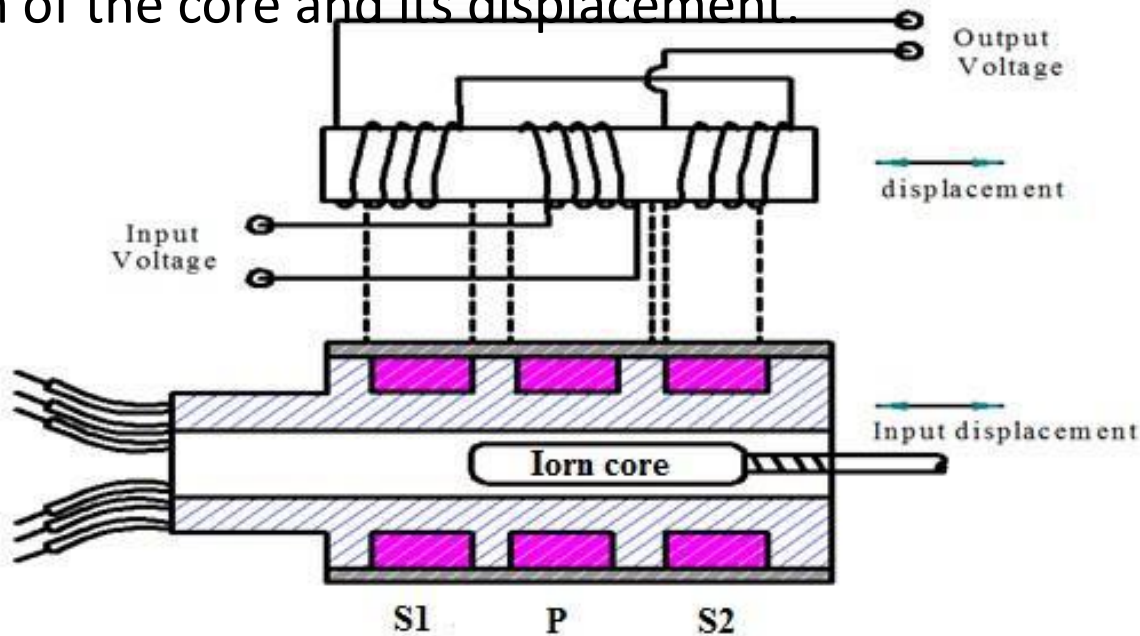
Description

- The LVDT consists of a primary winding and two secondary winding (S1 and S2) which are wound on a cylindrical former.
- The secondary windings have equal no. of turns
- The secondary windings are placed identically on either side of the primary winding.
- The primary winding is connected to an AC source.
- A movable core is placed inside the cylindrical former.

Operation

- As the primary winding is connected to AC source, it is excited and here a magnetic field is produced. Due to this magnetic field, a voltage is induced in the secondary windings.
- The differential output is $E_0 = E_{s1} - E_{s2}$. When the core is in the normal (null) position, the magnetic field linking with both secondary winding S1 and S2 are equal. Hence the emf induced in them is also equal. Therefore, at null position, $E_{s1} = E_{s2}$, and hence $E_0 = \text{zero}$.

- When the core is moved to right of the null position, more magnetic field links with winding S2 and less with winding S1. Therefore, E_{s2} will be larger than E_{s1} . Therefore, the output voltage $E_0 = E_{s1} - E_{s2}$ and is in phase with E_{s2} .
- When the core is moved to left of the null position, more magnetic field links with winding S1 and less with winding S2. Therefore, E_{s1} will be larger than E_{s2} . Therefore, the output voltage $E_0 = E_{s1} - E_{s2}$ and is in phase with E_{s1} .
- The output voltage E_0 of the LVDT gives a measure of the physical position of the core and its displacement.



Advantage of electrical comparator

- Small number of moving parts.
- Possible to have very high magnification.
- Used for variety of ranges.
- Remote operation can also be done.

Disadvantage of electrical comparator

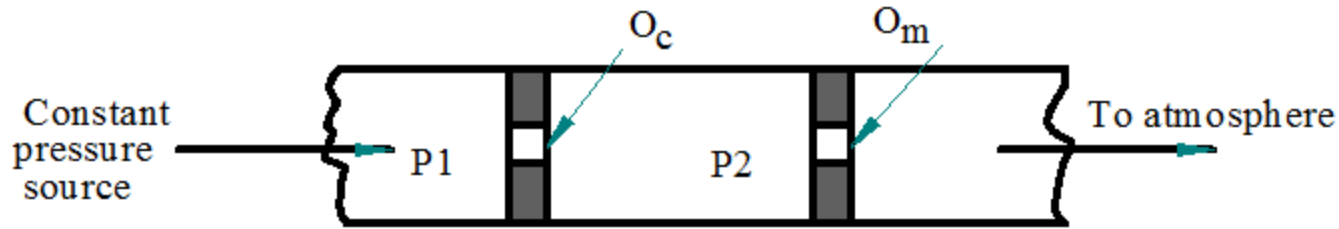
- Required an external agency to operate i.e., A.C .power supply.
- Heating coils may cause zero drift.
- More expensive than mechanical comparator.

PNEUMATIC COMPARATORS:

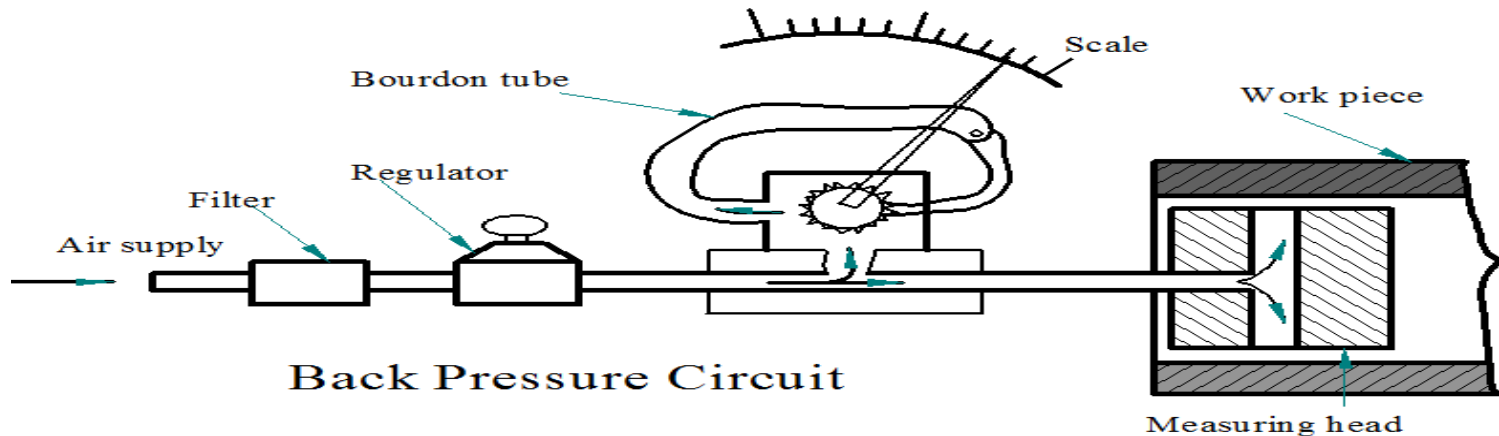
- These instruments utilize the variations in the air pressure or velocity as an amplifying medium.
- A jet or jets of air are applied to the surface being measured and the variations in the back pressure or velocity of air caused due to variations in load are used to amplify the output signals.
- Based on the physical phenomena, the pneumatic comparators are classified into two types.
 - Flow or velocity type
 - Back pressure type.

Back pressure type

- The principle of back pressure gauges is that when the orifice O_m is blocked, the upstream pressure P_1 becomes equal to pressure P_2 between the two orifices.
- When the orifice opening O_m is increased indefinitely, the pressure P_2 tends to become zero.
- In the basic back pressure unit shown in fig, a bourdon tube deflects according to back pressure changes built up in the circuit when work piece is placed over the measuring head.
- The deflection is amplified by gear & lever and indicated on a dial.



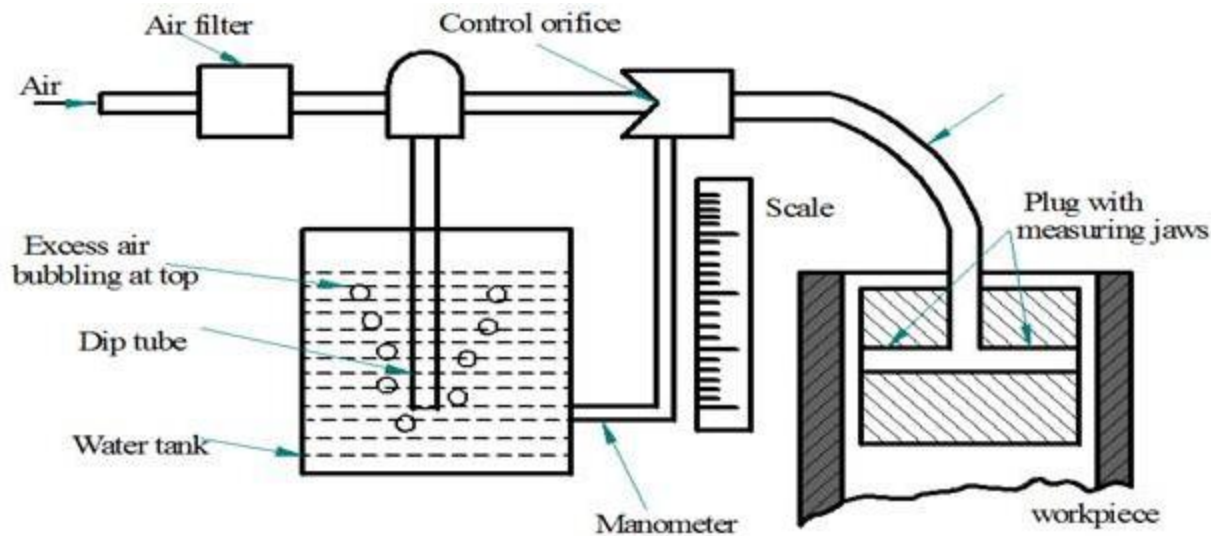
Principle of back pressure type Pneumatic comparator



Back Pressure Circuit

Solex Pneumatic Comparator

- This instrument was first commercially introduced by Solex Air Gauges Ltd. It uses a water manometer for the indication of back pressure.
- It consists of a vertical metal cylinder filled with water up to a certain level and a dip tube immersed into it up to a depth corresponding to the air pressure required.
- A calibrated manometer tube is connected between the cylinder and control orifice as shown in the fig.



Solex Pneumatic gauge

- The pressure of the air supplied is higher than the desired pressure, some air will bubble out from the bottom of the dip tube and air moving to the control volume will be at the desired constant pressure.
- The constant pressure air then passes through the control orifice and escapes from the measuring jets.
- When there is no restriction to the escape of air, the level of water in the manometer tube will coincide with that in the cylinder.
- But, if there is a restriction to the escape of air through the jets, a back pressure will be induced in the circuit and level of water in the manometer tube will fall.
- The restriction to the escape of air depends upon the variations in the dimensions to be measured.
- Thus the variations in the dimensions to be measured are converted into corresponding pressure variations, which can be read from the calibrated scale provided with the manometer.

- **Advantages:**

- It is possible to have high degree of magnification.
- It is the best method for determining the ovality and taperness of the circular holes.

- **Disadvantages:**

- The scale is generally not uniform.
- The apparatus is not easily portable.

- Thank You
- Questions/ Doubts are welcomed on the below contact details:
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- Reference: M. Mahajan, “A Text Book of Metrology”, 2006, published by Dhanpat Rai & Co. (P) LTD.