UNIT-5

COMPARATORS

Introduction:

A comparator is a precision instrument employed to compare the dimension of a given component with a working standard (usually slip gauges). It thus does not measure the actual dimension but indicates how much it differs from the basic dimension.

Need for a comparator:

In mass production identical component parts are produced on a very large scale. To achieve inter changeability these parts should be produced to a close dimensional tolerances.

Basic Principle of Operation:

The basic principle of operation of a comparator is:

The comparator is first adjusted to zero on its dial or recording device with a guage block in position. The gauge block is of dimension which the workpiece should have. The workpiece to be checked is then placed in position and the comparator gives the difference in dimension in relation to the gauge block.

Uses of Comparator:

The various Ways in which comparators can be used are:

1. Laboratory Standards: Comparators are used as laboratory standards from which working or inspection gauges are set and correlated.

2. Working Gauges: They are also used as working gauges to prevent work spoilage and to maintain required tolerance at all important stages of manufacture.

3. Final Inspection Gauges: Comparators may be used as final inspection gauges. Where selective assembly, of production parts is necessary.

4. Receiving Inspection Gauges: As receiving inspection gauges comparators are used for checking parts received from outside sources.

5. For checking newly purchased gauges: The use of comparators enables the checking of the parts (components in mass production at a very fast rate.)

Essential characteristics of a good comparator:

1. Robust design and construction: The design and construction of the comparator should be robust so that it can withstand the effects of ordinary uses without affecting its measuring accuracy. [Robust=strong]

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 comparator 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 in least possible time.

5. Versatility: Instruments should be designed that it can be used for wide range of measurements.

6. Minimum wear of contact point: The measuring plunger should have hardened steel contact or diamond to minimize wear effects. Further the contact pressure should be low and uniform.

7. Free from oscillations: The pointer should come rapidly to rest and should be free from oscillations.

8. Free from back lash: System should be free from back lash and unnecessary friction and it should have minimum inertia.

9. Quick insertion of workpiece: Means should be provided for lifting the plunger for quick insertion of work.

10. Adjustable Table: The table of the instrument should, preferably, be adjustable in a vertical sense.

11. Compensation from temperature effects: The indicator should be provided with maximum compensation for temperature effects.

12. Means to prevent damage: Suitable means should be provided for preventing damage of the instrument in the event of the plunger moving through a greater distance than that corresponding to the range of its measuring scale.

Classification of comparators:

A wide variety of comparators are commercially available at present. They are classified according to the method used for amplifying and recording the variations measured in to the following types.

1. Mechanical comparators
2. Optical comparators
3. Mechanical-Optical comparators
4. Electrical and Electronics comparators
5. Pneumatic comparators.
6. Fluid displacement comparators
7. Projection comparators
8. Multi check comparators
9. Automatic Gauging Machines
10. Electro-Mech. comparators.

In addition to above, comparators of particularly high sensitivity and magnification, used in standard rooms for calibration of gauges include.

1. The Brookes Level comparator
2. The Eden-Rolt 'millionth' comparator.

Mechanical Comparators:

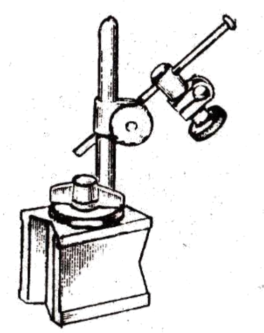
Principle of workings: A mechanical comparator employes mechanical means for magnifying the small movement of the measuring stylus, brought about due the difference between the standard and the actual dimension being checked. In these comparators the magnification of the small stylus movement is obtained by means of levers, gear trains, rack and pinion or a combination. The usual magnification obtained by these comparators ranges from about 250 to 1000. Mechanical comparators are of the following types:

1. Dial indicator (Dial gauge) 2. Johansson Mikrokator 3. Read type mechanical comparator

4. Sigma comparator.

1. Dial indicator (Dial gauge):

The simplest type of mechanical comparator is a dial indicator. It consists of a base with a rigid column risign from its rear. An arm is mounted on this column and it carries a dial gauge at its outer end. The arm can be adjusted vertically up and down along the column. An anvil or a worktable is mounted on the base, which provides a reference on which work pieces are placed during measuring operation. Such a simple comparator is ideal for the checking of components with a tolerance of say ± 0.05 millimeters.



Dial gauge

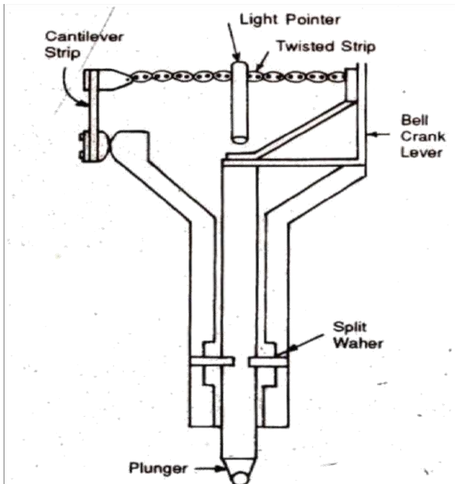
In its operation, the indicator is set to zero by the use of slip gauses representing the basic size of the part. The part to be checked is then placed below the measuring plunger of the indicator. The linear movement of the plunger is magnified by means of a gear and pinion train in to sizable rotation of the pointer. The variation in dimension of the part from the basic size is indicated on the dial.

Dial indicator is generally used for inspection of small precision machined parts. The dial indicator with various attachments may be used for large number of works; with V-block attachment it can be used for checking out of roundness of a cylindrical part.

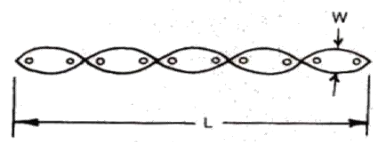
2. Johansson Mikrokator:

This instrument was first devised by m/s C.F. Johansson and hence the name. It uses a twisted strip to convert small linear movement of a plunger into a large circular movement of a pointer. It is therefore, also called as twisted strip comparator. It uses the simplest method for obtaining the mechanical magnification designed by H. Abramson which is known as ‘Abramson movement’.

A twisted thin metal strip carries at the centre of its length a very light pointer made of thin glass. One end of the strip is fixed to the adjustable cantilever strip and the other end is anchored to the spring elbow, one arm of which is carried on measuring plunger. The spring elbow acts as a bell crank lever. The construction of such a comparator is shown in Fig.



Johansson Mikrokator



Twisted strip of Mikrokator

A slight upward movement of plunger will make the bell crank lever to rotate.

Due to this a tension will be applied to the twisted strip in the direction of the arrow. This causes the strip to untwist resulting in the movement of the point. The spring will ensure that the plunger returns when the contact pressure between the bottom tip of the plunger and the workpiece is not there, that is, when the workpiece is removed from underneath the plunger.

The length of the cantilever can be varied to adjust the magnification. In order to prevent excessive stress on the central portion, the strip is perforated along the centre line by performation as shown in Fig. 5.3. The magnification of the instrument is approximately equal to the ratio of rate of change of pointer movement to rate of change in length of the strip, *i.e.*, $\frac{dQ}{dL}$. It can be shown that the magnification of the instrument $\frac{dQ}{dL} \propto \frac{L}{w^2 n}$,

where, $Q =$ twist of mid point of strip with respect to the end

$L =$ length of twisted strip measured along its neutral axis

$w =$ width of twisted strip and,

$n =$ number of turns.

It is thus obvious that in order to increase the magnification of the instrument a very thin rectangular strip must be used.

3. Read type mechanical comparator:

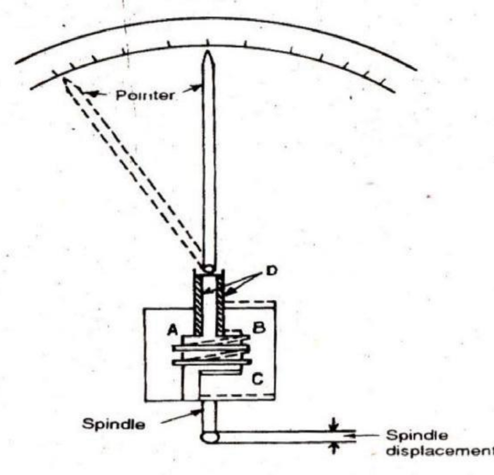
In reed type mechanical comparator, the gauging head is usually a sensitive, high quality, dial indicator. The dial indicator is mounted on a base supported by a sturdy column. Fig. 5.4 shows a read type mechanical comparator.

The reed mechanism is fricti nless device for magnifying small motions of the spindle. It consists of a fixed block. A which is rigidly fastened to the gauge head case, and floating block B, which carries the gauging spindle and is connected horizontally to the fixed block by reed C.

A vertical reed is attached to each block with upper ends joined together.

These vertical reeds are indicated by D. Beyond this joint extends a pointer. A linear motion of the spindle moves the free block vertically causing the vertical reed on the floating block to slide past the vertical reed on the fixed block. However, as the vertical reeds are joined at the upper end, instead of slipping, the movement causes both reeds swing through an arc.

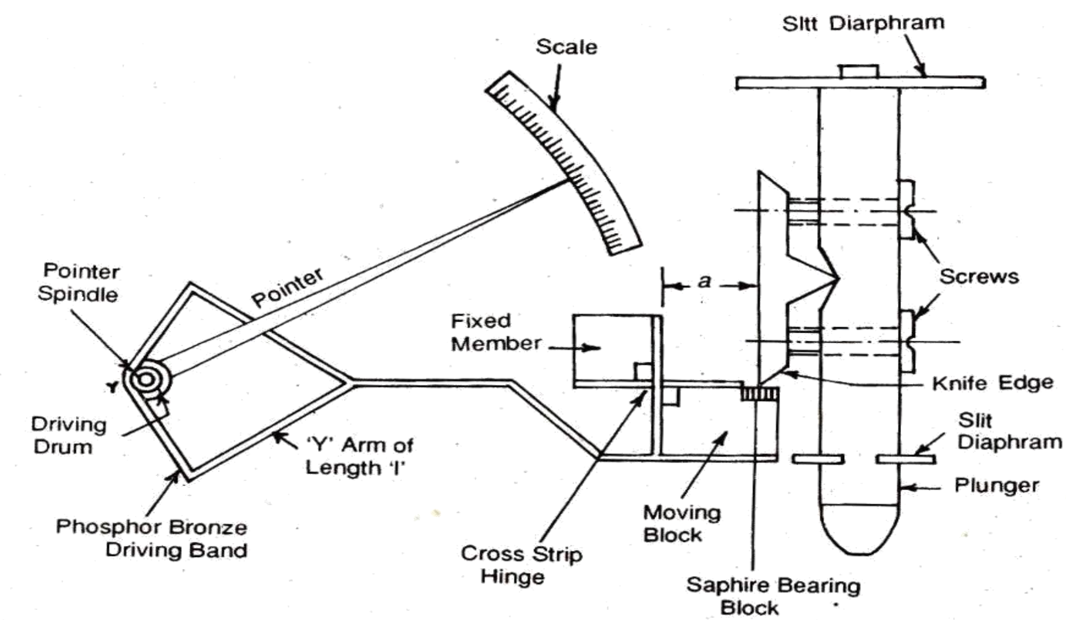
The scale may be calibrated by means of gauge block to indicate any deviation from an initial setting. The mechanical amplification is usually less than 100 but it is multiplied by the optical lens system. It is available in amplification ranging from 500 to 1000.



Reed type mechanical comparator

4. Sigma comparator:

This is a mechanical comparator providing magnification in the range of 300 to 5000. It consists of a plunger mounted on two flat steel strings (slit



Sigma of comparator

diaphrams). this provides a frictionless linear movement for the plunger. The plunger carries a knife edge, which bears upon the face of the mounting 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 a 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 the measuring plunger and hence that of the knife edge makes the moving block of the cross strip liver 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 (a) of the knife edge from the pivot gives the first stage magnification and the ratio of the pointer length (l) and radius (r) of the driving drum gives second stage magnification of the instrument. Total magnification of the instrument is thus $\left(\frac{L}{a} \times \frac{l}{r}\right)$. The magnification of the instrument can be varied by changing the distance (a) of Knife edge of tightening or slackening of the adjusting screws : The range of instruments available provides magnifications of x 300 to X 5000, the most sensitive models allowing scale estimation of the order of 0.0001 mm to be made.

Some important features (advantages) of the sigma comparator are :

1. Safety : As the knife edge moves away from the moving member of the hinge and is followed by it, therefore, if too robust movement of the plunger is made due to shock load, that will not be transmitted through the movement.

2. Dead beat Readings : By mounting a nonferrous disc on the pointer spindle and making it move in field of a permanent magnet, dead beat reading can be obtained.

3. Parallax : The error due to Parallax is avoided by having a reflective strip on the scale

4. Constant pressures. The constant measuring pressure over the range of the instrument is obtained by the use of magnet plunger. On the frame

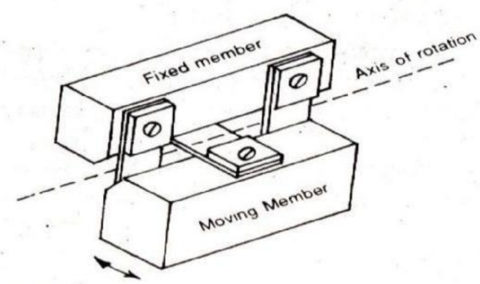


Fig. 5.6. cross strip liver used in sigma comperator.

5. Fine adjustments are possible

Disadvantages 1. Due to motion of the parts there is a wear in the moving parts.

2. It is not sensible as optical comparator due to friction of the morning parts.

<u>Advantages of Mechanical Comparators:</u>

1. Cheaper. Mechanical comparators are less costly as compared to other amplifying devices.

2. No need of external agency. These instruments do not require any external agency such as electricity or air and as such the variations in outside supply do not affect the accuracy.

3. Linear Scale. Usually the mechanical comparators have linear scale.

4. Robust and compact: These instruments are robust and compact in design and easy to handle.

5. Portable: For ordinary workshop conditions, these instruments are very suitable and being portable can be issued from the stores.

Disadvantages of Mechanical Comparators

1. Less accuracy (a) Due to more moving parts, the friction is more which reduces the accuracy

(b) Any slackness in moving parts also reduces the accuracy considerably.

2. Sensitive to vibrations: The mechanisms in mechanical comparators have more inertia and. this may cause them to be sensitive to vibrations.

3. Faults magnified: Any wear backlash or dimensional faults in the mechanical devices used will also be magnified.

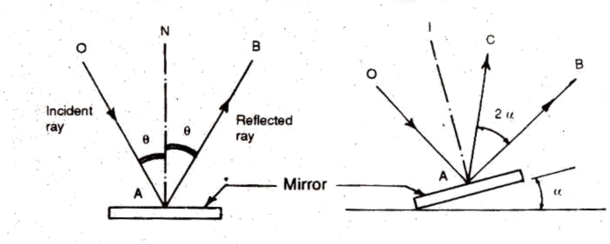
4. Limited range: The range of the instrument is limited as the pointer moves over a fixed scale.

5. Parallax error: Error due to Parallax are more likely with these instruments as the pointer moves over a fixed scale.

- **Optical Comparators:**

Working principle: In these comparators, use is made of a fundamental optical law and instead of a printer, the edge of the shadow is projected on to a curved graduated scale to indicate the comparison measurement. The optical principle adopted is that of 'optical lever' which is shown in Fig. If a ray of light OA strikes a mirror, it is reflected as ray AB such that,

$$\angle OAN = \angle NAB$$



Optical principle

Now, if the mirror is titled through an angle on the reflected ray of light has moved through an angle 2 . In optical comparators, the mirror is tilted by the measuring plunger movement and the movement of the reflected light is recorded as an image on a screen.

Mechanical-optical Comparators:

In mechanical optical comparators, small displacement of the measuring plunger are amplified first by a mechanical system consisting of pivoted levers. The amplified mechanical movement is further amplified by a single optical system involving the projection of an image. As shown in fig. The mechanical system causes a plane reflector to tilt about an axis and the image of an index is projected on a scale on the inner surface of a ground glass screen. Magnification as shown in fig:

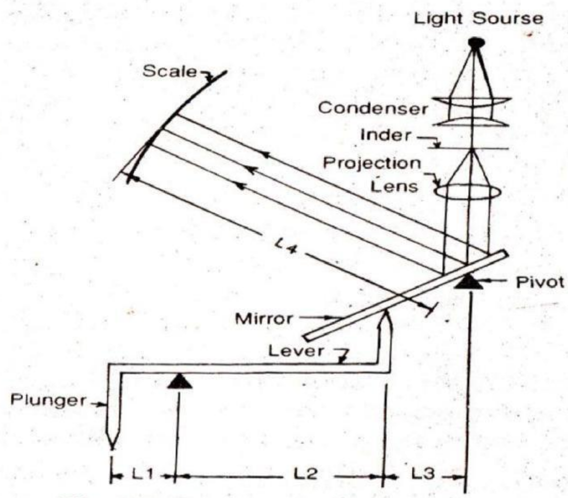


Fig. 5.8. Meeter optical comparator

Mechanical amplification $= \frac{L_2}{L_1}$ (by lever principle)

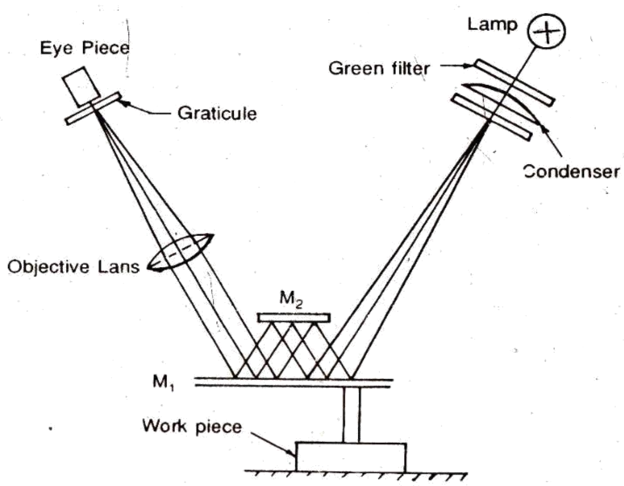
Now, if the movement of the plunger causes the mirror to tilt by an angle α, then the image will be tilted by 2α.

Therefore optical amplification $= 2 \times \frac{L_4}{L_3}$

Thus overall magnification of this system $= 2\frac{L_2}{L_1} \times \frac{L_4}{L_3}$

Zeiss -Ultra Optimeter:

The optical system of zeiss ultra optimeter involves double reflection of light and thus gives higher degree of magnification. Fig. Shows the optical system of this type of comparator. The light rays from the lamp falls on the green filter. The green filter filters all and only green light passes to a condenser, which projects is on to a movable mirror 1. It is then reflected to another fixed mirror 2 and then back again to first movable mirror. The objective lens brings the reflected beam from the first mirror to a focus at a transparent graticule containing a precise scale -which is viewed by an eye-piece.



Zeiss ultra optmer.

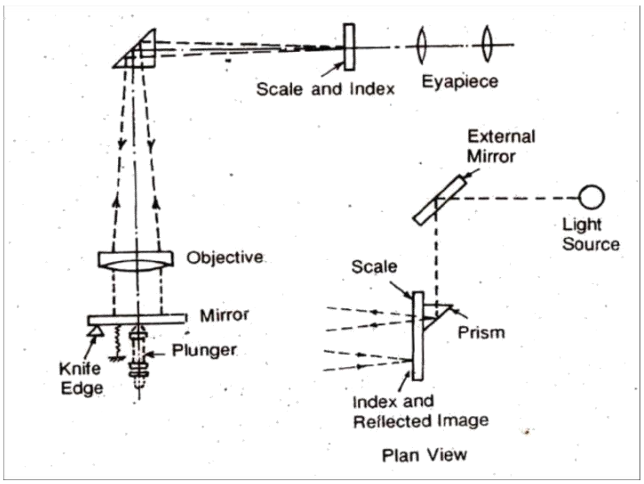
Magnification : If the distance from the plunger centre line to the first mirror pirot is x and the plunger moves a height h, then the angular movement of the mirror $\delta\theta = \frac{h}{x}$. If f be the focal length of the lens, then the movement of the scale is $2f.\ \delta\theta$, *i.e.*, $2f\frac{h}{x}$.

Therefore, magnification $= \frac{2fh}{xh} = \frac{2f}{x}$

overall magnification $= \frac{2f}{x} \times$ Eyepiece magnification.

Zeiss optotest Comporator:

This is a commercial measuring instrument. It consists of a plunger, tilted mirror, objective lens, prism and observing eye piece to provide a high degree of magnification. As shown in Fig. The mirror is mounted on a knife edge and it can be tilted about this fulcrum by any linear vertical movement of the contact plunger.



A beam of light passes through a graticule suitably engraved with a linear scale. The movement of the mirror causes this scale to move up or down past a translucent screen inside the observing hood of the instrument. The eye placed near the eye piece views the image of a small scale engraved on glass after reflection from the plunger-actuated mirror and the prism as shown in the plan view of the figure.

In the focal plane of the eyepiece a fine reference line (index) is provided and the system of lenses is so arranged that the image of the scale is projected in the same focal plane. Thus, only the movement of the scale image can be measured with reference to the fixed line. The division of the scale image opposite the index line indicates the amount of movement of contact plunger. The image of the scale and the index line could also be viewed, through a projection system. The overall magnification of this comparator is given by

$$\frac{2f}{d} \times \text{Eye piece magnification}$$

where f is the focal length of the lens and d is the distance between the knife edge of the planer.

Advantages optical comparators:

1. High accuracy: These comparators have very few moving parts and hence gives higher accuracy.

2. No parallax Error: The scale can be made past a datum line and thus have high range and no parallax error.

3. High magnification: Hence suitable for precision measurements.

4. Optical lever is weightless.

5. Illuminated scale: Since scale is illuminated, it enables readings to be taken irrespective of room lighting conditions.

Disadvantages:

1. As the magnification is high, heat from the lamp, transformers, etc. may cause the setting the drift.

2. Depends on external electrical power supply.

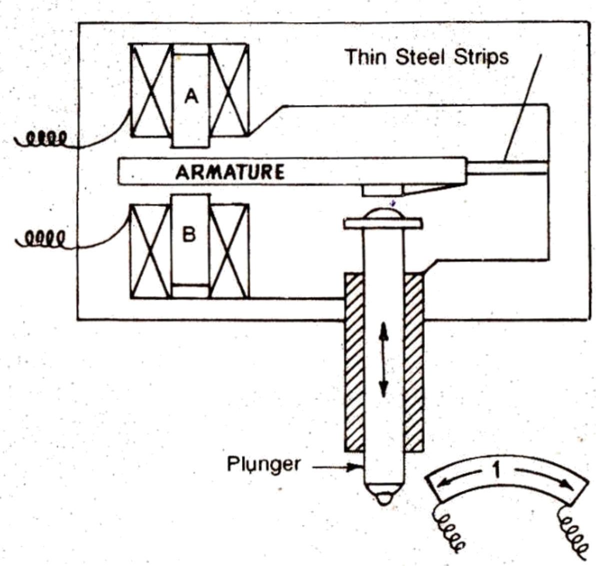
3. Apparatus is usually bulky and expensive.

4. When scale is projected on a screen, the instrument is to be used r in dark room.

5. Instrument is inconvenient for continuous use, because the scale is to be viewed through eyepiece.

- **<u>Electrical Comparators:</u>**

Principle: These comparators depend on their operation on an A.C. Whetstone bridge circuit incorporating a galvanometer. In these comparators, the movement of the measuring contact is converted into an electrical signal. This electrical signal is recorded by an instrument which can be calibrated in terms of plunger movement.



Visual Ganging Heads

The purpose of the visual gausing heads is to give visual inspection, using small coloured signal lamps, of the acceptability of an engineering component with regard to the dimension under test. Clearly an electrical principle is involved, which may be simply described, as follows, with reference to Fig. 5.12. Vertical displacement of an interchangeable plunger causes movement of the rod *C* either to the left or right, as shown in the figure *A* and *B* are electrical contacts, capable of precise adjustment in the direction of the arrows, a micrometer device is available.

In the position shown, that is to say with the rod in mid position between the contacts *A* and *B*, the dimension under test is within the limits. If the dimension is oversize, the rod *C* moves to the right and makes contact with *B*. Immediately the top red lamp is illuminated. Likewise if the dimension is undersize the rod moves to left, making contact with *A* and illuminating the yellow lamp.

It may, however, be noted that the actual magnifying device is not shown in the figure; levers and thin steel strips, together with knife-edge seatings, are employed.

With various detachable plungers, there is practically no limit to the application of this instrument. Fig. 5.12 illustrates the visual gauging of a single dimension, but the same principle can be applied in measuring the several dimensions simultaneously.

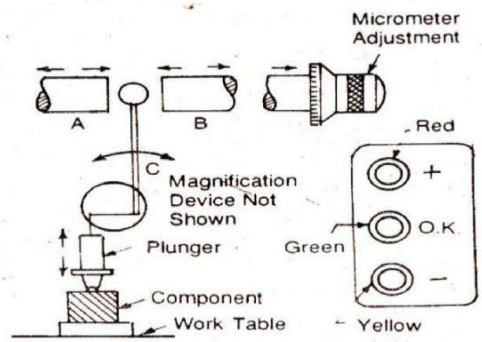


Fig. 5.12. Visual gauging head

<u>Advantages of electrical and electronic Comparators:</u>

1. Few number of moving parts: The electric and electronic comparators have few number of moving parts, and these is less friction and wear.

2. High magnification: It has a wide range of magnification.

3. Not sensitive to vibrations: The mechanism carrying the pointer is very light and not sensitive to vibrations.

4. Easy to set up and operate.

5. Less error due to sliding friction: operation of the instrument on AC supply reduces, sliding friction errors.

6. The instrument is small and compact.

7. The indicating' instrument need not be placed close to the measuring unit.

Disadvantages:

1. Fluctuation in the voltage or frequency of the electric supply may affect the results.

2. Heating of coils in the measuring unit may cause zero drift and alter the calibration.

3. When measuring unit is remote from the indicating unit, reliability is lower.

4. Cost is generally more than mechanical comparator.

Solex pneumatic Gauges

This instrument was commercially introduced by solex Air Gauges Ltd. It is generally designed for internal measurement, but with suitable measuring head it can be used for external gauging also.

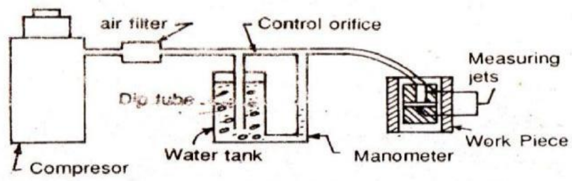


Fig. 5.15. Solex Pneumatic Gauge

It uses a water manometer for the indication of back pressure. It consists of a vertical metal cylinder filled with water upto a certain level and a dip tube immersed into it upto a depth corresponding to the air pressure required. A calibrated manometer tube is connected between the cylinder and control artifice as shown in Fig. 5.15.

If 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 escape 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 variation in the dimension to be measured are converted into corresponding pressure variations, which can be read from the calibrated scale provided with the manometer.

To find concentricity (roundness of any job at any section). the workpiece may be revolved around measuring gauge. If no change in reading is there, then it is perfectly round hole. Similarly the diameter can be noted down at several places along the length of bore and thus tapering of hole is determined. This method is therefore, best suited for measuring roundness and taperness of cylinder bases and gun barrel bores.

Advantages of pneumatic comparators:

1. The gauging member does not come in contact with the part to be measured and hence practically no wear takes place on gauging member.

2. It is probably the best method to determine the ovality and taperness of circular holes.

3. Single or number of dimensions can be inspects simultaneously.

Disadvantages:

1. Limited range of measurement is available with these comparators

2. It gives low speed of response compared with electrical magnification system.

3. It requires elaborate auxiliary equipment such 'as accurate pressure regulator.

The scale is generally not uniform.

Comparator	Measuring Instrument
1. It is used to compare dimensions of parts with working standards. It does not measure the actual dimension but indicates how much the size of the part differs from the working standards.	1. It is used to measure the actual dimensions of the parts.
2. The readings are magnified by suitable arrangement	2. No magnification system is provided.
3. Measurements can be done rapidly and accurately, so it is suitable in mass production.	3. Measurement is time consuming and therefore not suitable mass production system.
4. Comparators can be used to check dimensions as well as geometric forms.	4. Measuring Instruments can not be used to check geometric forms.
5. There are no chances of errors due to incorrect contact pressure or deformation of-workpiece.	5. Errors are caused due to misalignment or instrument or workpiece, incorrect contact pressure and deformation of instrument or workpice
6. Accuracy is independent of correct feel or operators skill.	6. Accuracy depends on the correct feel and operators skill.

Problem 4. *Differentiate between Comparator and a gauge*

Sol.

Comparator	Gauge
1. They are used to compare the dimensions of parts with working standards.	1. Gauges are used to determine whether the dimensions of parts lies within the given limits of size or not.
2. Determines the difference between the sizes of parts and standards.	2. Determine deviation firm the actual dimensions or form of parts.
3. The readings are magnified by suitable arrangement	3. Magnification system is not provided
4. Indicating device is provided to determine the deviation in dimension, size etc of part from the standard.	4. Indicating device is not provided. It only helps to determine whether the parts is within the given tolerance limit and hence acceptable or otherwise.
5. Comparator can be used to compare dimensions of larger and thin walles parts	5. Gauge is not suitable to gauge the dimensions of larger and thin walled parts.

Problem 5. *Compare between Electrical Comparator and Mechanical Comparator.*

Sol.

	Mechanical comparator		Electrical Comparator
1.	Mechanical comparator has more number of moving parts, hence, friction and wear is more, and accuracy is less.	1.	Small number of moving parts, hence less friction, wear, and accuracy is more.
2.	They are independent of any external power supply, so accuracy of the reading is not affected by variations in the power supply.	2.	Fluctuations in the voltage or frequency of the electric power supply may affect the results and accuracy of measurement.
3.	These instruments are portable and cheaper.	3.	Measuring and indicating units being separate and since they require electric supply they are not so easily portable and more costly also.
4.	Inertia of the moving parts makes the instrument sensitive to vibrations.	4.	The mechanism carrying the pointers being very light is not sensitive to vibrations.
5.	Range of the instrument is limited by the range of the fixed scale.	5.	It has wide range of magnification.

Problem 6. *State only the principle of working of mechanical comparator, Electrical comparator, optical comparator and pneumatic comparator.*

Sol. Mechanical comparator : A mechanical comparater employs mechanical means for magnifying the small movement of the measuring styles, brought about due to the difference between the standard and the actual dimension being checked. In these comparators the magnification of the small stylus movement is obtained by means of levers, gear trains, rack and pinion or a combination.

Electrical Compasator : Electrical comparators depend on their operation on an A.C. wheatstone bridge circuit incorporating a galvanometer. In these comparators, the movement of the moving contact is converted into an electrical signal. This electrical signal is recorded by an instrument which can be calibrated in terms of plunger movement.

Optical Comparator : These comparaters, makes use of fundamental optical principle of 'optical lever'.

In optical comparators the mirrors is tilted by the measuring plunger movement and the movement of the reflected light is recorded as an image on the curved graduated scale to indicate the comparison movement.

Pneumatic comparator : These comparators utilize the variation 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 variation in the back pressure or velocity of air caused due to variations in size are used to amplify the output signal.