Unit-2

Comparators and Angle measurement

Comparators:

Comparators are instruments for indicating the difference in size between the work piece and standard. This difference is magnified and indicated by a display system such as a pointer moving on a scale or a digital readout. A comparator should be able to record variations of one micron.

Comparators can give precision measurements, with consistent accuracy by eliminating human error. They are employed to find out, by how much the dimensions of the given component differ from that of a known datum. If the indicated difference is small, a suitable magnification device is selected to obtain the desired accuracy of measurements. It is an indirect type of instrument and used for linear measurement.

Characteristics of Good Comparators:

1. It should be compact.
2. It should be easy to handle.
3. It should give quick response or quick result.
4. It should be reliable, while in use.
5. There should be no effects of environment on the comparator.
6. Its weight must be less.
7. It must be cheaper.
8. It must be easily available in the market.
9. It should be sensitive as per the requirement.
10. The design should be robust.
11. It should be linear in scale so that it is easy to read and get uniform response.
12. It should have less maintenance.
13. It should have hard contact point, with long life.
14. It should be free from backlash and wear.

Mechanical Comparator:

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 various types of mechanical comparators are dial indicator, rack and pinion, sigma comparator, Johansson mikrokator.

A) Dial Indicator:

It operates on the principle, that a very slight upward pressure on the spindle at the contact point is multiplied through a system of gears and levers. It is indicated on the face of the dial by a dial finger. Dial indicators basically consists of a body with a round graduated dial and a contact point connected with a spiral or gear train so that hand on the dial face indicates the amount of movement of the contact point.

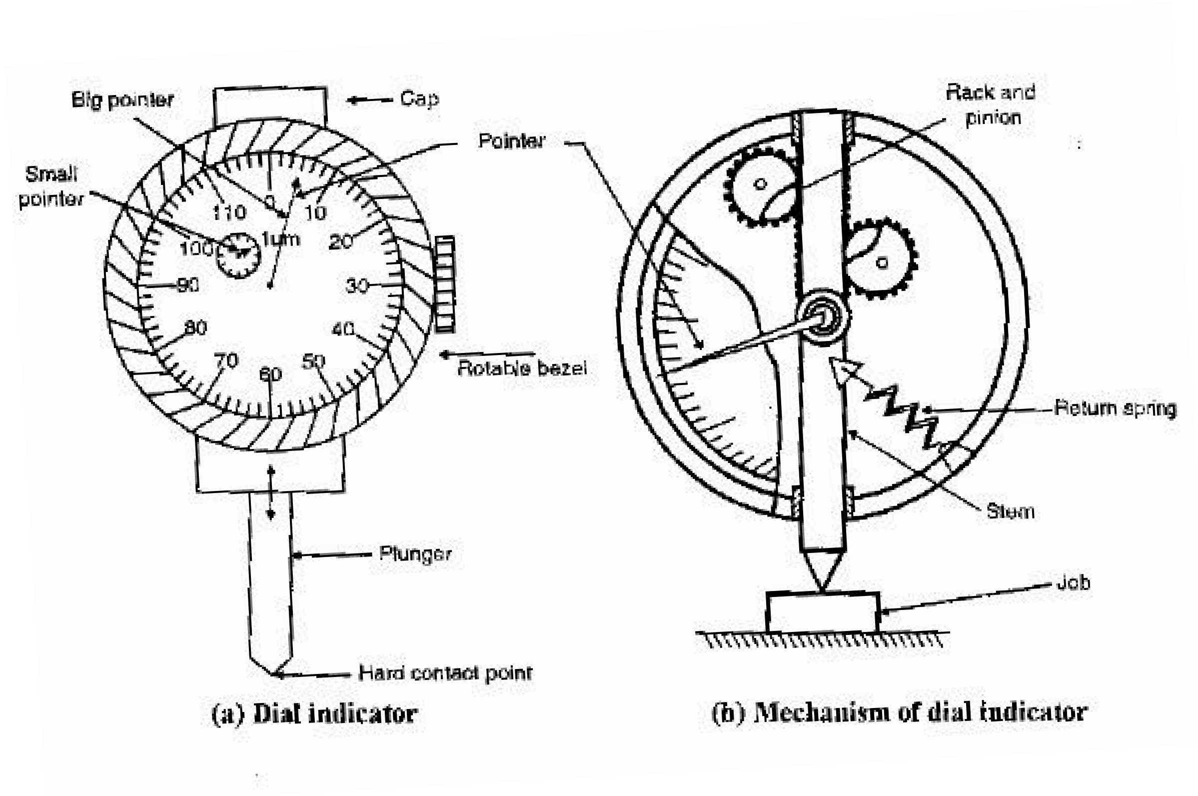


Fig. 2.1 Dial Indicator

The large dial scale is graduated into 100 divisions. The indicator is set to zero by the use of slip gauges representing the basic size of part.

Requirements of Good Dial Indicator:

1. It should be robust in design and construction so that it can give trouble free and dependable readings over a long period.
2. The pressure required on measuring head to obtain zero reading must remain constant over the whole range.
3. The pointer should indicate the direction of movement of the measuring plunger.
4. The accuracy of the readings should be within close limits of the various sizes and ranges.
5. The movement of the measuring plunger should be in either direction without affecting the accuracy.
6. The pointer movement should be damped, so that it will not oscillate when the readings are being taken.

Applications:

1. Comparing two heights or distances between narrow limits.
2. To determine the errors in geometrical form such as ovality, roundness and taper.
3. For taking accurate measurement of deformation such as in tension and compression.
4. To determine positional errors of surfaces such as parallelism, squareness and alignment.
5. To check the alignment of lathe centers by using suitable accurate bar between the centers.

B) Johansson Mikrokator:

Principle:

It works on the principle of a Button spring, spinning on a loop of string like in the case of Children's toys.

Construction:

The method of mechanical magnification is shown in Figure. It employs a twisted metal strip. Any pull on the strip causes the center of the strip to rotate. A very light pointer made of glass tube is attached to the center of the twisted metal strip. The measuring plunger is on the slit washer and transmits its motion through the bell crank lever to the twisted metal strip. The other end of the twisted metal strip is fastened to the cantilever strip. The overhanging length of the cantilever strip can be varied to adjust the magnification of the instrument. The longer the length of the cantilever, the more it will deflect under the pull of the twisted metal strip and less rotation of the pointer is obtained.

When the plunger moves by a small distance in upward direction the bell crank lever turns to the right hand side. This exerts a force on the twisted strip and it causes a change in its length by making it further twist or untwist. Hence the pointer at the centre rotates by some amount. Magnification up to 5000X can be obtained by this comparator.

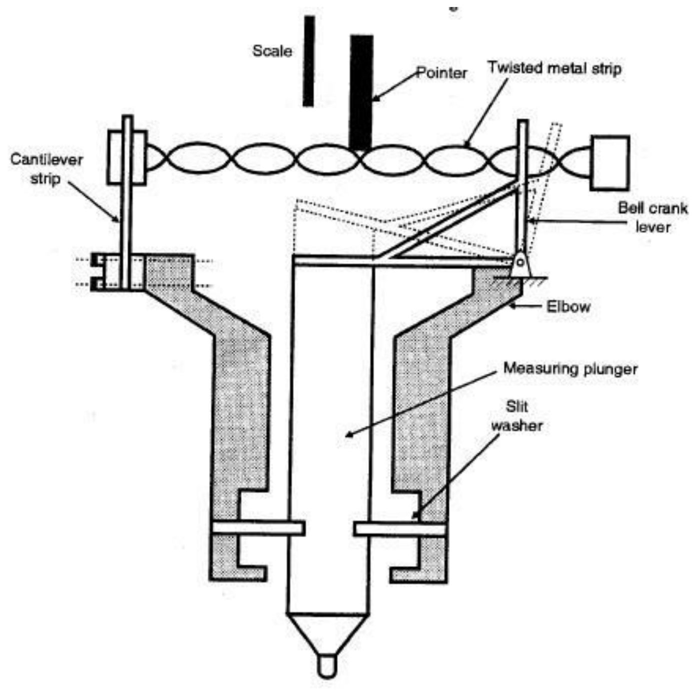


Fig 2.2 Johansson Mikrokator

Advantages of Mechanical Comparator:

1. They do not require any external source of energy.
2. These are cheaper and portable.
3. These are of robust construction and compact design.
4. The simple linear scales are easy to read.
5. These are unaffected by variations due to external source of energy such air, electricity etc.

Disadvantages:

1. Range is limited as the pointer moves over a fixed scale.
2. Pointer scale system used can cause parallax error.
3. There are number of moving parts which create problems due to friction, and ultimately the accuracy is less.
4. The instrument may become sensitive to vibration due to high inertia.

C) <u>Sigma Comparator:</u>

The plunger is attached to a bar which is supported between the bending plates at the top and bottom portion as shown in Figure (a) The bar is restricted to move in the vertical direction. A knife edge is fixed to the bar. The knife edge is attached to the sapphire plate which is attached to the moving block. The knife edge extorts a force on the moving block through sapphire plate. Moving block is attached to the fixed block with the help of crossed strips as shown in Figure (b). When the force is applied on the moving block, it will give an angular deflection. A Y-arm which is attached to the moving block transmits the rotary motion to the driving drum of radius r. This deflects the pointer and then the reading is noted.

If l = Distance from hinge pivot to the knife edge

L = Length of y-arm

R = Driving drum radius

D = Length of the pointer

Then the total magnification = (L/l) *(D/R)

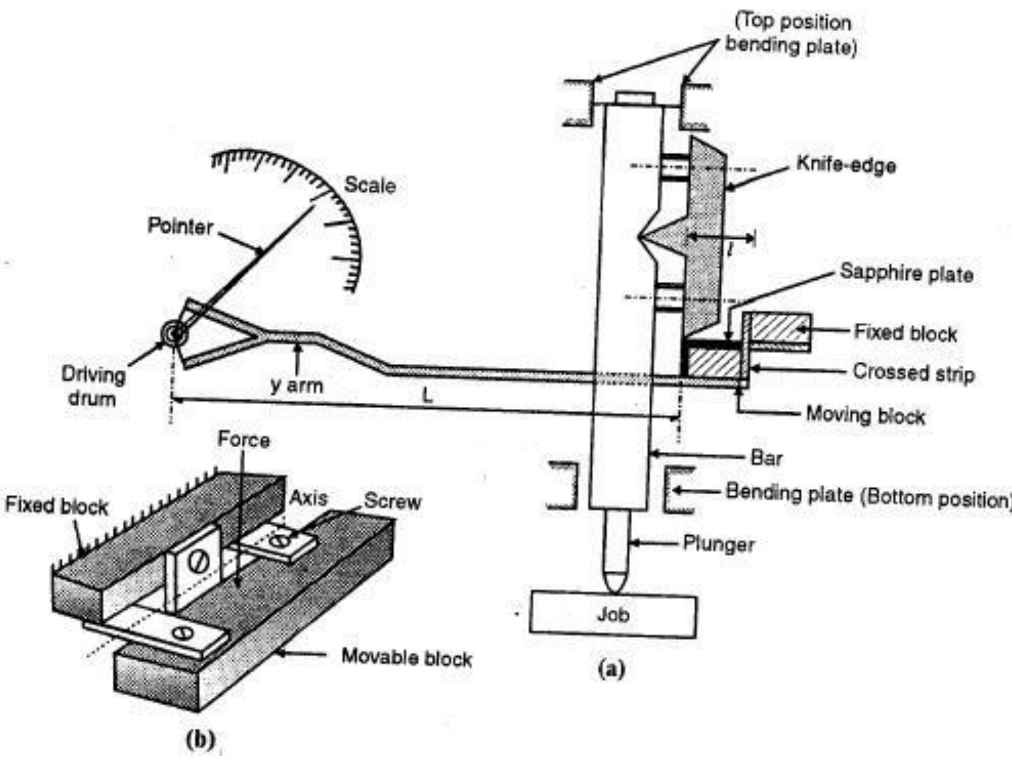


Fig 2.3 Sigma comparator

Advantages of Sigma Comparator:

1. Higher safety.
2. The error due to parallax is avoided by having a reflective strip on the scale.
3. Fine adjustments are possible.
4. The constant measuring pressure over the range of the instrument is obtained by the use of magnet plunger.

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 moving parts.

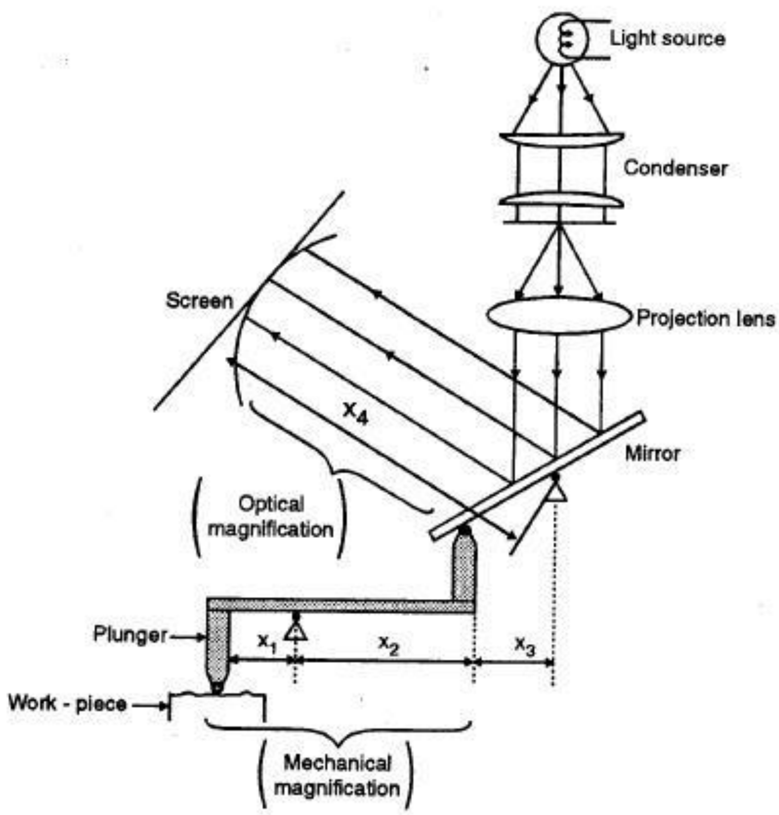
D) <u>Mechanical - Optical Comparator:</u>

Principle:

In mechanical optical comparator, small variation in the plunger movement is magnified: first by mechanical system and then by optical system.

Construction:

The movement of the plunger is magnified by the mechanical system using a pivoted lever. From the Figure the mechanical magnification = x2 / x1. High optical magnification is possible with a small movement of the mirror. The important factor is that the mirror used is of front reflection type only.



2.4 Mechanical Optical Comparator

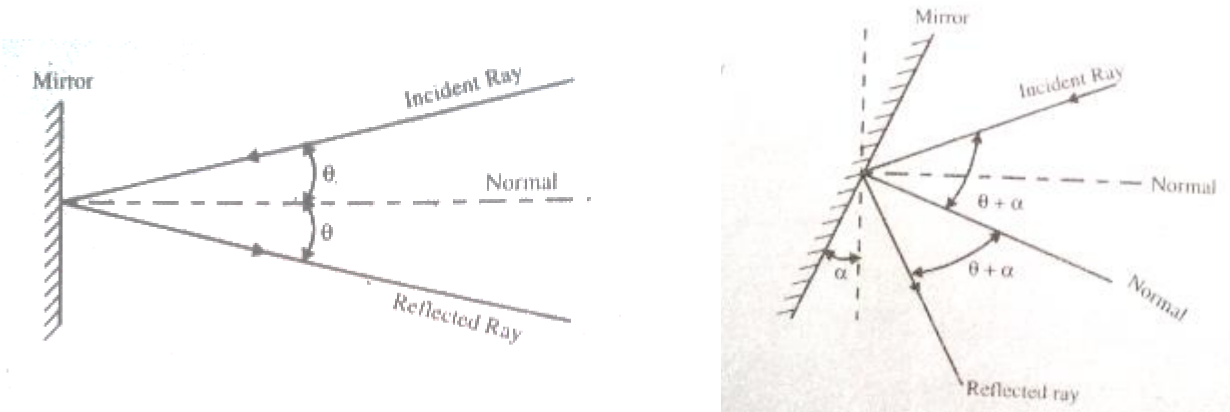


Fig 2.5 Working of optical comparator

Advantages:

1. These Comparators are almost weightless and have less number of moving parts, due to this there is less wear and hence less friction.
2. Higher range even at high magnification is possible as the scale moves past the index.
3. The scale can be made to move past a datum line and without having any parallax errors.
4. They are used to magnify parts of very small size and of complex configuration such as intricate grooves, radii or steps.

Disadvantages:

1. The accuracy of measurement is limited to 0.001 mm
2. They have their own built in illuminating device which tends to heat the instrument.
3. Electrical supply is required.
4. Eyepiece type instrument may cause strain on the operator.
5. Projection type instruments occupy large space and they are expensive.
6. When the scale is projected on a screen, then it is essential to take the instrument to a dark room in order to take the readings easily.

Electrical Comparators:

Electrical comparators give a wide range of advantages. As we know, components like levers, gears, racks and pinions, activate mechanical devices. The accuracy and life of the instruments are affected as they are subjected to wear and friction. Electrical comparators have no moving parts. Thus a high degree of reliability is expected from these instruments.

LVDT: The linear variable differential transformer (LVDT) is a very popular device for converting a mechanical displacement into electrical signal which can be magnified to obtain readings. It consists of three coils (Fig. 2.6) P, S1 & S2 wound around the insulated body. The primary coil P is connected to the mains. The secondary coils S1 and S2 are connected together in series but in opposition to each other. Thus when the core is centered in the centre, the voltage induced in each secondary coil will be identical and 180 degrees out of phase and the net output will be zero. As the core is moved the mutual inductance of the two secondary coils is changed upsetting the balance and this gives signal which is further magnified. LVDT probes are pen like probes, come in various sizes and with suitable circuitry. The magnifications can be changed.

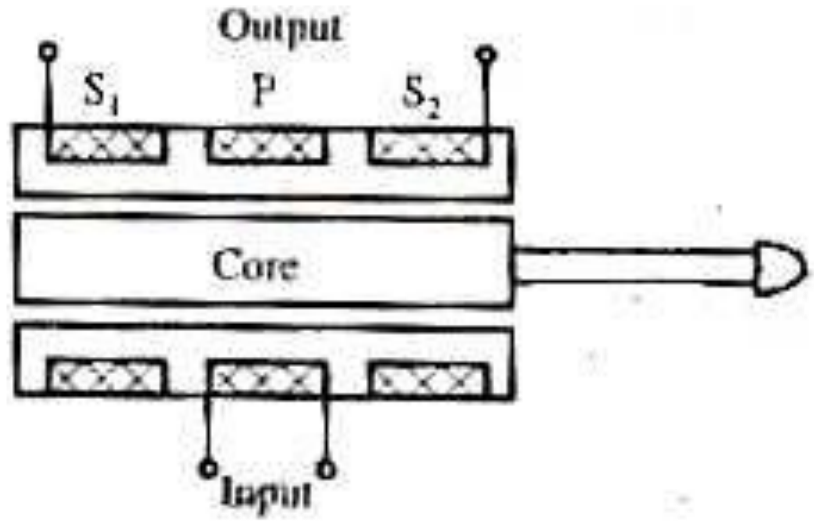


Fig 2.6 Electrical comparator (LVDT)

Advantages of Electrical Comparator:

1. Measuring units can be remote from indicating units.
2. Several magnifications are easily possible.
3. Compact sizes of the probes are available.

Disadvantages:

1. External source of energy is needed.
2. Heating of coils can cause zero drifts.

<u>Pneumatic Comparators (Solex Gauge):</u>

Principle:

It works on the principle of pressure difference generated by the air flow. Air is supplied at constant pressure through the orifice and the air escapes in the form of jets through a restricted space which exerts a back pressure. The variation in the back pressure is then used to find the dimensions of a component.

Working:

As shown in Figure (a) the air is compressed in the compressor at high pressure which is equal to Water head H. The excess air escapes in the form of bubbles. Then the metric amount of air is passed through the orifice at the constant pressure. Due to restricted area, at A1 position, the back pressure is generated by the head of water displaced in the manometer tube. To determine the roundness of the job, the job is rotated along the jet axis, if no variation in the pressure reading is obtained then we can say that the job is perfectly circular at position A1.

Then the same procedure is repeated at various positions A2, A3, A4, position and variation in the pressure reading is found out. Also the diameter is measured at position A1 corresponding to the portion against two jets and diameter is also measured at various position along the length of the bore. Any variation in the dimension changes the value of H, e.g. Change in dimension of 0.002 mm changes the value of H from 3 to 20 mm.

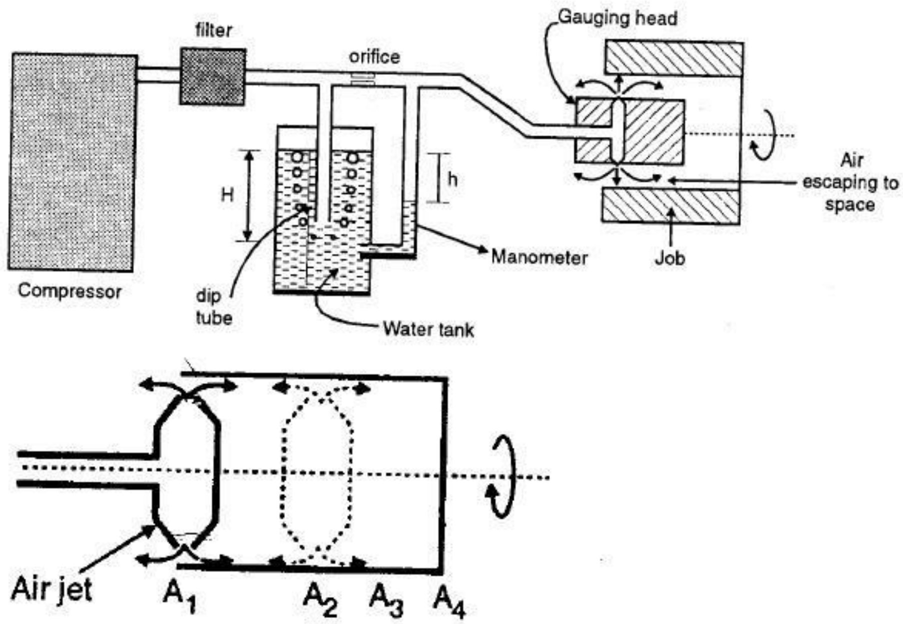


Fig 2.7 Pneumatic comparator

Advantages:

1. It is cheaper, simple to operate and the cost is low.
2. It is free from mechanical hysteresis and wear.
3. The magnification can be obtained as high as 10,000 X.
4. Indicating and measuring is done at two different places.
5. Tapers and ovality can be easily detected.
6. The method is self-cleaning due to continuous flow of air through the jets and this makes the method ideal to be used on shop floor for online controls.

Disadvantages:

1. They are very sensitive to temperature and humidity changes.
2. The accuracy may be influenced by the surface roughness of the component being checked.
3. Different gauging heads are needed for different jobs.
4. Auxiliary equipment's such as air filters, pressure gauges and regulators are needed.

Introduction to Angular Measurements:

For measuring the angle, no absolute standard is required. The measurement is done in degrees, minutes and seconds. The measurement of angular and circular divisions is an important part of inspection. It is concerned with the measurement of individual angles, angular changes and deflections on components, gauges and tools. For precision measurement of angles more skill is required. Like linear measurement, angular measurements have their own importance. The basic difference between the linear and angular measurement is that no absolute standard is required for angular measurement. There are several methods of measuring angles and tapers. The various instruments used are angle gauges, clinometers, bevel protractor, sine bar, sine centers, taper plug and ring gauges.

Vernier Bevel Protractor (Universal Bevel Protractor):

It is a simplest instrument for measuring the angle between two faces of a component. It consists of a base plate attached to a main body and an adjustable blade which is attached to a circular plate containing vernier scale.

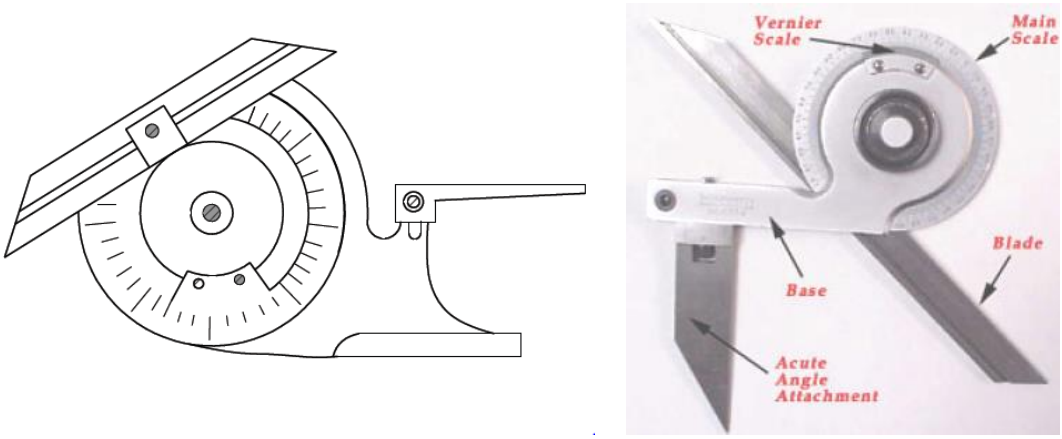


Fig 2.8 Vernier Bevel Protractor

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 along with the circular plate containing the vernier can rotate freely about the center of the main scale engraved on the body of the instrument and can be locked in any position with the help of a clamping knob.

The adjustable blade along with the circular plate containing the vernier can rotate freely about the center of the main scale engraved on the body of the instrument and can be locked in any position with the help of a clamping knob. The main scale is graduated in degrees. The vernier scale has 12 divisions on either side of the center zero. They are marked 0-60 minutes of arc, so that each division is $1/12^{th}$ of 60 minutes, i.e. 5 minutes. These 12 divisions occupy same arc space as 23 degrees on the main scale, such that each division of the vernier = (1/12)*23 = 1(11/12) degrees.

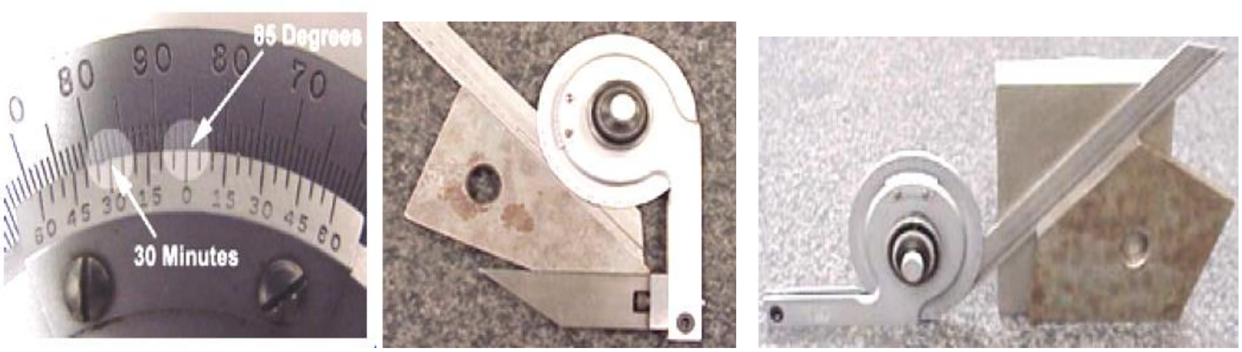


Fig 2.9 Working of Vernier Bevel Protractor

Sine Bars:

Sine bars are made from high carbon, high chromium, corrosion resistant steel which can be hardened, ground & stabilized. Two cylinders of equal diameters are attached at the ends as shown in fig. The distance between the axes can be 100, 200 & 300 mm. The Sine bar is designated basically for the precise setting out of angles and is generally used in conjunction with slip gauges & surface plate. The principle of operation relies upon the application of Trigonometry.

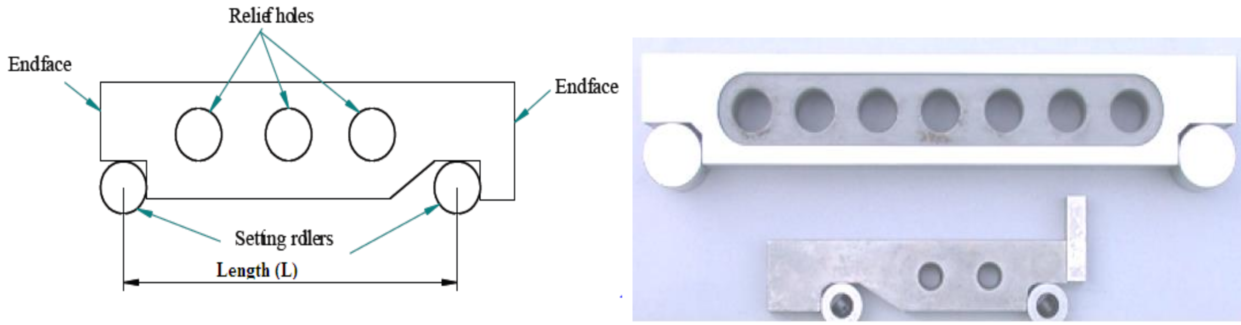


Fig 2.10 Sine Bar

In the above fig, the standard length AB (L) can be used & by varying the slip gauge stack (H), any desired angle q can be obtained as, $\theta=\sin^{-1}(H/L)$.

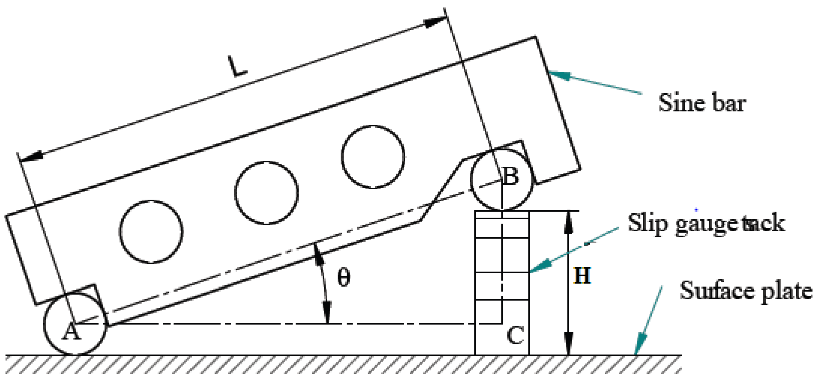


Fig 2.11 Working of sine bar

Use of Sine Bar:

1. **Checking of unknown angles**

For checking unknown angles of a component, a dial indicator is moved along the surface of work and any deviation is noted. The slip gauges are then adjusted such that the dial reads zero as it moves from one end to the other.

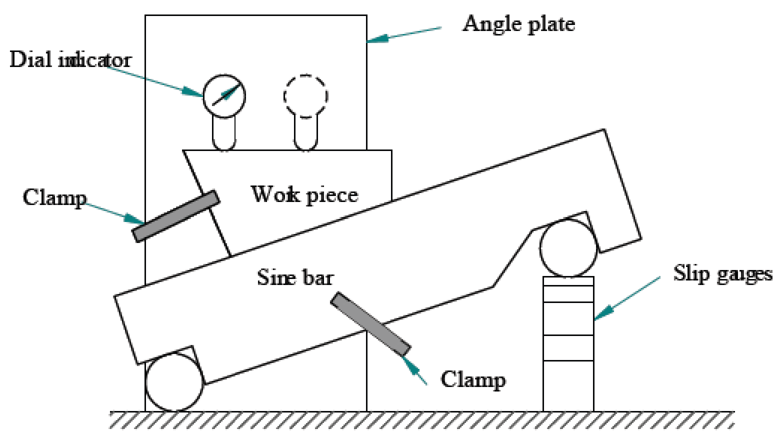


Fig 2.12.1 Use of sine bar

2. Checking of unknown angles of heavy component.

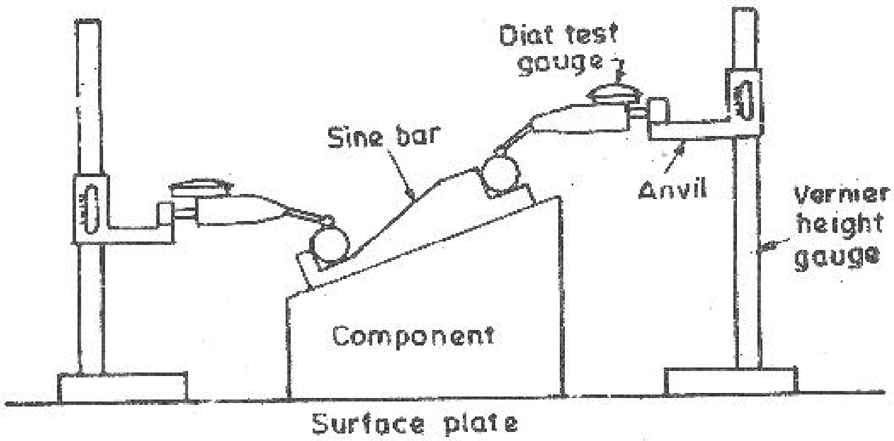


Fig 2.12.2 Use of sine bar

In such cases where components are heavy and can't be mounted on the sine bar, then sine bar is mounted on the component as shown in Fig. The height over the rollers can then be measured by a vernier height gauge ; using a dial test gauge mounted on the anvil of height gauge as the fiducial indicator to ensure constant measuring pressure. The anvil on height gauge is adjusted with probe of dial test gauge showing same reading for the topmost position of rollers of sine bar. The difference of the two readings of height gauge divided by the centre distance of sine bar gives the sine of the angle of the component to be measured. Where greater accuracy is required, the position of dial test gauge probe can be sensed by adjusting a pile of slip gauges till dial indicator indicates same- reading over roller of sine bar and the slip gauges.

Advantages of sine bar:

1. It is used for accurate and precise angular measurement.
2. It is available easily.
3. It is cheap.

Disadvantages:

1. The application is limited for a fixed center distance between two plugs or rollers.
2. It is difficult to handle and position the slip gauges.
3. Large angular error may results due to slight error in sine bar.
4. If the angle exceeds 45°, sine bars are impracticable and inaccurate.

Sine center:

It is the extension of sine bars where two ends are provided on which centers can be clamped, as shown in Figure. These are useful for testing of conical work centered at each end, up to 60°. The centers ensure correct alignment of the work piece. The procedure of setting is the same as for sine bar. The dial indicator is moved on to the job till the reading is same at the extreme position. The necessary arrangement is made in the slip gauge height and the angle is calculated as

$$\alpha = \theta = \sin^{-1} (H/L)$$

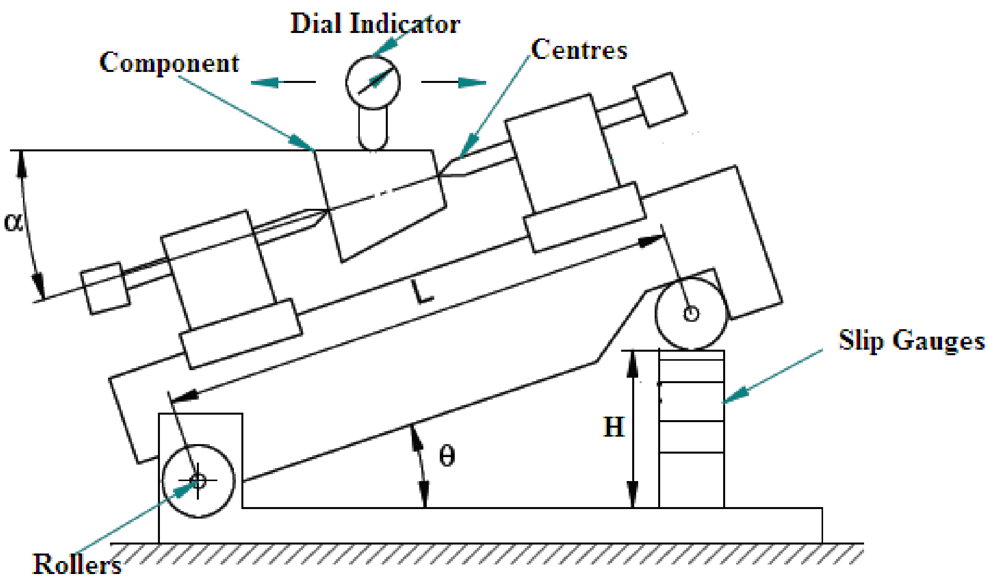


Fig 2.13 Sine centre

Angle Gauges:

These were developed by Dr. Tomlinson in 1939. The angle gauges are hardened steel blocks of 75 mm length and 16 mm wide which has lapped surfaces lying at a very precise angle.

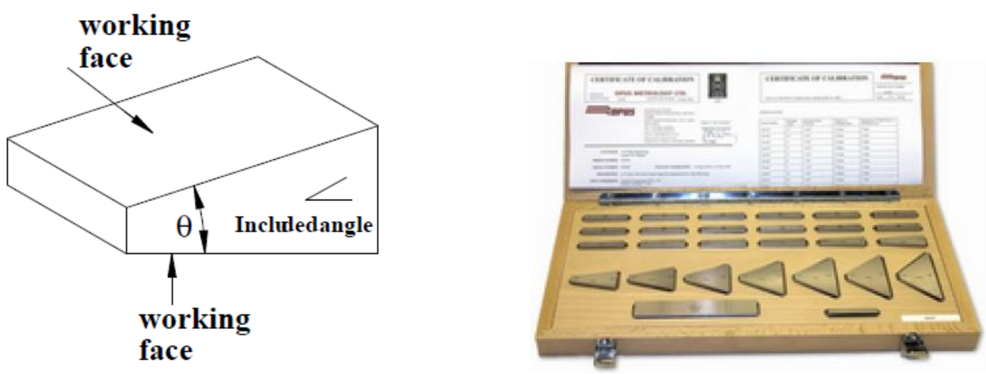


Fig 2.14 Angle Gauges

The engraved symbol ‘<’ indicates the direction of the included angle. Angle gauges are available in a 12 piece set and 13 piece set.

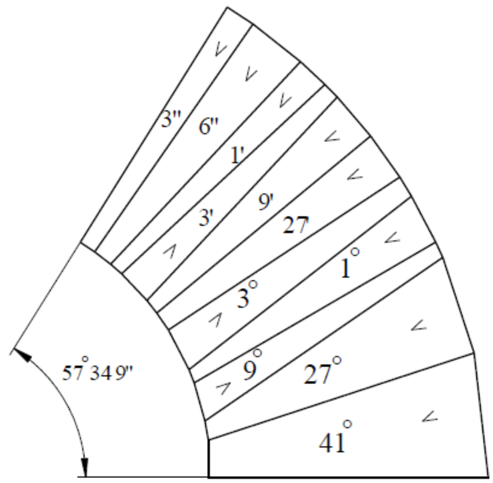
Table 2.1 Angle gauge sets

12 Pieces & a Square block set							13 Pieces & a Square block set					
Deg.	**1**	**3**	**9**	**27**	**41**		**Deg.**	**1**	**3**	**9**	**27**	**41**
Min.	**1**	**3**	**9**	**27**			**Min.**	**1**	**3**	**9**	**27**	
Sec.	**6**	**18**	**30**				**Sec.**	**3**	**6**	**18**	**30**	

These gauges together with a square block enable any angle between 0^0 & 360^0 to be built within an accuracy of 1.5 seconds of the nominal value. The wringing is similar to that of slip gauges.

Numerical 1:

Build an angle of 57º 34' 9"



Solution:

Degree = 41º +27º -9º +1º-3º =57º

Minutes = 27'+9'-3'+1' = 34'

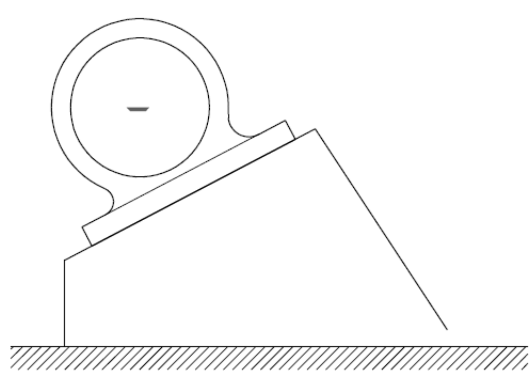
Seconds = 6"+ 3" =9"

Clinometer:

A clinometer is a special case of the application of spirit level. In clinometer, the spirit level is mounted on a rotary member carried in a housing. One face of the housing forms the base of the instrument. On the housing, there is a circular scale. The angle of inclination of the rotary member carrying the level relative to its base can be measured by this circular scale. The clinometer mainly used to determine the included angle of two adjacent faces of work piece. Thus for this purpose, the instrument base is placed on one face and the rotary body adjusted till zero reading of the bubble is obtained. The angle of rotation is then noted on the circular scale against the index. A second reading is then taken in the similar manner on the second face of work piece. The included angle between the faces is then the difference between the two readings.

Clinometers are also used for checking angular faces, and relief angles on large cutting tools and milling cutter inserts. These can also be used for setting inclinable table on jig boring; machines and angular work on grinding machines etc.

The circular glass scale is totally enclosed and is divided from 0° to 360° at 10′ intervals. Sub-division of 10′ is possible by the use of an optical micrometer. A coarse scale figured every 10 degrees is provided outside the body for coarse work and approximate angular reading. In some instruments worm and quadrant arrangement is provided so that reading upto 1′ is possible.



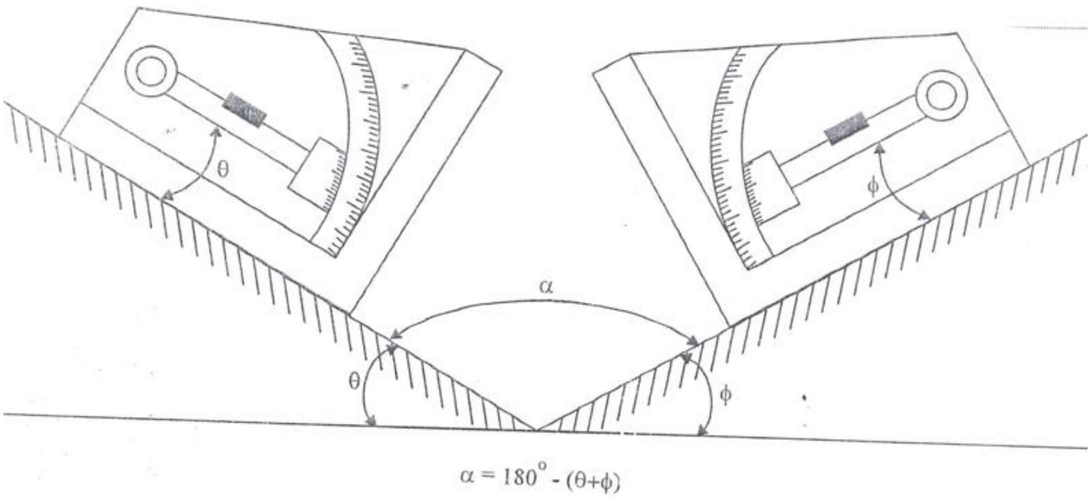


Fig 2.15 Clinometer

The included angle is then the difference between the two readings.
i.e. from fig, α=180-(θ+ϕ).

Auto-Collimator:

This is an optical instrument used for the measurement of small angular differences. For small angular measurements, autocollimator provides a very sensitive and accurate approach.

Principle of working:

O is a point source of light placed at the principal focus of a collimating lens in Fig. 2.16. The rays of light from O incident on the lens will now travel as a parallel beam of light. If this beam now strikes a plane reflector which is normal to the optical axis, it will be reflected back along its own path and refocused at the same point O. If the plane reflector be now tilted through a small angle θ, then parallel beam will be deflected through twice this angle, and will be brought to focus at O' in the same plane at a distance x from O. Obviously OO'=x=2θ.f.
Where *f* is the focal length of the lens and θ is angle of inclination of reflecting mirror.

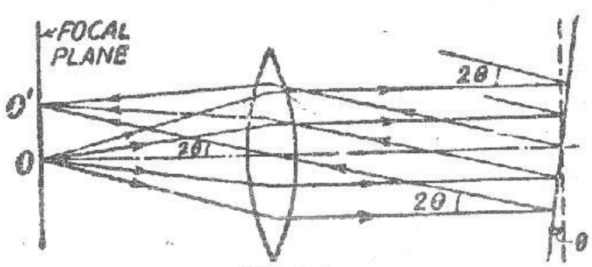


Fig 2.16 Auto-Collimator working principle

Construction:

In an auto-collimator there are three parts. Micrometer, microscope, lighting unit and collimating lens. A line diagram of a modern auto-collimator is shown in fig. 2.17.

A 45^0 transparent beam splitter reflects the light from the graticule towards the objective (Collimating lenses). The image seen after reflection is in the external reflector, whose angular variations are being measured is formed by the light from the objective lens. This light passes through the beam splitter and the image is picked up by the microscope. For simultaneous measurements in two planes at right angles a micrometer is fitted to the largest graticule, optically at right angles to that on the eyepiece graticule.

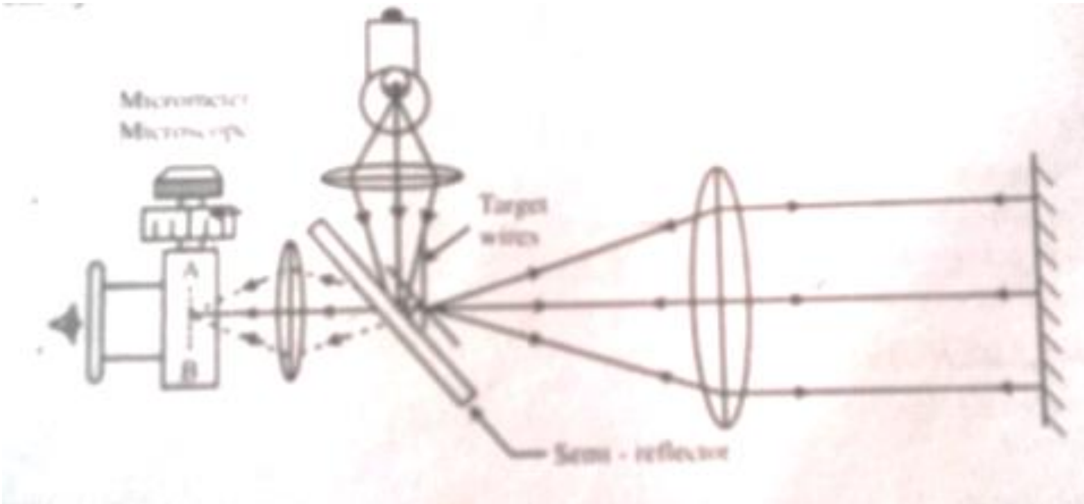
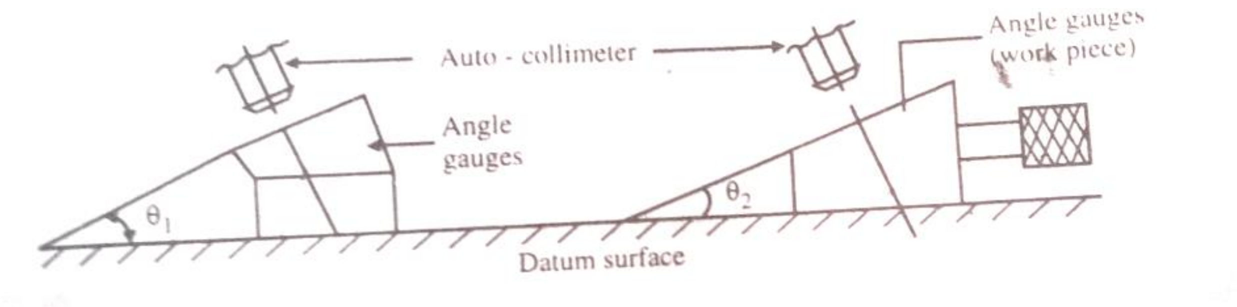


Fig 2.17 Auto-Collimator working principle



Reading X_1 Reading X_2

Fig. 7.13 (a)

$(\theta_1 - \theta_2)$ = Difference in angle = $(X_1 - X_2)$

Angle Deckker:

This is a type of auto-collimator. It consists of microscope, objective (collimating) lens and two scales engraved on a glass screen which is placed in the focal plane of the objective lens. One of the scales called datum scale, is horizontal and fixed. It is engraved across the centre of the scale and is always visible in the microscope eye-piece. Another scale is an illuminated vertical scale fixed across the centre of the screen and the reflected image of the illuminated scale is received at right angles to this fixed scale, and the two scales, in the position inserted each other. Thus the reading on illuminated scales measures angular deviations from one axis at 90^o to the optical axis, and the reading on the fixed datum scale measures the deviation about an axis mutually perpendicular to the other two.

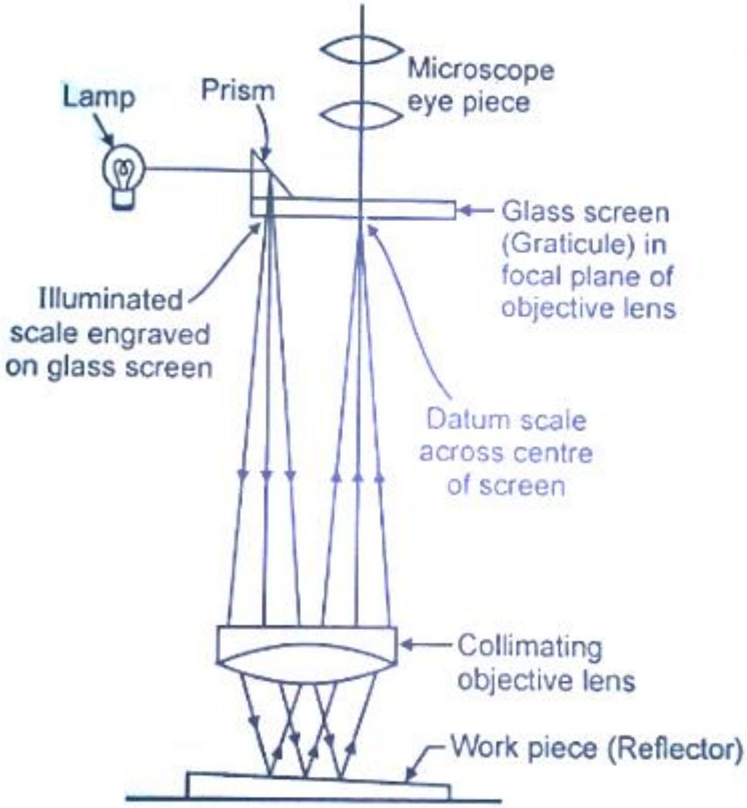


Fig 2.18 Working principle of Angle Deckker

Thus, the changes in angular position of the reflector in two planes are indicated by changes in the point of intersection of the two scales. Readings from scale are read direct to 1 minute without the use of a micrometer.