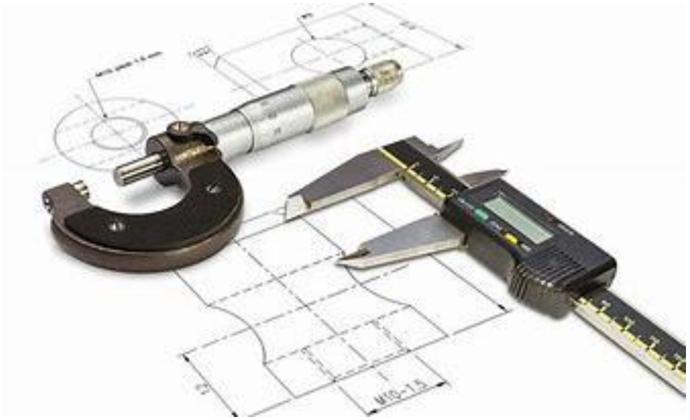
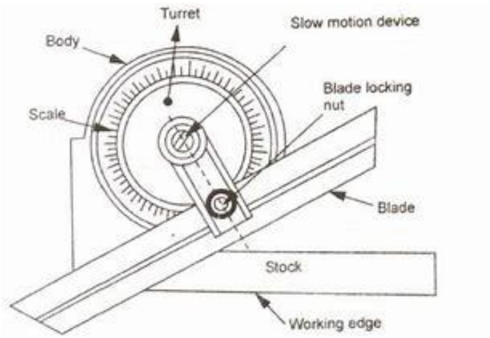
Ch-1
Introduction to Metrology, Linear and Angular Measurement





Subject:- MMM Code:-3141901	Prepared by: Asst.Prof.Chirag Mevada (Mechanical Department,ACET)	AMIRAJ COLLEGE OF ENGINEERING & TECHNOLOGY

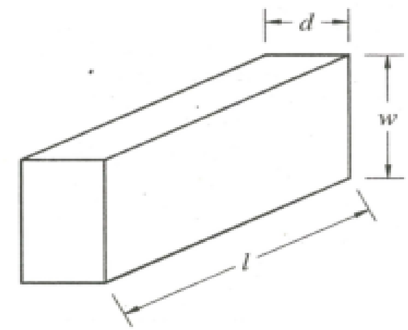
Sr. No.	Content	Hrs
1	**Introduction to Metrology, Linear and Angular Measurement:** Definition, objectives and concept of metrology, Need of inspection, Principles, process, methods of measurement, Classification and selection of measuring instruments and systems. Accuracy, precision and errors in measurement. System of measurement, Material Standard, Wavelength Standards, Subdivision of standards, Line and End standards, Classification of standards and Traceability, calibration of End bars, standardization. Slip gauges- Indian standards on slip gauge, method of selection of slip gauge, stack of slip gauge, adjustable slip gauge, wringing of slip gauge, care of slip gauge, slip gauge accessories, problems on building of slip gauges (M87, M112). Measurement of angles- sine bar, sine center, angle gauges, optical instruments for angular measurements, Auto collimator-applications for measuring straightness and squareness.	12

Slip Gauges

Slip Gauge

- Slip gauges were first developed by Johnson, and sometimes also called as 'Johnson Gauge Blocks'.
- These are rectangular blocks of high grade hardened steel.
- It is having a cross-section of about 9 mm x 30 mm for size upto 10 mm and 9 mm x 35 mm for larger sizes.
- These blocks are hardened to resist wear.
- After hardening they are carefully finished by high grade lapping to a high degree of finish, flatness and accuracy.

- The slip gauge is classified according to their accuracy:
- AA for Master slip gauges
- A for reference purpose
- B for working slip gauges



Indian Standard specifications for slip gauges

1. **Reference Grade :** Used as Standards by manufacturers.
2. **Calibration grade :** Used where highest level of accuracy is required in normal engineering practice.
3. **Grade-OO :** These are placed in the standard room and used for highest precision work as checking other lower grade slip gauges (Grade I and II)
4. **Grade-O :** These slip gauges are used for inspection of jobs in quality control department where high precision is required.
5. **Grade-I :** These slip gauges are used for general purpose manufacturing gauges in applications like tool, gauges and component production.
6. **Grade-II :** These slip gauges are used for rough setting purposes and checking of components having wide tolerances. These are also known as workshop grade.

Available Sets of Slip Gauges

1. Normal Set (M-45)
2. Special Set (M-87)
3. Set M 112
4. Set E 28

(1) Set M 45 (Normal set)			(2) Set M 87 (special set)		
Range (mm)	Steps (mm)	No. of blocks	Range (mm)	Steps (mm)	No. of blocks
1.001 – 1.009	0.001	9	1.001 – 1.009	0.001	9
1.01 – 1.09	0.01	9	1.01 – 1.49	0.01	49
1.1 – 1.9	0.1	9	0.5 – 9.5	0.5	19
1 – 9	1	9	10 – 90	10	9
10 – 90	10	9	1.005	—	1

(3) Set M 112		
Range (mm)	Steps (mm)	No. of blocks
1.001 – 1.009	0.001	9
1.01 – 1.49	0.01	49
0.5 – 24.5	0.5	49
25 – 100	25	4
1.0005	—	1

(4) Set E28	
9 Pieces from	0.01– 0.209 in
9 Pieces from	0.21– 0.029 in
9 Pieces from	0.01– 0.09 in
1 Pieces from	0.02005 in

Material for Gauge Blocks

- The material used for gauge blocks must have excellent wear resistance, size stability and ability to take extremely fine surface finish.
- Tool steel, chrome plated steel, stainless steel, tungsten carbide, chrome carbide and Cervit are some of the materials used for gauges. Of these, tungsten carbide, chrome carbide, and Cervit are the most interesting cases.
- Depending upon the material used the slip gauges may be heat treated to obtain size stability and required degree of hardness. The surface is lapped to obtain the desired smoothness and accuracy.
- The carbide block are very hard and therefore does not scratch easily. The finish of the gauging surfaces is as good as steel, and the lengths appear to be at least as stable as steel, perhaps even more stable.
- Tungsten carbide has a very low expansion coefficient and because of the high density the blocks are heavy.
- Chrome carbide has an intermediate thermal expansion coefficient and is roughly the same density as steel.
- Carbide blocks have become very popular as master blocks because of their durability and because in a controlled laboratory environment the thermal expansion difference between carbide and steel is easily manageable.
- Cervit is a glassy ceramic that was designed to have nearly zero thermal expansion coefficient. The drawbacks are that the material is softer than steel, making scratches a danger, and by nature the ceramic is brittle.

Manufacture of Slip Gauges

- The following operations are carried out to obtain required qualities in slip gauges during manufacture.

Step -1: The approximate size of slip gauges is made by preliminary operations.

Step -2: The blocks are hardened and wear resistant by a special heat treatment process.

Step -3: For stabilization of the whole life of blocks, seasoning process is carried out.

Step -4: The approximate required dimension is done by a final grinding process.

Step -5: Lapping operation is carried out to get the exact size of slip gauges.

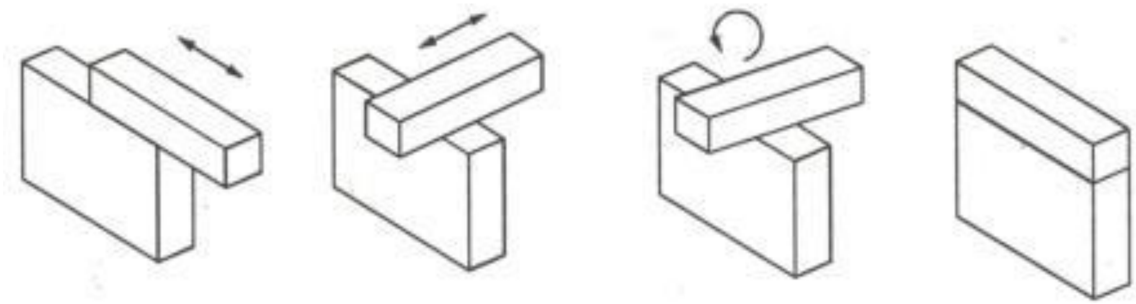
Step -6: Comparison is made with grand master sets.

Slip Gauges accessories

- The slip gauges can be used for many purpose without help of any accessories, however, the application of slip gauges can be increased by providing accessories to the slip gauges.
- The following various accessories are used with slip gauges:

1. **Measuring jaw:** It is available in two designs specially made for internal and external features.
2. **Scriber and Centre point:** It is mainly formed for marking purpose.
3. **Holder and base:** Holder is nothing but a holding device used to hold combination of slip gauges. Base is designed for mounting the holder rigidly on its top surface. It is made of robust construction and designed such that it remains stable when used with the longest size holder.

Wringing of Slip Gauges



- If two slip gauge blocks are wrung together to each other as shown in Fig. and considerable pull is required to break the wring.
- This phenomenon of wringing occurs due to molecular adhesion between a liquid film (not more than 6 to 7 microns thick) and the mating surfaces. This wringing process is used to build up desired dimensions over a range of sizes in specific increments.
- The success of the wringing operation depends upon the surface finish and flatness of the blocks used and absence of dirt, grease, burrs and scratches. When the slip gauges are correctly wrung together, the error in the total length is negligible.

Applications of Slip Gauges

1. They are used to check the accuracy of vernier, micrometers and other measuring devices.

2. They are used to set the comparator to a specific dimension.

3. They are used for direct precise measurement where the accuracy of work piece is important.

4. They are frequently used with sine bar to measure angle of work piece.

5. They can be used to check gap between parallel locations.

Calibration of Slip Gauges

- The slip gauges are liable to show signs of wear after appreciable period of use due to handling in the laboratory or inspection room. Hence they should be checked or recalibrated at regular intervals.
- Workshop and inspection grade gauges are calibrated by direct comparison against calibration grade gauges with help of a comparator. A variety of comparators are available such as mechanical, optical and pneumatic comparators.
- Eden Rolt millionth comparator and Brook level comparator have been specially designed for slip gauges.
- Various forms of interferometers and optical flat are applicable to measuring gauge block flatness. Interferometers are optical instruments used for measuring flatness and determining the length of the slip gauges by direct reference to the wavelength of light.
- Parallelism between the faces of a gauge block can be measured in two ways; with interferometry or with an electro-mechanical gauge block comparator.

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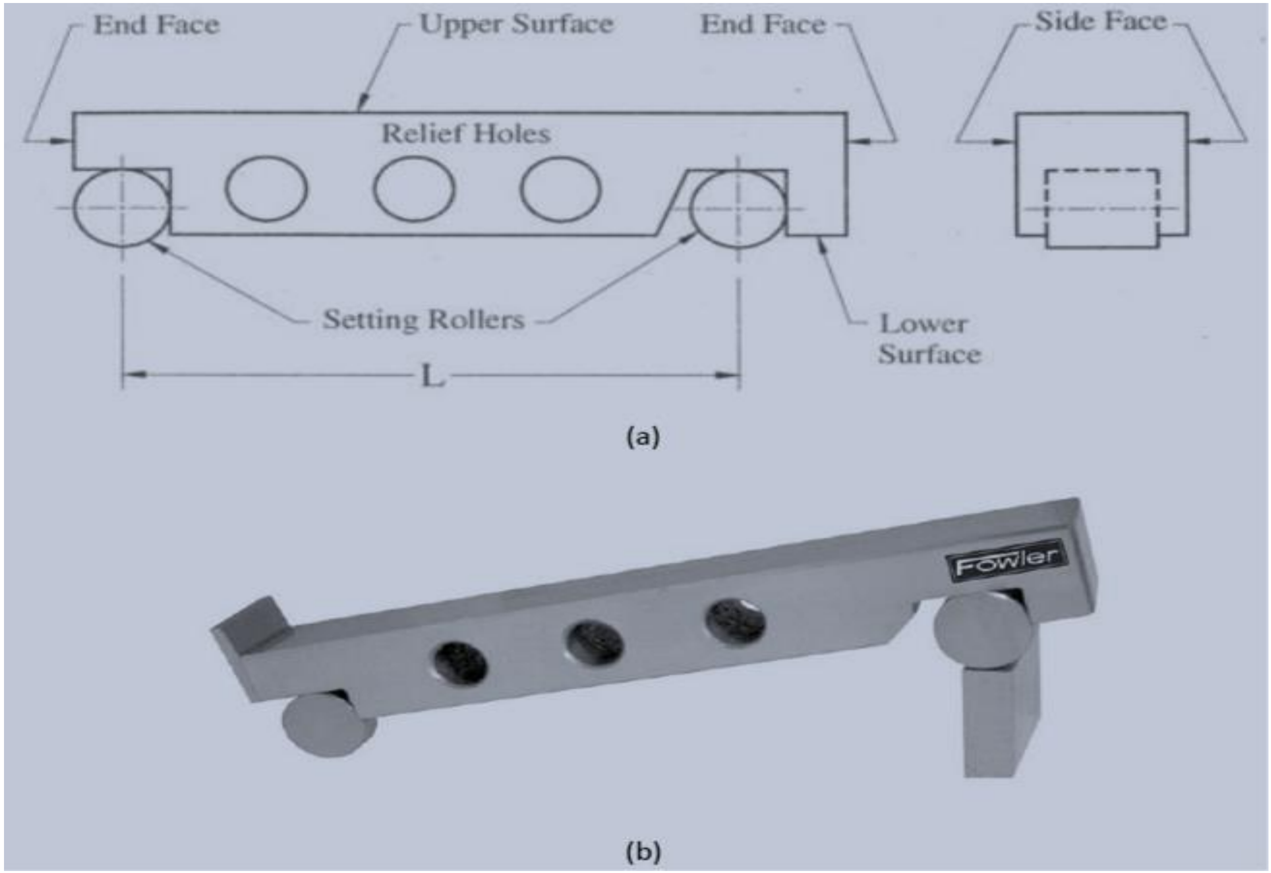
Measurement of angles

Sine Bar

➤Sine bar is a precision angle measuring instrument used along with slip gauges. It is used to measure the angles very accurately and or to locate the work to a given angle.



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Sine Bar : Construction

- Sine bars are made from high carbon, high chromium, corrosion resistant steel, suitably hardened, precision ground and stabilized. Two cylinders of equal diameters are attached at the ends.
- The axes of these two cylinders are mutually parallel to each other and also parallel to and at exact distance from the upper surface of the sine bar. The center to center distance between the rollers or plugs is available for fixed distance i.e. L= 100 mm, 200 mm, 250 mm, 300 mm.
- The diameter of the plugs or roller must be of the same size and the center distance between them is accurate. The important condition for the sine bar is that the surface of sine bar must be parallel to the center lines of the roller.
- Some holes are drilled in the body of the sine bar to reduce the weight and to facilitate handling.

Sine Bar : Working principle

- The principle of operation of the sine bar relies upon the application of trigonometry. One roller of the bar is placed on the surface plate and the combination of slip gauges is inserted under the second roller for setting a given angle. If h’ is the height of the combination of slip gauges and 'L' the distance between the rollers centres. Then,

$$\sin\theta = \frac{h}{l}\ ;\ or\ \theta = \sin^{-1}\left(\frac{h}{l}\right)$$

- Thus the angle to be measured or to be set is determined by indirect method as a function of sine, for this reason, the device is called a 'sine bar'.

❖ Accuracy requirements of a sine bar:

1. The rollers must be of equal diameter and true geometric cylinders.
2. The distance between the roller axes must be precise and known, and these axes must be mutually parallel.
3. The upper surface of the bar must be flat and parallel with the roller axes, and equidistant from each other.

Use of sine bar

1 Locating any work to a given angle:

- As we have discussed in the working principle of sine bar,

$$\text{Sin}\ \theta = \frac{h}{l}$$

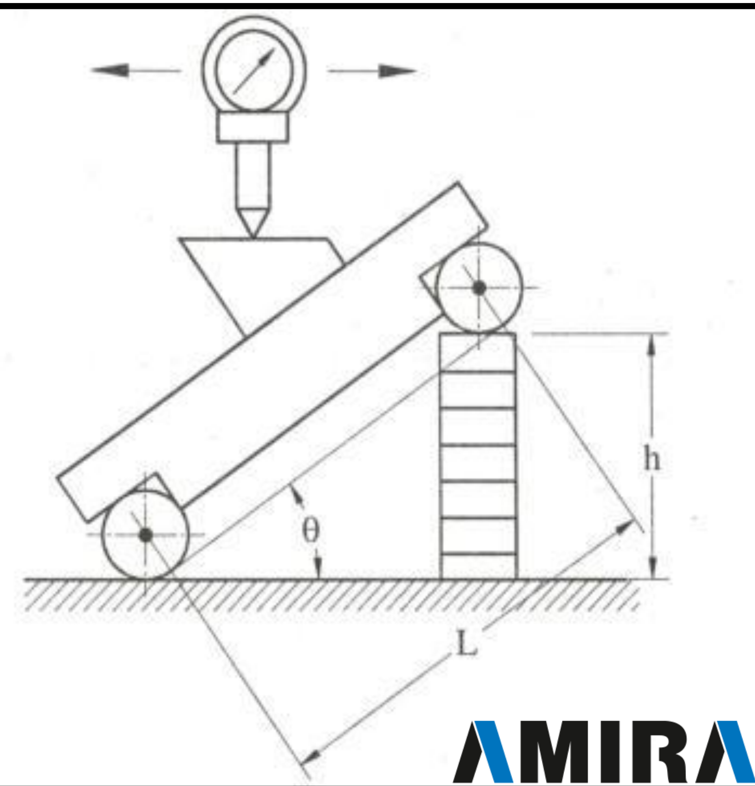
- Where, h be the height of slip gauge combination, L is the distance between the centre of the rollers, and θ is angle to be set.
- Thus knowing θ, h can be found out and any work could be set at this angle; as the top face of the sine bar is inclined at angle θ to the surface plate. For better results, both the rollers could also be placed on slip gauges of height h1 and h2 respectively.

2 Checking or measuring unknown angles:

a. When component is of small size:

- Fig. shows how the sine bar is used to check small components that may be mounted upon it. The dial gauge is mounted upon a suitable stand then set at one end of the work and moved along the upper surface of the component.
- If there is a variation in parallelism of the upper surface of the component and the surface plate, it is indicated by the dial gauge. The combination of the slip gauges is so adjusted that the upper surface of the component is truly parallel with the surface plate:
- The angle of the component is then calculated by the relation.

$$\theta = \text{Sin}^{-1}\left(\frac{h}{l}\right)$$



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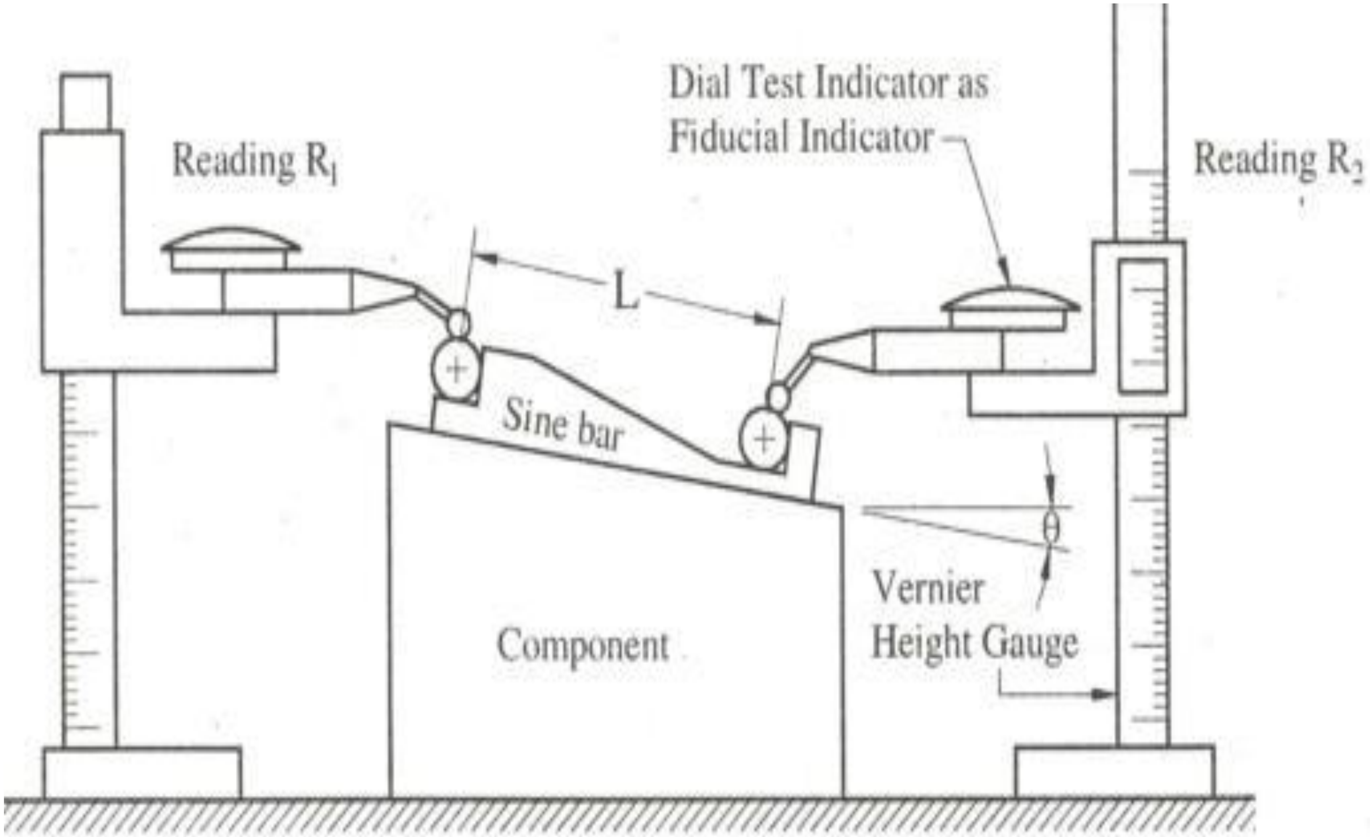
Use of sine bar

b. When the component is of large size:

- When the component is too large to be mounted on the sine-bar, the sine-bar can often be mounted on the component as shown in Fig.

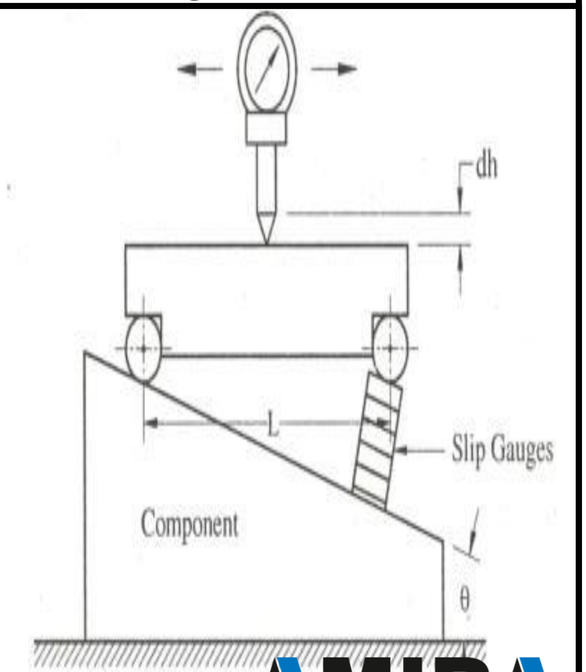


...to be continue

- 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 to ensure constant measuring pressure. This is achieved by adjusting the height gauge until the dial gauge shows the same zero reading each time.
- The difference of the two height gauge readings being the rise of the sine-bar as shown and Sin $\theta = \frac{R_1 - R_2}{L}$
- Another arrangement of determining angle of large size part is shown in Fig.
- The component is placed over a surface plate and the sine bar is setup at approximate angle on the component so that its surface is nearly parallel to the surface plate. A dial gauge is moved along the top surface of the sine bar to note the variation in parallelism.
- If' h' is height of the combination of the slip gauges and 'dh' the variation in parallelism over distance 'L' then

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

- It is impractical to use sine bar for angle above 45°, as beyond this angle the errors due to the centre distance of rollers, and gauge blocks, being in error, are much magnified.



Sources of errors:

- The establishment of angle by the sine principle is essentially a length measuring process. The following are the various possible sources of errors using sine bar:

1. Error in measurement of centre distance of two precision rollers.
2. Error in equality of size of rollers and cylindrical accuracy in the form of the rollers.
3. Error in geometrical condition of measurement like, flatness of the upper surface of the bar, parallelism of roller axes with each other, parallelism between the gauging surface and plane of roller axes, etc.
4. Error in slip gauge combination used for angle setting.

Advantages and Disadvantages of sine bar

Advantages:

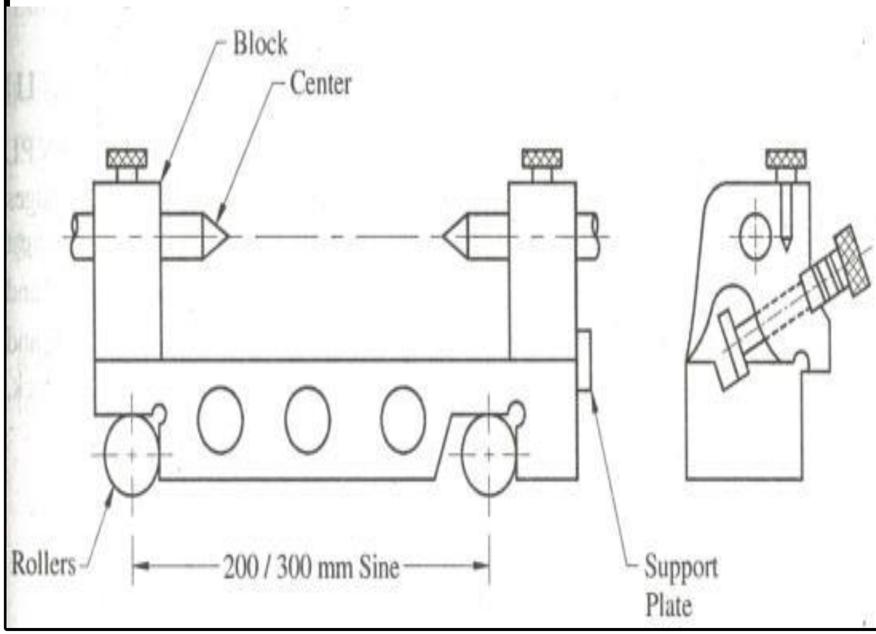
1. It is precise and accurate angle measuring device.
2. It is simple in design and construction.
3. It is easily available.

Disadvantages:

1. It is fairly reliable at angles less than 15° but become increasingly inaccurate as the angle increases. It is impractical to use sine bar for angle above 45°.
2. It is difficult to handle and position the slip gauges.
3. The sine bar is physically clumsy to hold in position.
4. The application is limited for a fixed center distance between two rollers.
5. Slight errors of the sine bar cause larger angular errors.

SINE CENTRE

- Sine centre is basically a sine bar with block holding centers which can be adjusted and rigidly clamped in any position. These are used for the testing of conical work, centered at each end as shown in Fig.
- These are extremely useful since the alignment accuracy of the centers ensures that the correct line of measurement is made along the work piece. The centers can also be adjusted depending on the length of the conical work piece, to be hold between centers.



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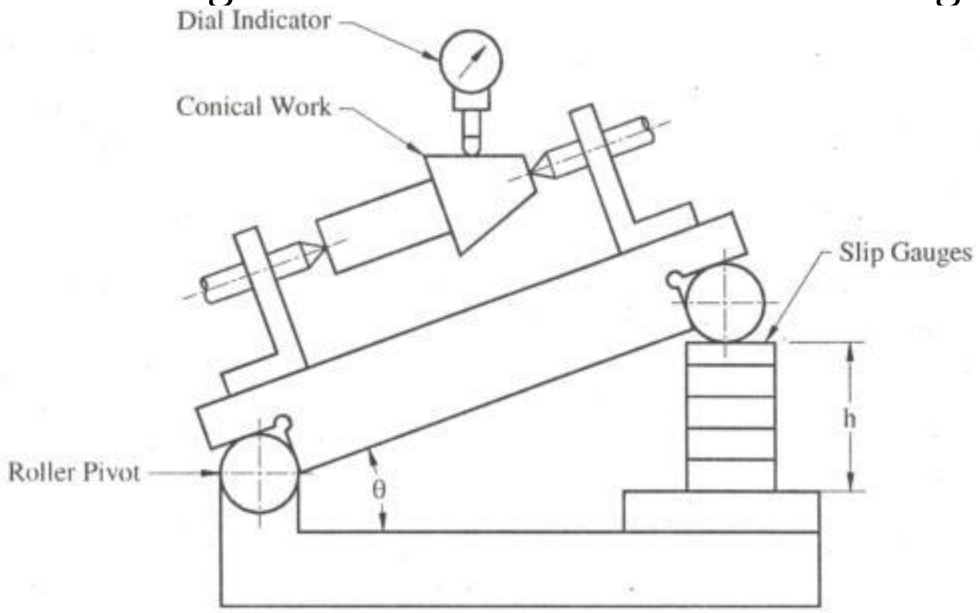
SINE CENTRE

- The procedure for its setting is the same as that for sin bar. Fig. shows sine table,



- Which is the most convenient and accurate design for heavy work-piece. It consists of a self-contained sine bar, hinged at one roller and mounted on its datum surface. The work being held axially between centers, the angle of inclination will be half the included angle of the work. The necessary adjustment is made in the slip gauge height and the angle is calculated as

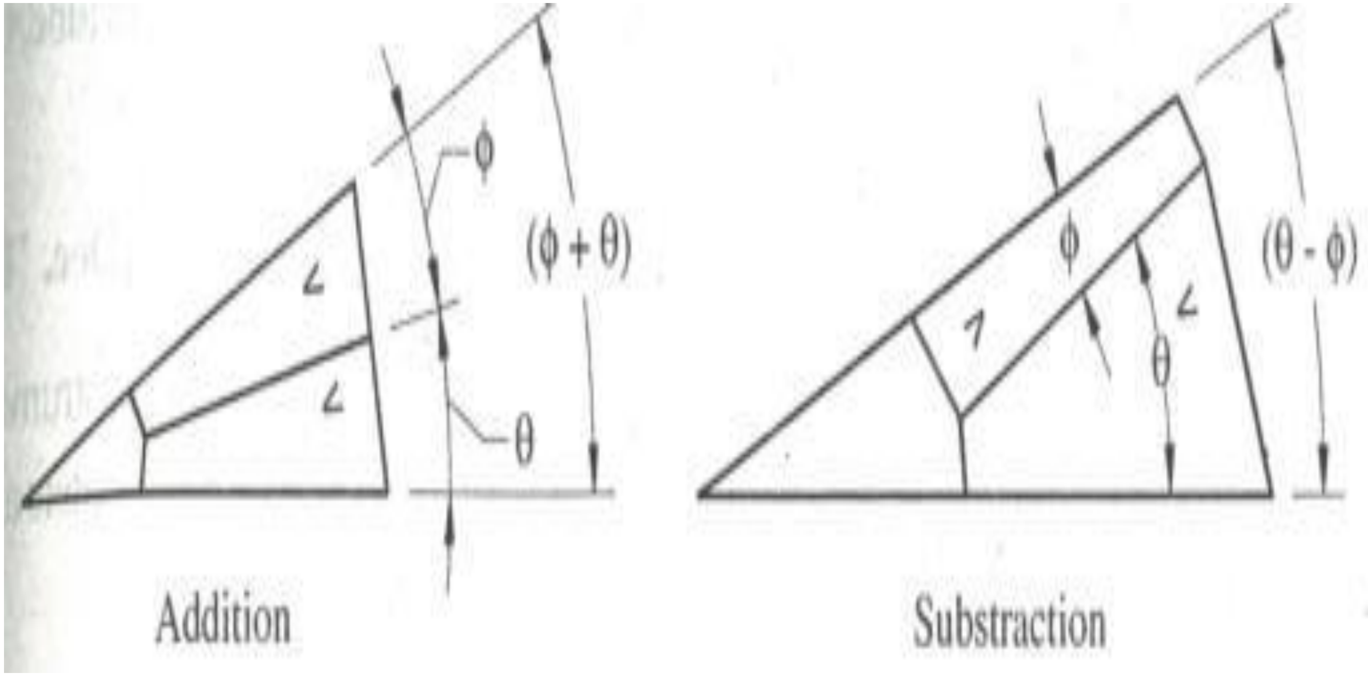
$$\theta = \text{Sin}^{-1}\left(\frac{h}{l}\right)$$

ANGLE GAUGES

- The first set of combination of angle gauges was developed by Dr. Tomlinson of N.P.L in 1941. The slip gauges are built up to give a linear dimension, same way as the angle gauges can be built up to give a required angle.
- These gauges enable any angle to be set to the nearest 3" These are pieces of hardened and stabilized steel. The measuring faces are lapped and polished to a high degree of accuracy and flatness.
- These gauges are about 76 mm long and 16 mm wide and are available in two sets.
- One set consists of 12 pieces and a square block, in three series of values of angle viz,
- 1°, 3° , 9°,27° and 41°
- 1', 3', 9' and 27', and
- 6", 18", and 30"
- Another set contains 13 pieces and a square block.
- 1°, 3°, 9°,27° and 41°
- 1', 3', 9' and 27', and
- 3", 6”, 18" and 30"

ANGLE GAUGES

- All these angle gauges in combination can be added or subtracted as shown in Fig. Thus, making a large number of combinations is possible. Each angle gauge is accurate to within one second and is marked with engraved V which indicates the direction of the inclined angle.



ANGLE GAUGES

❖Applications:

1. Angle gauges have been widely used in engineering industries for the quick measurement of angles between two surfaces. A frequent use of these gauges is to check whether the components is within its off angle tolerance.
2. Where the angle to be measured between the two surfaces exceeds 90°, the use of precision square becomes essential. The reflective properties of their lapped surfaces make them particularly suitable for use with collimating type of instruments.

❖Limitations:

1. The block formed by the wringing (combination) of number of these gauges become bulky and cannot always be conveniently applied to work, so they are more suitable for reference along with other angle measuring devices.
2. Errors are easily compounded when they are wrung in combination.

AUTO-COLLIMATOR

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

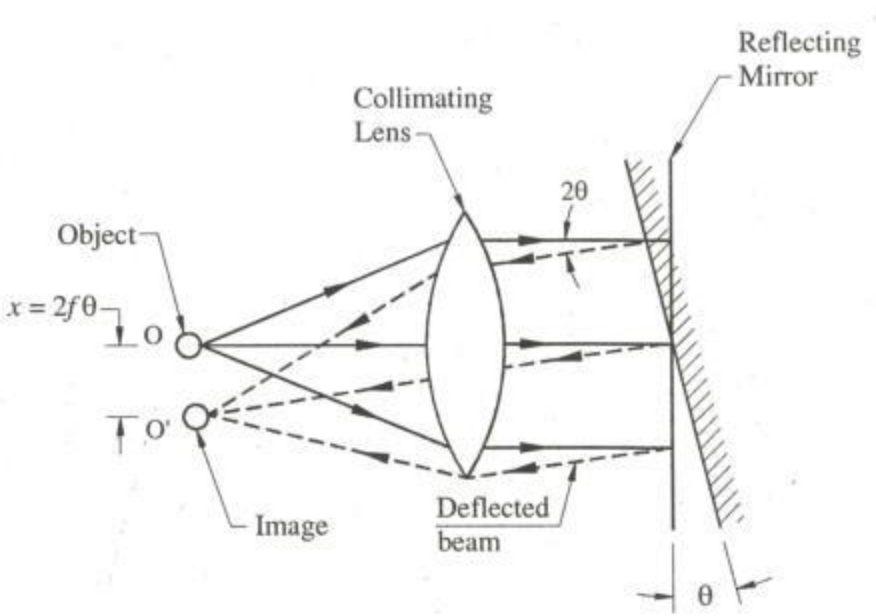
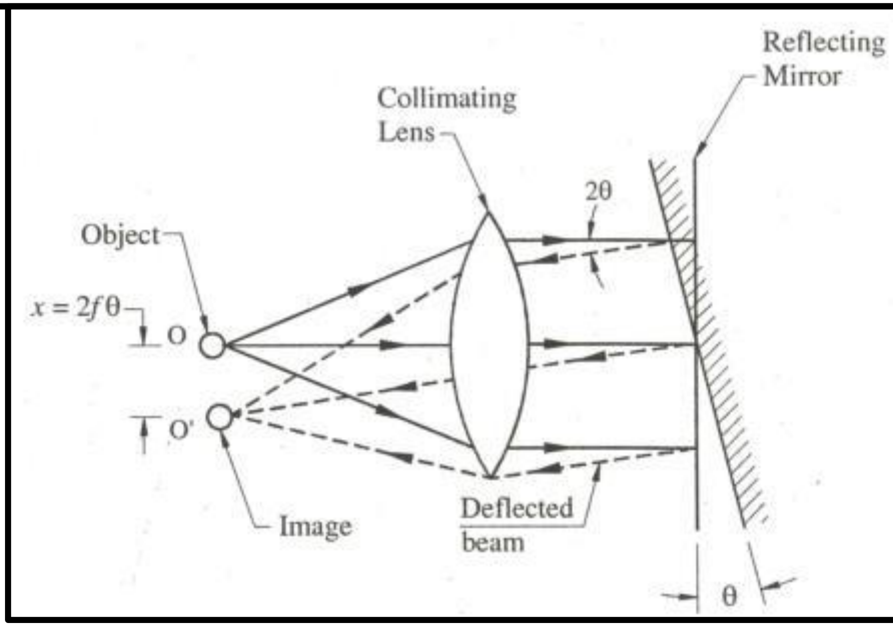


Fig. Principle of auto-collimator

AUTO-COLLIMATOR

❖Working principle:

- Auto-collimator is essentially an infinity telescope and a collimator combined into one instrument. If a light source is placed in the focus of a collimating lens, it is projected as a parallel beam of light.

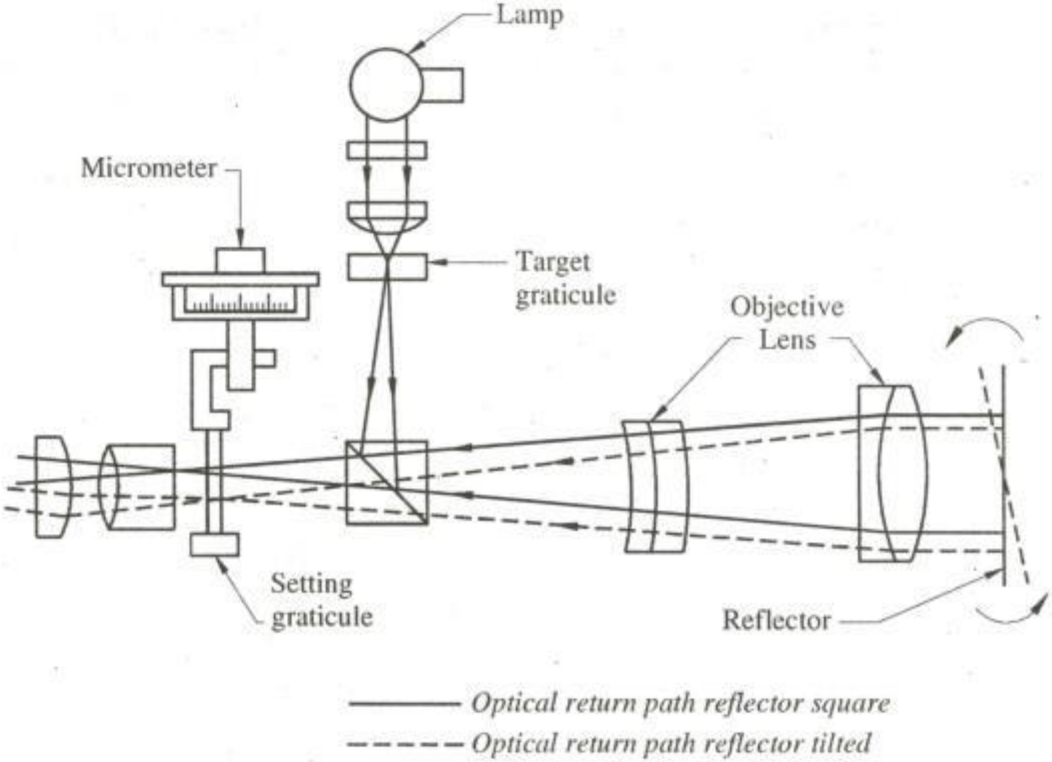


- If this beam now strikes a plane reflector which is normal to the optical axis, it will be reflected back along its own path and focused at the same point 0.
- If the plane reflector be now tilted through a small angle 9 as shown in Fig., then parallel beam will be deflected through twice this angle, and will be brought to focus at 0' in the same plane at a distance from O. Obviously OO' = $x = 2f\theta$
- Where f= the focal length of the lens, θ = angle of inclination of reflecting mirror.

AUTO-COLLIMATOR

❖Construction:

➢An autocollimator consists of three parts viz, micrometer microscope, lighting unit and collimating lens. A line diagram of injected graticule autocollimator is shown in Fig. have the graticule situated to one side of the instrument on an axis at right angles to the main axis.



AUTO-COLLIMATOR

❖Construction:

➢A 45° transparent beam splitter, similar to the original illuminated reflector but further down the main axis, reflects the light from the graticule towards the objective and thus no direct image is formed by the microscope.

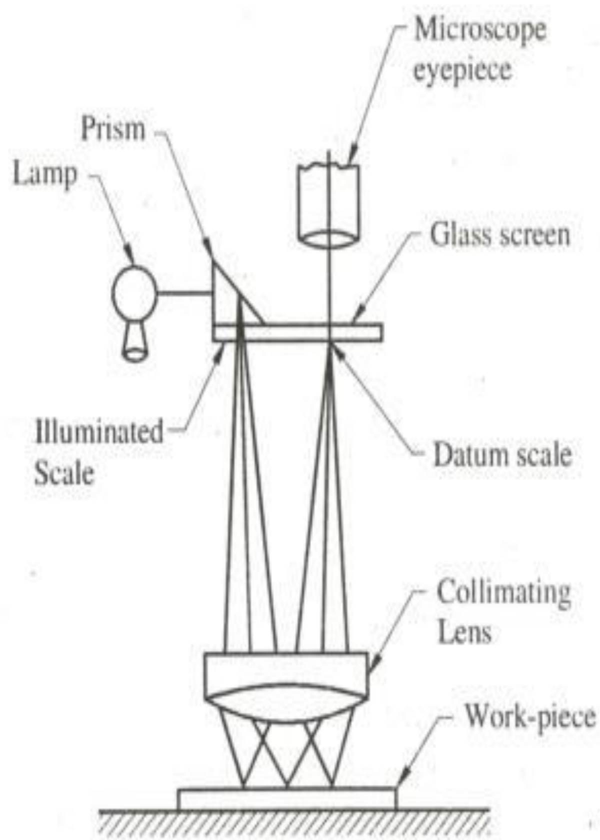
➢The image seen after reflection in the external reflector, whose angular variations are being measured, is formed by the light from the objective which passes through the 45° beam splitter and this image is picked up by the microscope. In this instrument also, a micrometer is fitted to the target graticule, optically at right angles to that on the eyepiece. Thus simultaneous measurements can be made in two planes at right angles.

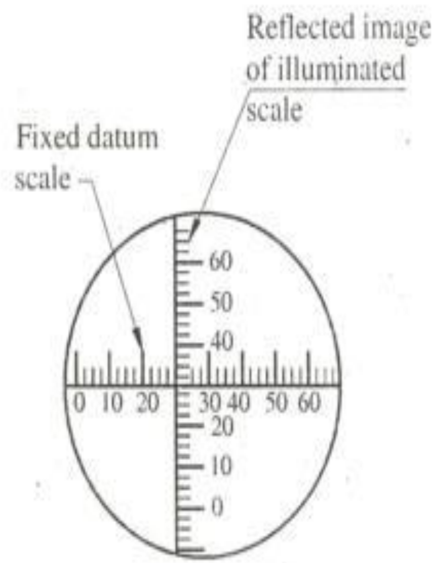
❖Applications:

1. Checking of an internal tight-angle.
2. Comparative measurement using master angles.
3. Measuring straightness and flatness of the surfaces.
4. Measuring small linear dimensions.
5. Assessment of squareness and parallelism of components.
6. For precise angular indexing in conjunction with polygons etc.

ANGLE DEKKOR

- Angle dekkor works on the same principle as that of auto-collimator. It consists of microscope, collimating lens and two scales engraved on a glass screen which is placed in the focal plane of the objective lens.



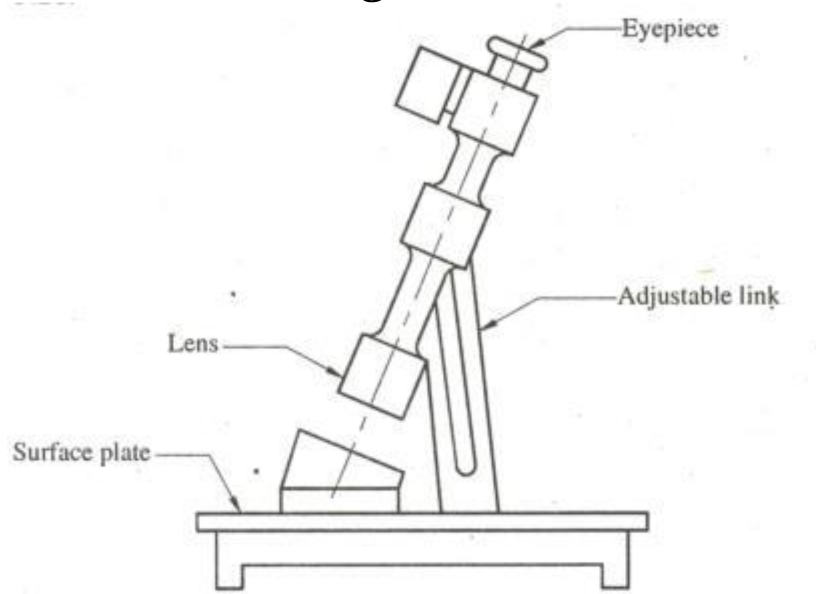


ANGLE DEKKOR

- The screen, which lies at the focal plane of the lens, has two mutually perpendicular scales marked on it which are graduated in minutes enabling estimations to about 0.2 minutes to be made.
- The essential function of the instrument is to transmit an image of one of the scales to a reflecting surface which returns the image through the lens to be superimposed on to the other scale which is fixed.
- Thus the reading on illuminated scale measures angular deviations from one axis at 90° to the optical axis, and the reading on the fixed datum scale measures the deviation about an axis mutually perpendicular to the other two.
- 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' without the use of a micrometer.
- Although the angle dekkor is not as sensitive as the auto-collimator, it is extremely useful for a wide range of angular measurements at short distances.

ANGLE DEKKOR

➢The whole optical system as shown in Fig. is enclosed in a tube which is mounted on an adjustable bracket. The adjustable bracket is attached to a flat lapped reflective base as shown in Fig.



❖Applications:

➢1. Measuring the angle of a component.

➢2. Checking the sloping angle of a v-block.

➢3. Measuring the angle of a cone or taper gauges.

➢4. Precise angular settings for machining operations.

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Thank You