

Linear measurement:

Linear measurement is defined as the measurement of length, diameter, heights and thickness which includes external and internal measurement.

Linear measuring Instruments:

Linear measurement are classified into two types based on their accuracies. They are,

① precision instruments which possess high degree of accuracy in measuring the dimension.

The various precision measuring instruments are as follows,

- a, vernier callipers
 - b, vernier height gauge
 - c, vernier depth gauge
 - d, micrometer
 - e, differential screw micrometer
 - f, vernier micrometer
 - g, depth micrometer
 - h, telescopic gauge
 - i, slip gauge
 - j, inside micrometer
 - k, outside micrometer
- 1, screw thread micrometer
 - 2, disc type micrometer
 - 3, sheet metal micrometer
 - 4, spline micrometer
 - 5, tube micrometer

② Non-precision instruments which possess low degree of accuracy in measuring the dimension

The various non-precision measuring instruments are as follows,

- a, steel rule
- b, callipers
- 1, firm joint callipers
- 2, spring callipers
- 3, outside callipers
- 4, inside callipers
- 5, transfer callipers
- 6, odd leg callipers

Discuss the need for wavelength as a standard for length :

Due to considerable difficulty faced in the comparison and verification of the sizes of gauges, the wavelength of light as a linear standard lead to a free and acceptable performance. Using wave-length, the working standard is no more dependent unit of length, the working standard is no more dependent upon the physical standard.

Since the definition of standard of length relative to the meter is expressed in terms of the wave length of red radiation of cadmium.

Since wave length standard is not a physical one it need not be preserved. This is reproducible standard of length, and the error of reproduction can be of the order of 1 part in 100 million.

Thus, for all practical purposes the use of phenomenon of the interference of light waves to provide working standard may be accepted as ultimate.

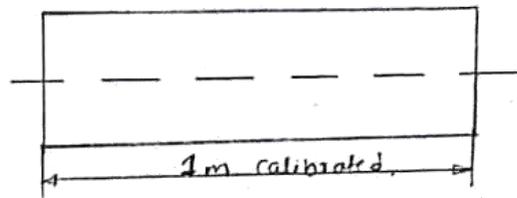
Advantages of wavelength standard :

- 1, It is not a material standard and hence it is not influenced by effective or variation of environmental conditions like temperature, pressure, humidity and ageing.
- 2, It need not be preserved or stored under security and thus there is no fear of being destroyed as in case of meter and yard.
- 3, It is not subjected to destruction by wear and tear.
- 4, It gives a unit of length which can be produced consistently at all the times in all circumstances, at all the places. In other words it is easily reproducible and thus identical standards are available with all.
- 5, This standard is easily available to all standardizing laboratories and industries.
- 6, There is no problem of transferring this standard to other standards.
- 7, It can be used for making comparative measurements of very high accuracy. The error of production is only of the order 3 part in 10⁸.

Describe the procedure for deriving end standards from line standards with suitable examples?

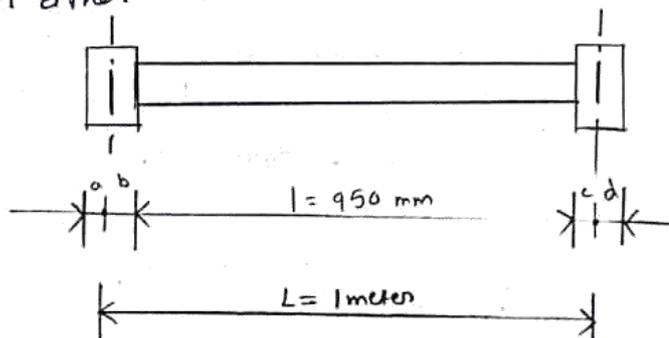
Ans Line standard is a primary standard whereas end standard is a practical, workshop standard derived from the length standards. In end standard, the length is measured between the two flat parallel faces of the measuring instruments. This end standard must be calibrated from a primary line standard.

The procedure for deriving end standard from a line standard can be explained by using a composite line standard. For example, a primary line standard of a basic length of 1 meter is shown in figure (1) whose actual length is accurately known.



fig(1) composite line standard

Another example is a line standard of a basic length of one meter with a central bar of length 950 mm and two end blocks of 50 mm on either side of the bar as shown in below figure (2).



Also, each block has an engraved central line and therefore the basic length, $L = l + b + c$

Thus, we can obtain four possible combinations with the two end blocks i.e.,

$$L = l + b + c$$

$$L = l + b + d$$

$$L = l + a + c \text{ and}$$

$$L = l + a + d$$

By adding the above equations, we get

$$4L = 4l + 2a + 2b + 2c + 2d$$

Compare Line and End standards:

S.No	characteristics	Line Standard	End Standard
1,	Principle	Length is expressed as the distance b/w two lines, limit to ± 0.2 mm for high accuracy Scales to be used in conjunction with magnifying glass & microscope. measure-ment is quick and easy	Length is expressed as the distance b/w two flat parallel faces. Highly accurate for measurement of close tolerances upto ± 0.001 mm
2,	Ease and time to measurement	measurement is quick and easy	use of end standard requires skills and is time consuming. These are subjected to wear on their measuring surfaces.
3,	effect of wear	Scale marking are not subject to wear. However, significant wear may occur on leading ends. Thus it may be difficult to assume zero of scale as datum	
4,	Alignment	cannot be easily aligned with the axis of measurement	can be easily with the axis of measurement.
5,	manufacture and cost	simple to manufacture at low cost	manufacture process is complex and cost is high
6,	parallax effect	They are subjected to parallax error	They are not subjected to parallax error
7,	Examples	scale [yard, meter]	v. calliper, micrometer.

INSTRUMENT: Instrument is a device used to measure the given object to its accuracy and precision. The characteristics to be considered in selection of an instrument are its measuring range, accuracy and precision. usually, accuracy is poor at the lower end of scale which should be avoided. The precision of instrument is very important feature since it should give repeatable readings which is possible with precise instrument.

Slip gauge or precision Gauge Blocks:

Slip gauge provide industry with linear standards of high accuracy that are necessary for everyday use in manufacturing plants. These blocks are small, rectangular, square, & round in cross section and are made from steel & carbide with two very flat and parallel surfaces that are certain specified distance apart. These slip gauge are made of alloy steel, hardened and carefully heat treated to relieve internal stresses and to minimize subsequent dimensional change. Carbide gauge blocks provide extra wear resistances. The measuring surfaces of each block are surface ground to approximately the required dimension and then lapped and mirror polished to bring the final dimension and to produce a very flat and smooth surfaces.

USES of gauge:

- 1, Direct precise measurement, where the accuracy of the workpiece demands it.
- 2, For checking accuracy of vernier callipers, micrometers, and such other measuring instruments.
- 3, Setting up a comparator to a specific dimension.
- 4, To check gap between parallel location such as in gap gauge or between two mating parts.
- 5, For measuring angle of workpiece and also for angular setting in conjunction with sine bar.

Describe briefly material used and the manufacture of slip gauges!

Slip gauge are rectangular blocks of steel with a cross section of about 30x10 mm. These are made from a high grade steel with coefficient of thermal expansion $[11.5 \pm 1.5] \times 10^{-6}/^{\circ}\text{C}$ between 10°C to 30°C. They are hardened through and suitably heat treated so as to stabilize their dimensions & it is provided with hard measuring faces like carbide faces. The hard measuring faces are free from any defects and are finished by high grade lapping and have good working surfaces.

Manufacture of slip gauges:

The national physical laboratory (N.P.L) method of manufacturing slip gauges utilizes a special type of magnetic chuck on which eight similar steel blanks are mounted and spot ground on each face. All the blanks are made parallel to about 0.0002 mm and within about 0.002 mm of size by a preliminary lapping operation.

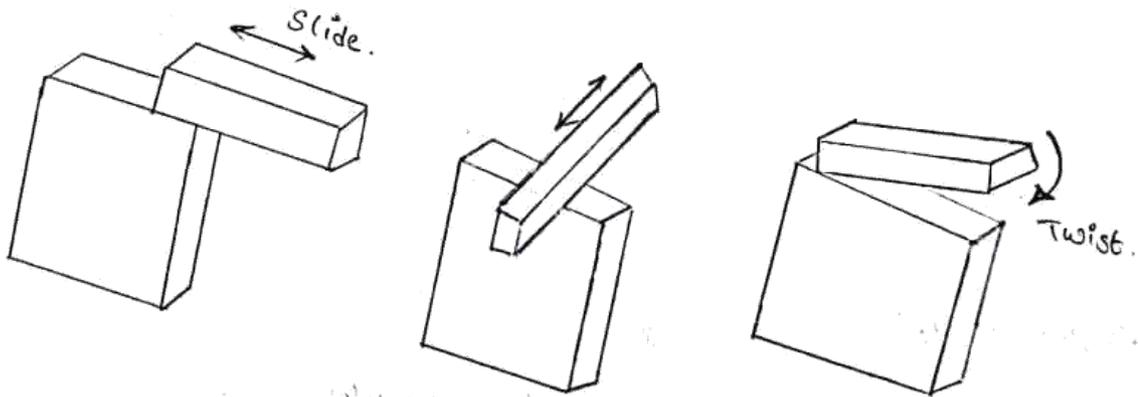
Wringing: It is defined as the property of measuring faces of gauge blocks a combined sliding and twisting motion against the measuring faces of the other gauge blocks.

Procedure for wringing:

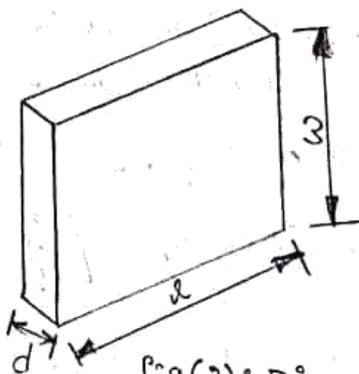
- 1, Initially slip gauge are cleaned using a lint free cloth.
- 2, Applying light pressure one slip gauge is oscillated over other slip gauge.
- 3, Again applying pressure, rotate one gauge on another gauge until the gauges are in one line.
- 4, Hence, the gauge blocks adhere.

The wringing gap between correctly wrung gauge is about 5 Nm [$5 \times 10^{-9} \text{ m}$]. But this may be as large as one micrometer in wringing if not fully effective. So for more accuracy careful wringing is essential.

The cross-section of these gauges are $9 \text{ mm} \times 30 \text{ mm}$ for size up to 10 mm and $9 \text{ mm} \times 35 \text{ mm}$ for larger sizes.



Fig(1):- Wringing of slip gauge.

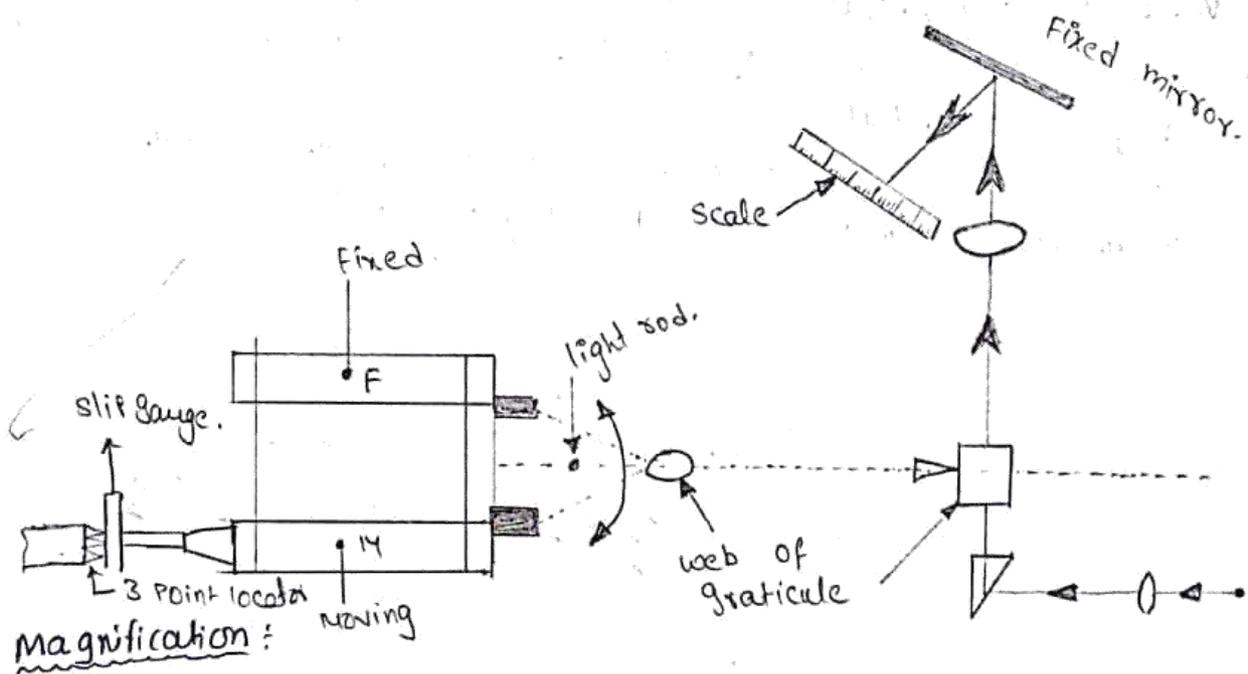


Fig(2): Dimensions of a slip gauge.

Eden - bolt - Millionth comparator :

It is also called as millionth comparator. It is a mechanical cum optical comparator which utilizes both mechanical and optical magnification system. It is suitable in standard room for calibration of gauges under appropriate conditions. Its design is simple and economical.

In order to understand its working, it is better to consider two systems of magnification separately. Mechanical magnification system consists of a fixed anvil, moving anvil, a fixed block [F] and a moving [M]. The fixed block and the moving blocks are connected together by parallel thin steel strips. The pointer arm carries at its other end a ring across which is stretched a spider web.



Magnification :

Let,

d = distance between the pointer parallel strips

L = length of pointer arm

δ = movement of the movable block.

The angular deflection of pointer strips = δ/d radians

Linear displacement of web = $\frac{\delta}{d} \times L$

Therefore, mechanical magnification = $\left[\frac{\delta L}{d} \right] / \delta$

Now, if 'f' is the optical magnification, then overall magnification = $\frac{L}{d} \times f$

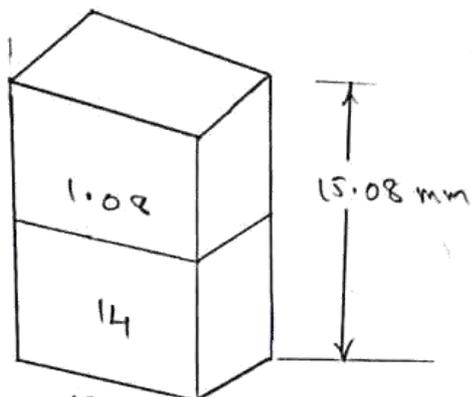
a) 15.08 mm :

For last decimal place of 0.08 mm, select 1.08 mm slip gauge.

Then, the dimension left = 15.08 mm - 1.08 mm = 14 mm.

Hence, 14 mm and 1.08 mm slip gauge are selected to build the dimension 15.08 mm

Thus, we have 14 mm + 1.08 = 15.08 mm



(a) slip gauge.

b) 38.925 mm :

For last decimal place of 0.005 mm, choose 1.005 mm slip gauge

Now, the dimension left = 38.925 mm - 1.005 mm = 37.92 mm

For second decimal place of 0.02, select 1.02 mm slip gauge.

Then, the dimension left = 37.92 mm - 1.02 mm = 36.9 mm

For third decimal place of 0.9 select 1.9 mm slip gauge.

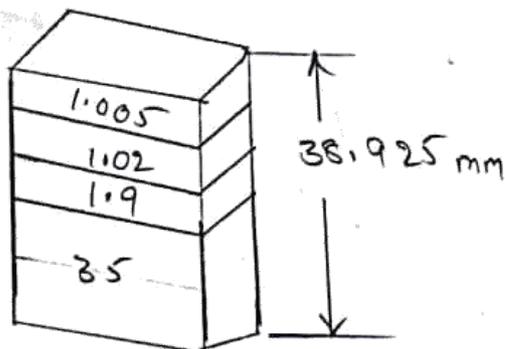
Then, the dimension left = 36.9 mm - 1.9 mm = 35 mm.

Now, select 35 mm slip gauge to build up the required combination

Thus,

we have 35 mm + 1.9 mm + 1.02 mm + 1.005 mm = 38.925 mm.

Therefore, 35 mm, 1.9 mm, 1.02 mm and 1.005 mm slip gauges are selected to build the dimension 38.925 mm

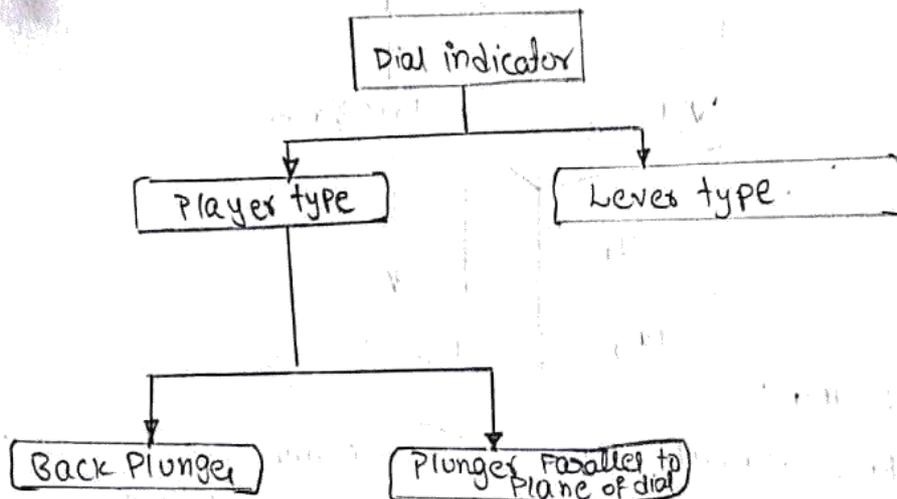


Classification of Dial Indicators: Dial indicators are mainly classified into two groups based on design criteria.

According to the design criteria:

- 1) Sector type dial indicators
- 2) circular type dial indicators.

The further classification of dial indicators based on required applications are as follows,



Working of Mechanisms of Dial Indicator:

In this instrument, the high magnification ratio is obtained by using gear and pinion arrangement in a small area.

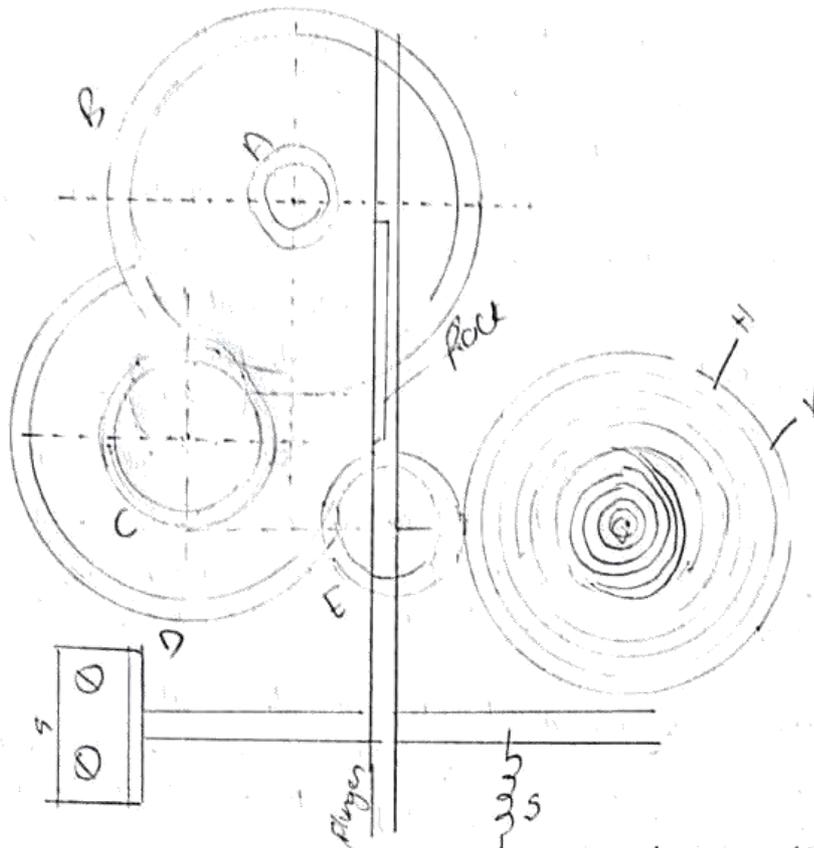
It consists of a plunger which slides in its own bearings and carries a rack which accurately meshes with a pinion A. There is a pin attachment in plunger to prevent it from rotation about its own axis. A light coiled spring is attached to keep the plunger in its normal or extended position.

A small movement in the point of contact causes the rack to move which in turn, turns the pinion (A) meshed to it. The spindle of the pinion (A) carries a large gear B which meshes with pinion C. The pinion C magnifies the movement of pinion A. The gear D which meshes with a third pinion E mounted on the spindle having indicator pointer. The overall magnification of final pinion is

$$\frac{T_{Dn}}{T_{Ep}} \times \frac{T_{Ba}}{T_{Ca}}$$

where 'T' represents number of teeth of gears B and C.

The suffix P represents the pinion and G represents the gear.



Depending upon the length of the pointer, the magnification is further enlarged at the tip of the movement pointer. Thus, the overall magnification can be impressed by the distance between the divisions of the scale and dividing it by the equivalent movement of the plunger.

A light hair spring is provided to take up the backlash and is attached to the gear V which is meshed with pinion E.

After the final assembly, a dial meshed with pinion throughly checked and tested and calibrated by using micrometers & by slip gauges.

In case of more than one revolution of pointer, a revolution centre is incorporated which indicate the number of revolution made by the pointer and thus enables a complex reading.

TYPES of SCALES:

Two types of scales are commonly used on dial indicators.

At first, the standard scale is calibrated in units of 10.

one small division = 0.01 mm

one bigger division = 0.1 mm

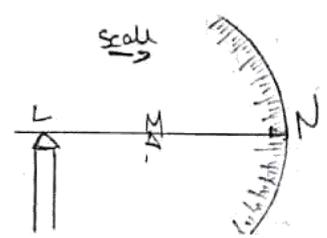
The small dial gives the number of complete pointer revolutions, hence the total movement of the plunger can be determined.

Advantages of Dial Indicators:

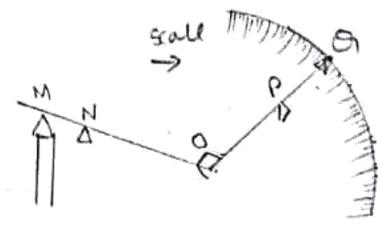
- 1) For mass production, dial indicators are best suited for precision dimension control.
- 2) Dial indicators can be easily used and can read even by unskilled worker.
- 3) Low and uniform contact pressure on the work piece.
- 4) It is portable, easy to handle and can be set very quickly.
- 5) Dial indicators detect the small dimensional variations that are beyond the range of conventional gauges.
- 6) The costly and large collection of specially made gauges can be avoided by intelligent use of dial indicators.
- 7) Dial indicators are not subjected to problems such as gauge wear, temperature variations etc.
- 8) Dial indicators are accurate and economical.
- 9) It eliminates the uncertain human errors while taking references.
- 10) It eliminates save time and avoid the necessity of using different inspections and expensive "Setup".

Describe the working principle and uses of lever type dial test indicators!

(A) This dial indicator is based on the principle of simple lever mechanism. LMN represents a simple form of magnifying lever, pivoted at 'M' obviously the magnification ratio is $\frac{MN}{LM}$



Simple lever mechanism



Compound lever mechanism

A simple dial indicator as shown in fig(1) is constructed on the principle the gauge is restricted to few degrees on either side of zero. But it very robust and very useful within its range for comparison purposes. For higher magnification a compound lever system is used. In this case the magnification ratio is $\frac{QP}{PO} \times \frac{NO}{MN}$. However, this type of lever is more difficult to construct due to the difficulty of making a fork joint at 'O'. It also suffers from disadvantages of low accuracy and less range.

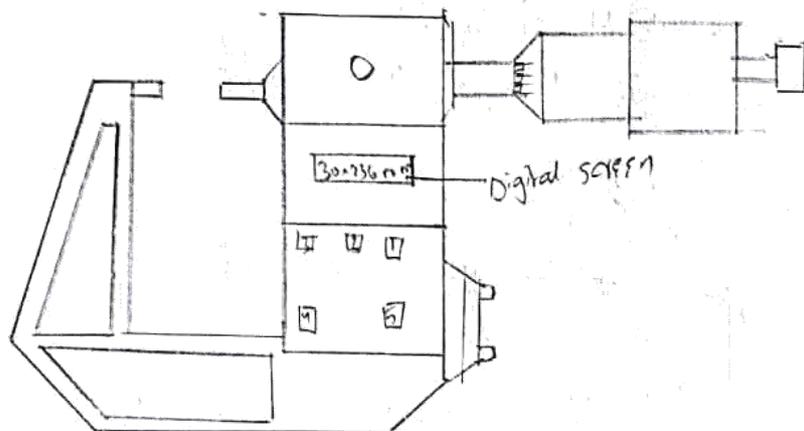
MICROMETERS :

Types of micrometers are,

1. Disc type micrometer.
2. Blade type micrometer.
3. Micrometer with veeformed anvil.
4. Micrometer with conical spindle tip.
5. Depth micrometer.
6. Bench micrometer.
7. Pointed contact micrometer.
8. Three-point contact micrometer.
9. Ball contact micrometer.
10. Indicator micrometer.
11. Micrometer heads.

Digital micrometer provides direct reading to 0.001 mm and employ liquid display. These are operated on an alkaline manganese battery.

Digital micrometer spindle is made of stainless steel. Threads are hardened, ground and lapped. The measuring faces are carbide tipped for a long tool life. For appropriate and easy readings, large diameter pead thimbles are incorporated. The anvil and spindle are hardened and precision ground with micro-top finish on the ends. The operation is simple, quick and easy with zero adjustments. The micrometer is incorporated with positive locking clamp to lock the spindle at any desired position.



Digital micrometer

The control push buttons are used to operate the digital micrometer, according to numbered buttons for performing different operations. The push buttons are as follows.

1. Button ON/OFF;

Is used for power switching ON or OFF

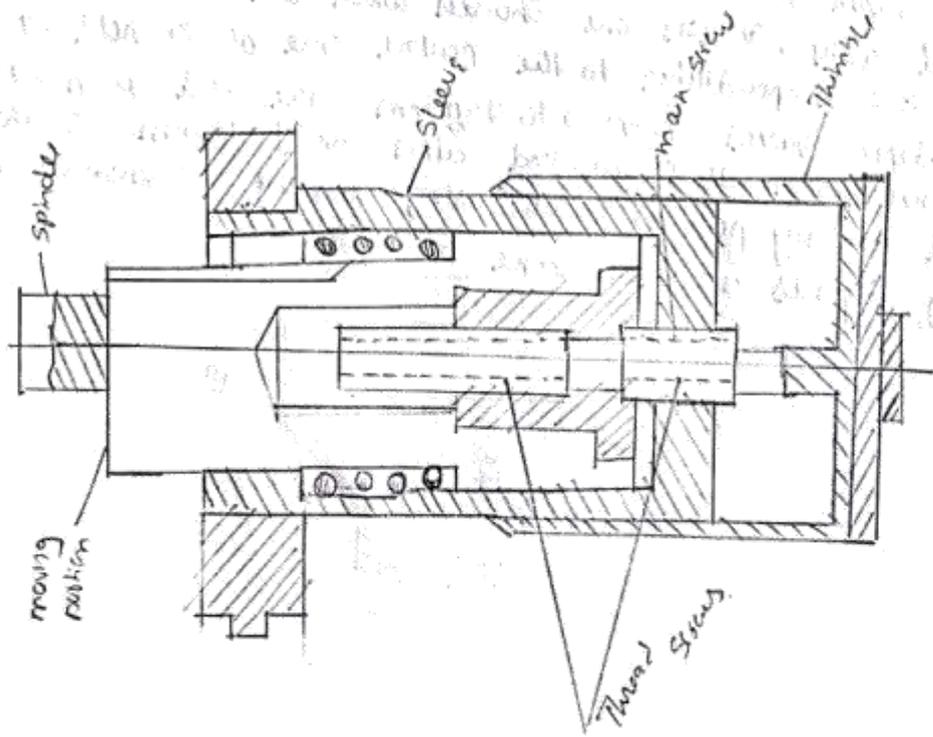
2. Button IN/MM

It is used to select the measurement unit (Inches or mm)

When the power is switched ON, the selected unit displays on the screen.

Outside micrometer and their uses:

- 1, Screw Thread micrometer: It is used to measure pitch of threaded.
- 2, Sheet Metal micrometer: It is used to check the thickness of sheet metal.
- 3, Outside micrometer with Dial Indicator on the Anvil Side: It is used to read the values directly by eliminating human error.
- 4, DISC TYPE micrometer: It is used to measure the distance between the gear teeth of helical gear or spur gear.
- 5, Indicating micrometer: It has an indicator fitted in the micrometer, which works as go gage. This micrometer has tolerance bands which can be set at desired tolerances.
- 6, TUBE micrometer: It is used to measure the thickness of slides or split bearings, rings, tubing sleeves etc.
- 7, V-ANVIL micrometer: It is used to measure milling cutters, reamers, odd fluted taps, etc. Any tools which are out of roundness conditions can be easily checked in centerless grind and machining operation.
- 8, Spline micrometer: It is used for checking the diameter of spline shafts groove.
- 9, Limit micrometer: It has two micrometer heads arranged in parallel in a single frame and is adjusted to go and no go dimensions of a gage.
- 10, Point micrometer: It is used for measuring web thickness of drills, taps, recesses and small grooves which is not possible by conventional micrometer.



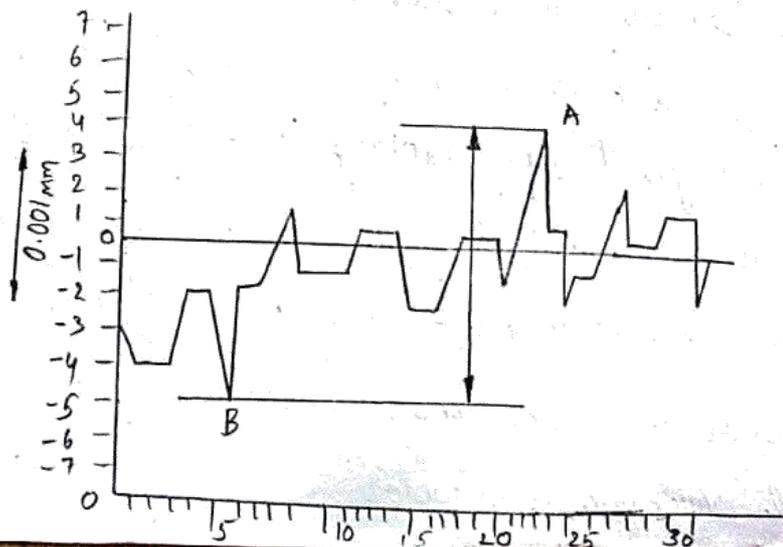
Differential screw micrometer.

Advantages of digital Measuring Instruments :-

- Measuring Element is free from errors caused by mechanical Elements such as screws, gears etc.
- Excessive reading errors are eliminated.
- Binary coded digital (BCD) output makes the instrument Computer compatible.
- The clear readability of digital readout is advantageous for persons with impaired vision.
- More accurate measurements, the spread of measurements and the mean error are reduced to about 1/3.
- Amateurs measure as quickly and well as professionals.
- The system can be zeroed whenever desired.

Progressive Errors in Micrometers :-

The continuous use of micrometer leads to wear of threads inside it. Due to wear of threads, an error is developed and the micrometer may give inaccurate results. The trend of error is progressively away from the axis as the error builds up. This trend of error is called cumulative or progressive error.



Progressive Error curve

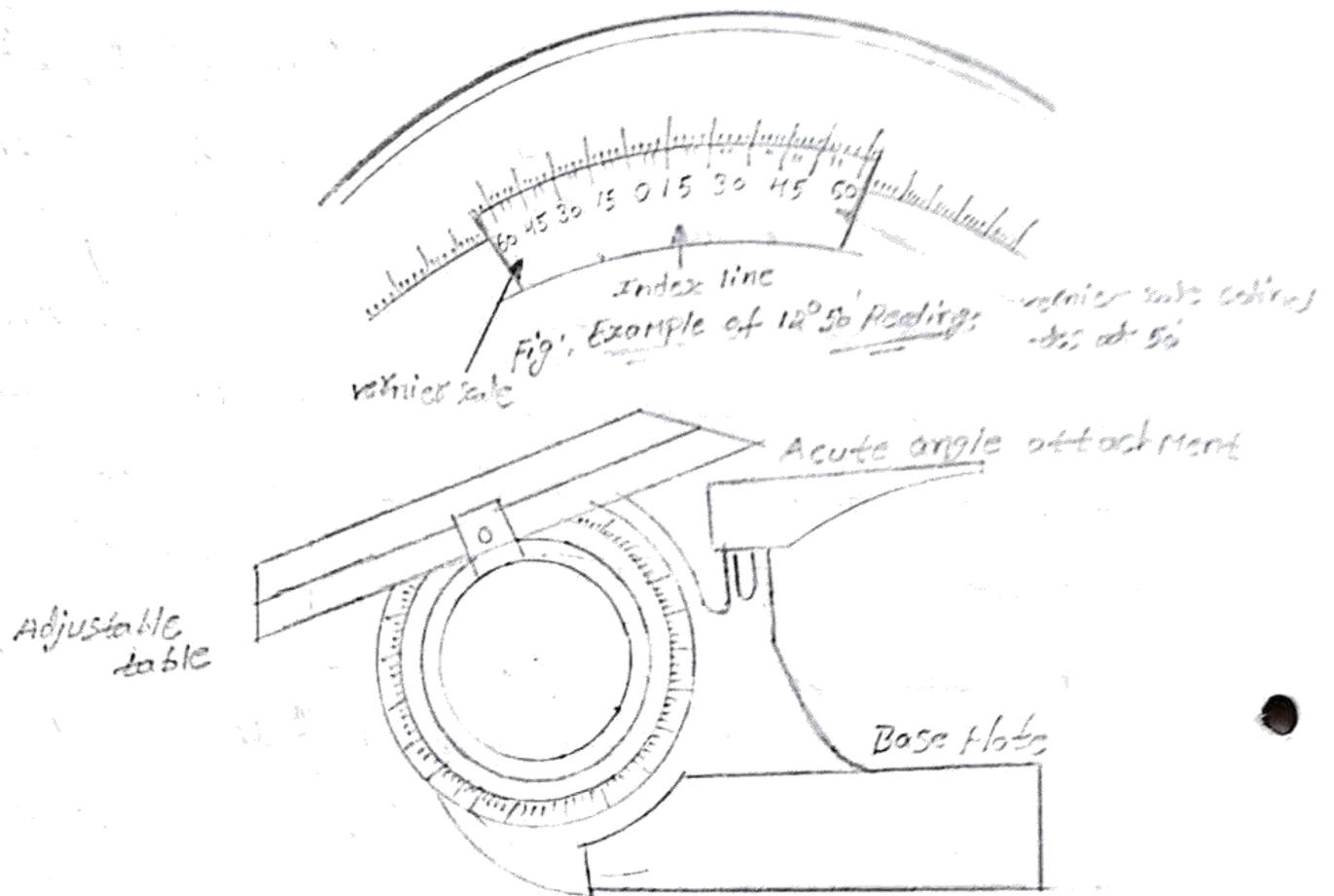
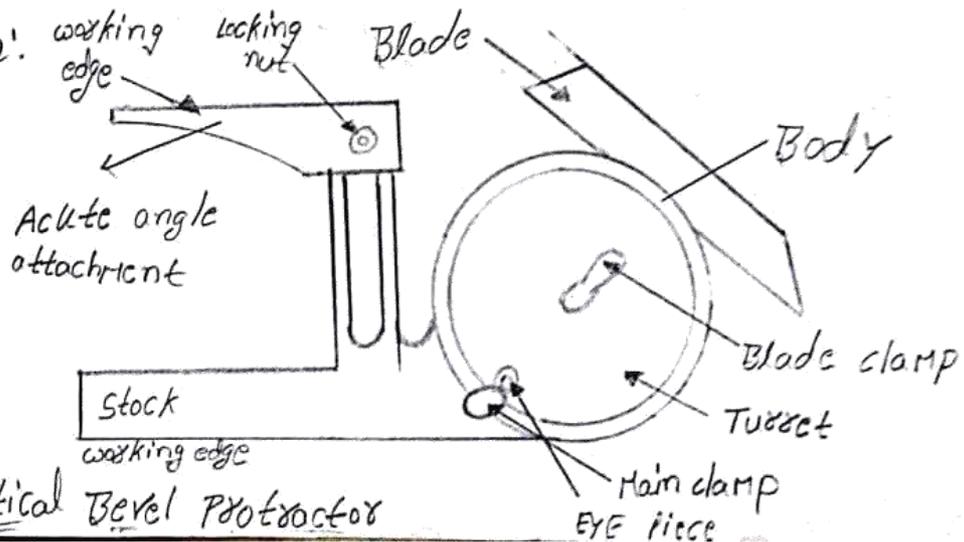


Figure (2)

(b) optical level protractor

A recent development of the vernier level protractor is optical level protractor. In this instrument, a glass circle divided at 10' intervals throughout the whole 360° is fitted inside the main body. A small microscope is fitted through which the circular graduation can be viewed. The adjustable blade is clamped to rotating member which carries this microscope. with the aid of microscope it is possible to read by estimation of about 2'.



Fig(3): Optical Level Protractor

Angle gauge blocks:-

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Angle gauge block was developed by Dr. Tomlinson in the year 1941. Angle gauge enables any angle to be set to the nearest of 3". Angle gauges are made of hardened and stabilized steel.

The measuring faces of the block are first lapped, then polished to a high degree of accuracy and flatness. These gauges are about 75 mm long, 16 mm wide and are available in 2 sets. One set comprises of 12 pieces and a square block

1°, 3°, 9°, 27° and 41° - first series.

1', 3', 9' and 27' - second series.

6", 18" and 30" - third series.

Each angle block is accurate to within 1 second. It is marked with engraved 'v' that shows the direction of the inclined angle. These gauges along with a square block can be used such that any angle between 0°-360° can be set.

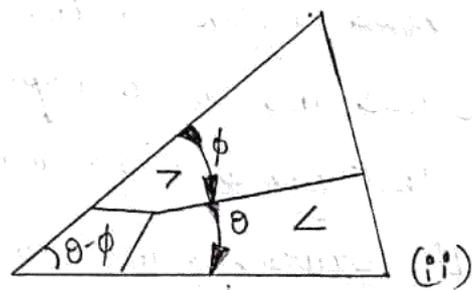
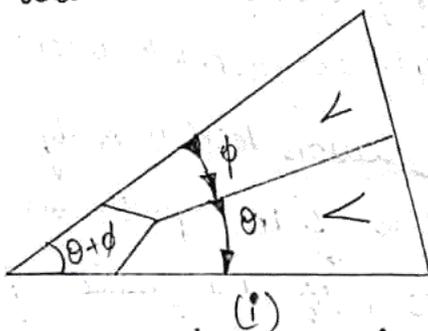


Figure (i) shows two gauges with their narrow ends together gives an angle, which is the sum of the individual gauge angles.

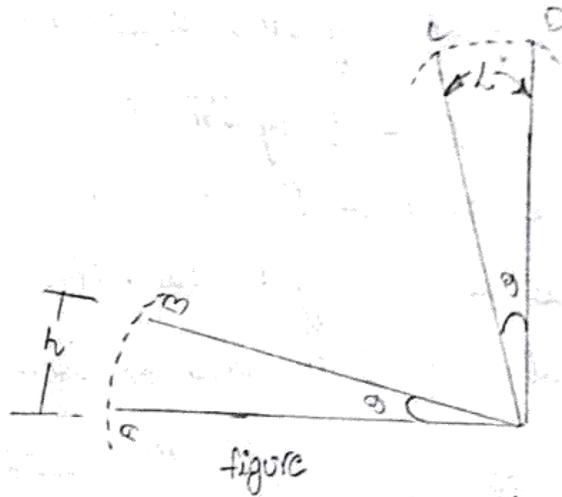
Figure (ii) shows two gauges with their narrow ends opposed gives an angle, which is the difference of the individual gauge angles.

Limitations on angle gauge block Accuracy:

- By combining angle gauge, any angle can be made up, but the block formed by the combination of these gauge is rather heavy and cannot always be applied to work conveniently.
- when angle blocks are wrong in combination, errors are quite easily compounded.
- whenever angle to be measured exceeds 90° , the use of precision square is necessary.
- An angle blocks the necessity use a primary standards.
- The absolute verification of angle blocks generally depends on some other primary standards.

Principle and measurement of Spirit Level:

The spirit level comprises a sealed glass tube which is mounted on the base, a scale engraved on the top of this glass tube and a liquid filled in the tube. The inner surface of the tube is ground to a convex barrel shape that has a larger radius. The precision level is solely dependent upon the accuracy of this radius of the tube. If the spirit level is placed on a horizontal surface, then the bubble rests at the centre of the scale whenever the level is tilted through some small angle, the bubble moves relative to the tube. Fig explains two positions of the base of the level i.e., OA and OB and corresponding positions of the bubble C and D respectively.



Consider

θ = Small angle through which the base is tilted.

L = Distance travelled by the bubble.

h = Difference in heights between the ends of the base.

L = Base length

R = Radius of curvature of the tube

$$\text{Then, } L = R\theta \quad \text{---(1)}$$

$$\text{also } h = L\theta \Rightarrow \theta = h/L \quad \text{---(2)}$$

from Equations (1) and (2) we get

$$L = h \frac{R}{L}$$

Thus, sensitivity of spirit level depends upon the length of bubble internal radius of the tube and the radius of curvature.

Accuracy of the graduations on a spirit level:

By making "1 Div = 0.005 mm in 100mm" on a precision level means that if the level were placed on a 100mm long straight edge and if one end of the straight edge was raised by (0.005mm), then the bubble would move on division.

The accuracy of spirit level depends upon the setting of tube relative to the base. In all the higher sensitivity levels, the tube is mounted kinematically in the body, one end of the tube resting on a

Angle Gauges

(40)

As slip gauges are built up to give a linear dimension, the angle gauges can be built up to give a required angle. Angle gauges are made of hardened steel and seasoned carefully to ensure permanence of dimension. Accuracy, and the measuring faces are lapped and polished to a high degree of accuracy and flatness like slip gauges. These gauges are about 3 inch (76.2 mm) long, 5/8 inch (15.87 mm) wide with their faces lapped to within 0.0002 mm and angle between two ends of ± 2 seconds.

These angle gauges are available in two sets. Each set is again divided into three series: degrees, minutes and fractions of a minute (or) seconds. The first set of angle gauges consists of 12 pieces and a square block.

Degree series: $1^\circ, 3^\circ, 9^\circ, 27^\circ$ and 41°

Minute series: $1', 3', 9', 27'$

Seconds series: $3'', 6'', 18''$ and $30''$.

The second set of angle gauges consists of 13 pieces included with a square block.

Degree series: $1^\circ, 3^\circ, 9^\circ, 27^\circ$ and 41°

Minute series: $1', 3', 9', 27'$

Seconds series: $3'', 6'', 18''$ and $30''$.

These gauges are used either in combination with each other or may be subtracted from the square block and can set any angle between 0° to 360° . Each angle gauge is marked with engraved 'v' which indicates the direction of included angle. When the angles of the individual angle gauges are to be added up, then the 'v' of all the gauges should be in the same line and when any angle is to be subtracted, its engraved 'v' should be in the opposite direction.

Generally, angle gauges are used to measure any given angle and for checking angles greater than 90° , the use of square block is made. These gauges have been widely used in engineering industries for the quick measurement of angles between two surfaces. The gauges, which are manufactured to the same high standards as gauge blocks are stabilized have "wringing" characteristics, and are calibrated to a high degree of precision. The reflective properties of their lapped surfaces make them particularly suitable for use with collimating type of instruments.

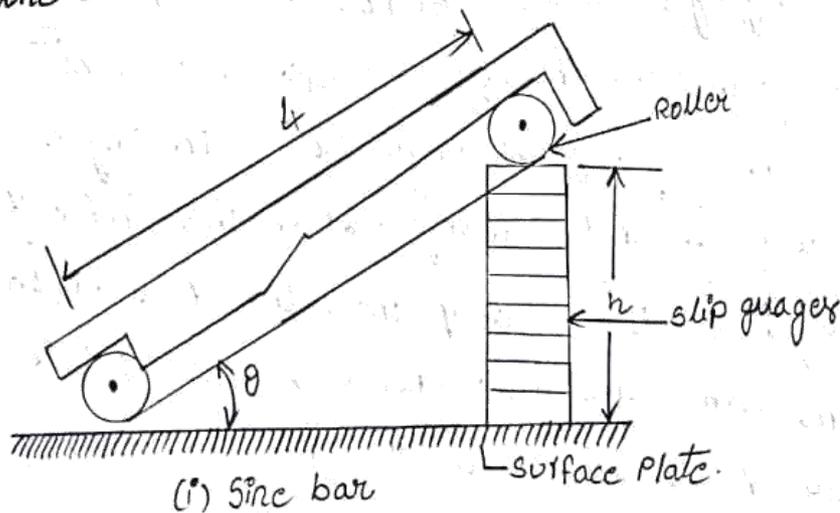
Sine bar for Measurement of Angle:

The sine bar is a tool or device that is used to measure angles with a great accuracy. This instrument is made up of high carbon, high chromium corrosion resistant steel.

Use of Sine bar:

i. Locating any work to a given angle:

Let l be the length of the sine bar and the surface plate is assumed to be flat and horizontal, since to set the given angle. As it consists of two rollers at each end of the sine bar, one roller is placed on the combination of slip gauges as shown in figure (1)



from the above figure, we can note that

h_2 = height of the slip gauge

θ = The angle at which sine is to be set

L = The distance between centre of the rollers

Then $\sin \theta = h/L$

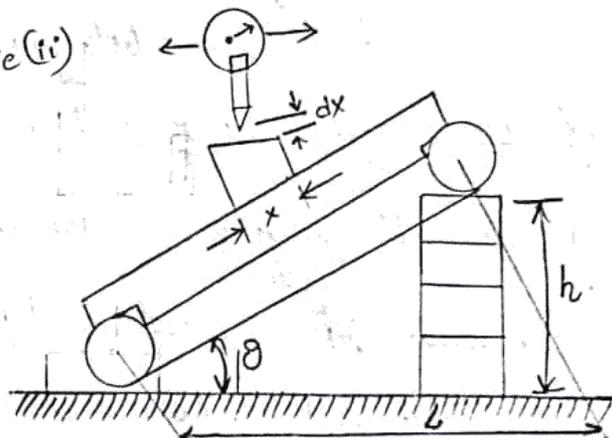
for accurate results, rollers should be placed on slip gauges of height h_1 and h_2 respectively

$$\therefore \sin \theta = \frac{h_2 - h_1}{L}$$

- (ii) Checking or Measuring unknown Angles, when the component is of small size:

In this case, at first the angle is measured with the help of a level protractor. Then, sine bar is setup at that angle in such a way that one roller is placed on the surface plate and a combination of slip gauge is placed under the second roller. The component which is to be checked is placed over the surface of sine bar with a dial gauge placed on it as shown in fig (2)

figure (ii)



Hence,

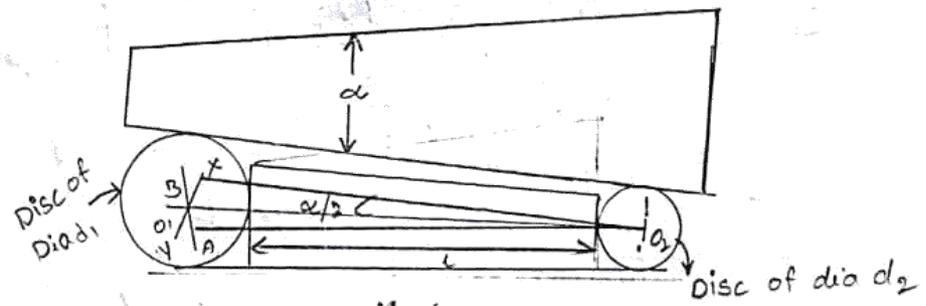
The angle of component can be calculated by the

Equation

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

1) Angle of right-tapered piece:

It can be measured by using two rollers of different size, dial indicator and slip gauge. The two rollers with slip gauge is placed on the surface plate. The rollers or disc are clamped in position against angle plate by C-clamps. The workpiece is placed on top of roller and clamped in position against angle plate by C-clamp. If the angle of the piece is all right, then the top edge will be parallel to the surface plate and dial gauge will show no variation in reading when it is traversed along surface of the work piece. figure (1) for this method.



from figure

figure.

$$\tan \theta = \frac{OA}{O_2A}$$

$$\tan \theta/2 = \frac{\frac{d_2}{2} - \frac{d_1}{2}}{1 + \frac{d_1}{2} + \frac{d_2}{2}}$$

$$\tan \theta/2 = \frac{d_2 - d_1}{2l + d_1 + d_2}$$

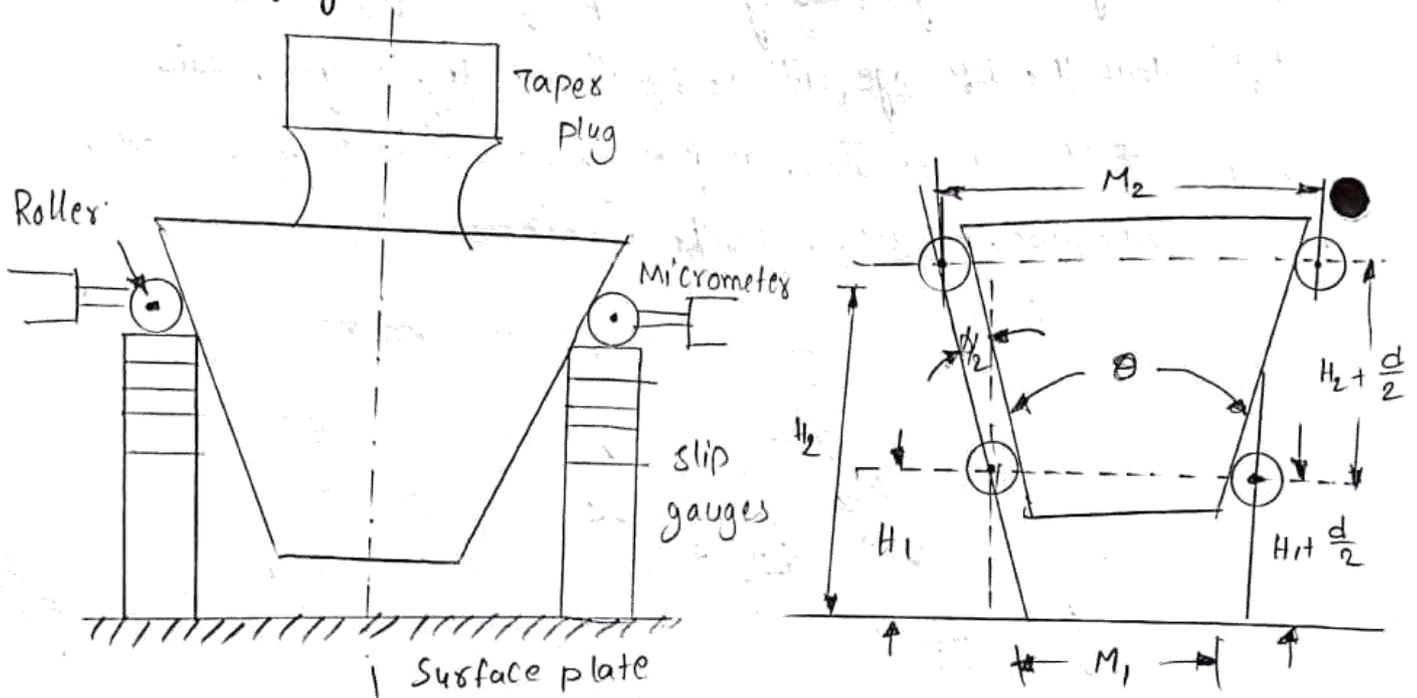
where 'l' is the length of slip gauge combination and d₁ and d₂ are the diameters of rollers.

$$\therefore l = \frac{\left[\frac{d_2 - d_1}{2} \right] - \left[\frac{d_1 + d_2}{2} \right]}{\tan \theta/2}$$

Thus, the length of slip gauges can be calculated by above formula and two discs are placed just in contact with end of slip gauge.

2, check the angle of tapers using rollers, micrometer and slip gauges.

The figure for checking the angle of taper using micrometer, rollers and slip gauges is shown in figure (2).



Taper plug is placed on a surface plate and two rollers of equal diameters are placed touching on opposite side of lower surface of the plug on the slip gauge combinations. The height of slip gauge combinations on both sides is equal and be " H_1 ". The distance between the ends of the roller is measured with a micrometer and be " M_1 ". Now the rollers are placed on slip gauge combination of height H_2 touching on opposite sides of top position of the plug. Let M_2 be the distance between the end of roller measured in this position by micrometer.

If d is the diameter of roller. Then,

$$\tan \frac{\theta}{2} = \frac{\left[\frac{M_1 - d}{2} \right] - \left[\frac{M_1 - d}{2} \right]}{\left[\frac{H_2 + d}{2} \right] - \left[\frac{H_2 + d}{2} \right]}$$

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$$\tan \frac{\theta}{2} = \frac{M_2 - M_1}{2(H_2 - H_1)}$$

where,

$\frac{\theta}{2}$ is half the taper angle of the plug.

- 3, To check the angle of a taper hole, this method requires two balls of different sizes, height gauge, depth gauge etc. This is suitable for checking angle of internal taper of taper ring gauge.

In this method a small ball of radius r_1 is inserted in the tapered hole in position and depth h_1 from the upper surface of tapered hole to the top of ball is measured with height gauge. The big ball of radius r_2 is placed in the tapered hole and distance h_2 i.e. measured with height gauge - consider figure. Let O_1 and O_2 be the centres of two balls. Draw O_1P parallel to line xy tapered hole in section and O_2P perpendicular to O_1P .

Then $O_2O_1P = \frac{\theta}{2}$ where θ is the angle of tapered hole, the figure we

get

$$\sin \frac{\theta}{2} = \frac{O_2P}{O_1O_2} = \frac{r_2 - r_1}{h_1 + h_2 + r_1 + r_2}$$

Thus, the angle of taper can be found out by using above formula.

Measurement of Included angle of an Internal Dovetail

Dovetail are intensively used in machine tool construction. The sloping side of dovetail act as guide and prevents the lifting of female mating part. For measuring include angle we require

- It is essential to have flat upper portion of sine bar and it must be parallel to the axes of contact rollers.
- The rollers must have equal size of diameter and must possess true geometric tolerance.

The accuracy of the angle which is to be set by a sine bar depends upon the errors in dimensions. The combination of slip gauge (h) required to set any particular angle "θ" is given by,

$$\sin \theta = h/l \text{ or } h = l \sin \theta$$

where, l = length of the sine bar.

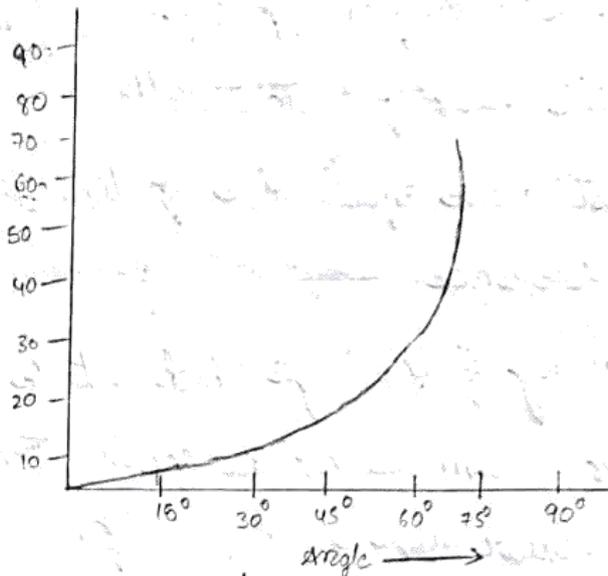
The relationship between the angular setting accuracy (dθ) and any error present in the combination of slip gauge (dh) or the spacing of the rollers (dl) can be obtained by differentiating the equation $\sin \theta = h/l$

Now, $\sin \theta = h/l$

∴ By differentiation it gives

$$\begin{aligned} \cos \theta \cdot d\theta &= \frac{dh - hdl}{l^2} \\ &= \frac{dh}{l} \times \frac{h}{l} - \frac{hdl}{l^2} \\ &= \frac{dh}{l} \sin \theta - \frac{dl}{l} \sin \theta \\ &= \sin \theta \left[\frac{dh}{h} - \frac{dl}{l} \right] \\ \therefore d\theta &= \tan \theta \left[\frac{dh}{h} - \frac{dl}{l} \right] \end{aligned}$$

From the above Equation we can say that the effect or error is spacing of rollers or combination of slip gauges is the function of the tangent of the angle "θ".



From the graph represented above, we can note that as the angle increases, the error in seconds also increases and above 45° the value is more significant because $\tan \theta$ also increases which is greater than unity. And, we can see that the effect is very small below 45° . Hence, it is preferable not to use sine bar for measuring angles more than 45° .

The angle of wedge shaped block is being checked with 200mm sine bar with slip gauges of 26.867 mm height at one end of sine bar, the dial gauge readings at each end of the work piece vary by 0.06 mm, the gauge block end being low. If the work piece is 30 mm long what should be the gauge blocks tried? Also calculate the angle of the work piece.

Given that,

Length of the sine bar = 200 mm

Height of the slip gauges = 26.867 mm.

Length of the work piece = 30 mm.

As there is a low of 0.6 mm in work piece length 30 mm and sine bar length 200 mm, therefore the required increase in gauge block length

$$\frac{0.06}{30} \times 200 = 0.4 \text{ mm}$$

Hence, the next height of the gauge block,

$$H = 26.867 + 0.4 = 27.267 \text{ mm.}$$

And the work required angle of the workpiece is,

$$\sin \theta = \frac{H}{L} = \frac{27.267}{200}$$

$$\sin \theta = 0.136$$

$$\theta = \sin^{-1}(0.136) = 7.835^\circ$$

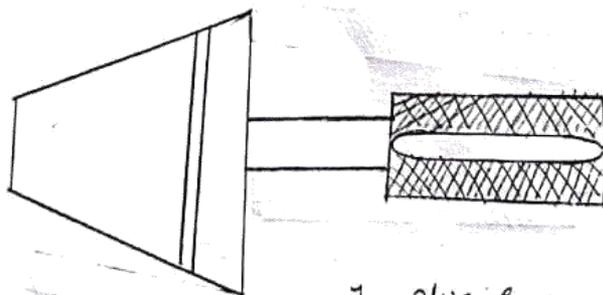
$$\therefore \theta = 7.835^\circ$$

Limit gauges for Tapers:

A taper is measured by using taper plug and ring gauges. Tapers can be both internal as well as external and thus plug and ring gauges have to be employed. These gauges are used for self-holding tapers.

plug gauge (plain):

Figure (1) shows a plug gauge which is a full form "Go" gauge representing a plain or tapered end shank. It has one ring marked on gauge plane and another ring to represent the minimum depth of the internal taper. It is used for checking internal taper of corresponding size.

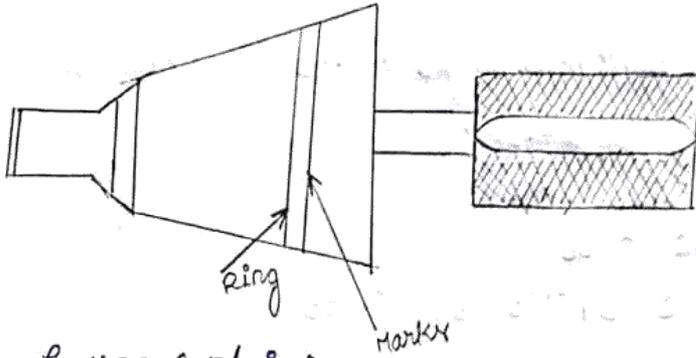


1. plug gauge (plain)

plug gauge (Tanged):

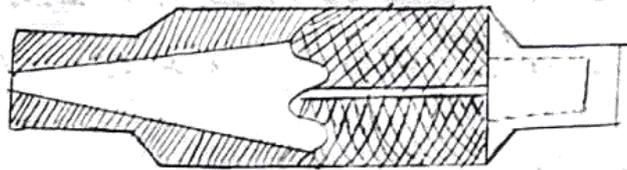
It is also a full form "Go" gauge representing a virtual size of the shank of basic dimensions having a tang employed to verify the internal taper of sockets or machine tool. It also ensures of the

of the tang slot should be able to accept the tang.



Ring gauge (plain) :-

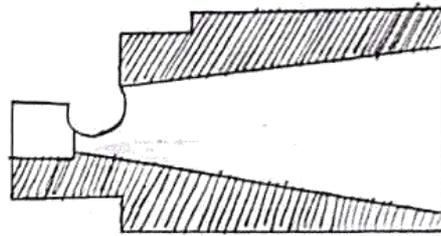
It is representing a basic size of internal taper, used for verifying the taper of tapered or plain end shank.



Ring gauge (Plain)

Ring gauge (Tanged) :-

Represents an internal taper of basic size with a limit step, which verifies length of shank and external taper.



Ring gauge (Tanged)

Essential conditions for the selection of material for gauge

- 1, Hardness to resist wear
- 2, Stability to preserve size and form.
- 3, Corrosion resistance

- (46)
4. Machinability for obtaining the required degree of accuracy
 5. Low coefficient of linear expansion to avoid temperature effect.

A high grade finish (0.10 μm CLA value) is provided which reduces the initial wear on the working surface of the gap gauge.

Various materials commonly used and the manufacturing process employed

(a) High Carbon Steel:-

Water or oil hardened cast steel (0.8 to 1% C) is the most common material used for gauges. It is relatively inexpensive. It is available in the form of gauge plate and silver steel. If there is a risk of cracking during hardening, oil hardening type is preferred. Plug gauge between 15 to 32 mm diameter are made from cast steel, smaller sizes are made from silver steel and bigger size are made from case-hardening steels which have lower carbon content and are to be hardened locally by carburizing process.

Heat Treatment for Hardening Steel:-

Steel is heated to a temperature of 730°C and is subsequently quenched in water. It is then tempered at 200°C for about 7 to 10 hours so as to reduce the brittleness and achieve stability.

(b) Mild Steel:-

Mild steel gauges are generally case hardened on the working surface. Heat treatment consists of carburizing the gauge to the necessary depth, either by heating in bath containing carbonaceous

- ② reduced due to wear and that of ring or snap gauges is increased. Hence, a wear allowance is provided to the gauges in the direction opposite to that of the wear. In case of Go plug gauges wear allowance is added, while in ring or snap gauge it is subtracted. For 'NOT GO' gauges wear allowance is not provided as they are not subjected to much wear as Go gauges, wear allowance is usually taken as 50% of work tolerance. wear allowance is applied to a normal Go gauge diameter before gauge tolerance is applied. —
- According to British standards, wear allowance is provided when the work tolerance is greater than 0.09 mm.

Classification of plain limit gauges

plain gauges which are used for checking plane (un-threaded) holes and shafts are classified in the following ways:

1. Based on their type used they are classified as,
 - i, standard gauges and
 - ii, limit gauges.
2. on the basis of their purpose, they are classified as,
 - i, workshop gauges
 - ii, inspection gauges and
 - iii, Reference or master gauges or control gauges.
3. According to the form of the tested surface, they are again classified as,
 - i, plug gauges for checking holes.
 - ii, Snap and ring gauges for checking shafts,
4. At last, based on their design, they are classified as,
 - i, single limit and double limit gauges.

(ii) single ended and double ended gauges.

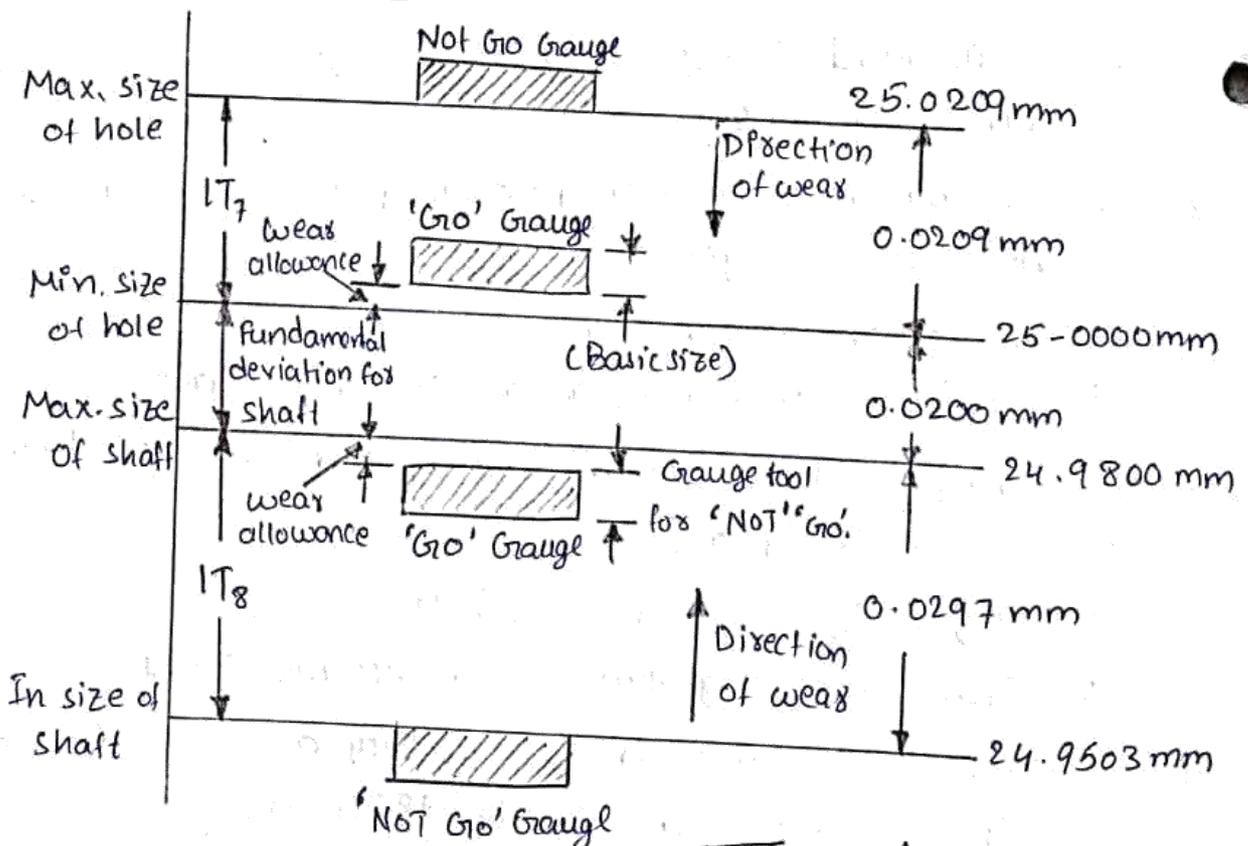
(iii) fixed and adjustable gauges.

Four types of plug gauges:

(i) Taper plug gauges:

The taper is tested by using taper plug and ring gauges. The taper plug gauge is used for checking tapered holes and taper ring gauges for checking the shaft. A plug gauge is a full form "Go" gauge respecting a plain or tapered end shank. It is used for the verification of internal taper of corresponding size. For this the gauging position represents these of a plain end shank of basic size.

It is provided with two rings marked. One is for the gauge plane and the other to indicate the minimum depth of the internal taper. The distance between the two rings marks gives the permissible deviation of the gauge plane position for the particular taper.

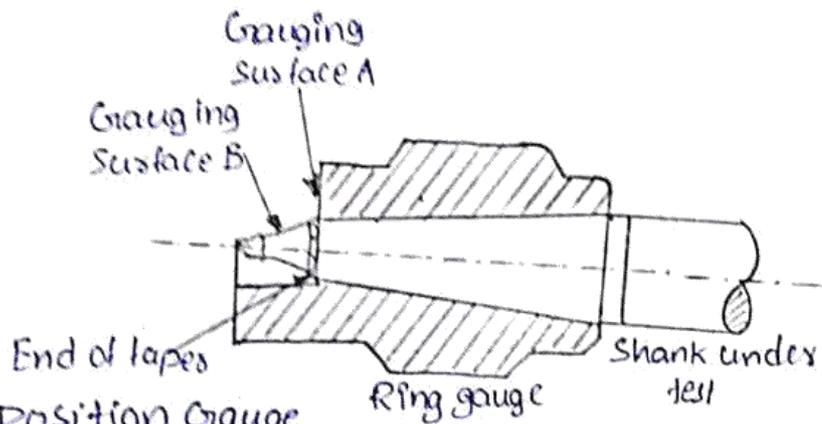


Taper plug gauge.

(ii) Taper Ring gauge:

A taper ring gauge is used for checking the shaft. This is used to check the diameter at the bigger end and the change in diameter per unit length. This gauge represents an internal taper of basic size. It is used to verify the taper of end shank.

For inspecting the external taper of a tapered or plain end shank, the ring gauge is inserted, with light pressure. At the last position, the small end of taper shank under test should lie flush or short of the face of the ring angle on the small end. This can be verified with the help of a straight edge.



(iii) Position Gauge.

For answer refer Unit - II, Q 52 (ii)

(iv) Profile Gauge:

For answer refer Unit - II, Q 62 (i).

Difference between workshop gauge and inspection gauges.

Workshop gauges	Inspection gauges.
1. Workshop gauges are used by an operator.	1. Inspection gauges are used by an inspector.
2. These gauges are used during the manufacturing process.	2. These gauges are used after completion of the manufacturing process for the purpose of final inspection of the parts.

Disadvantages of limit Gauge:

(3)

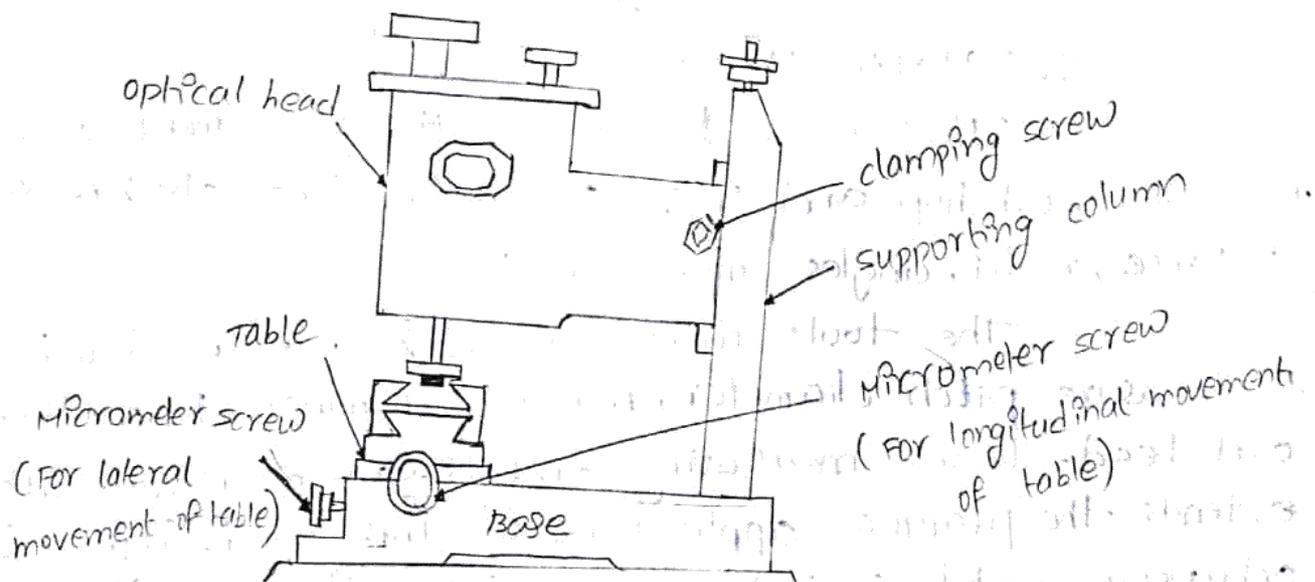
1. High cost of manufacturing [i.e., to get the accuracy]
 2. Any error in manufacturing may cause the superimposing of the error on the respective part to be inspected.
 3. For cylindrical work errors like lobing, raised surface imperfection can't be detected by Go gauges [specially in gap gauges]
 4. Errors like basselling, special-elliptical sections and other intended imperfections are not possible to detect with NOGO gauge [in case of ring gauge].
6. Hence, NOGO (ring) gauges only can check the end of shafts and nothing else.

Tools Maker's Microscope :- Unit-III Optical Measuring Instruments (59)

The tool maker's microscope is a versatile instrument that measures by optical means with no pressure being involved. It is thus a very useful instrument for making measurements on small and delicate parts.

The tool maker's microscope is designed for the following measurements i.e., measurements on part of complex form. For example, the profile of external threads as well as for tools, templates and gauges, measuring centre to centre distance of hole in any plane and other wide variety of linear measurement and accurate angular measurements.

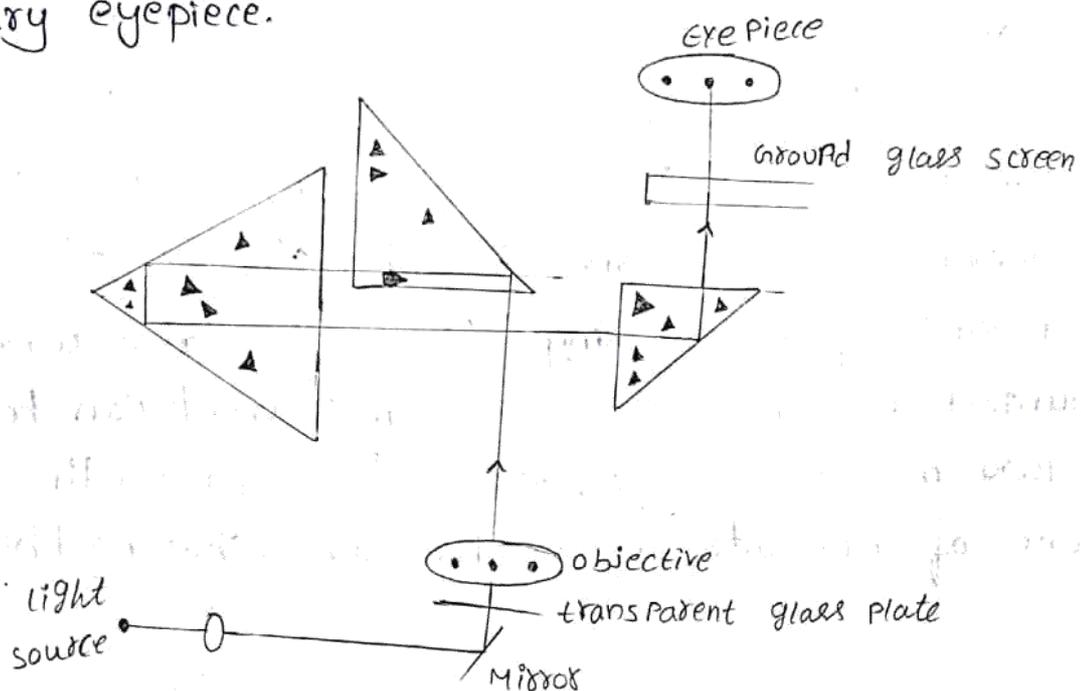
A tool maker's microscope is as shown in below figure. The optical head can be moved up (or) down the vertical column and can be clamped at any height by means of a clamping screw. The table which is mounted on the base of the instrument can be moved in two mutually perpendicular horizontal directions by means of accurate micrometer screws having thimble scale.



and Verniers

A ray of light from a light source is as shown in fig (2) is reflected by a mirror through 90° . It then passes through a transparent glass plate. A shadow image of the outline (or) contour of the workpiece passes through the objective of the optical head and is projected by a system of three prisms to a ground glass screen.

Observations are made through an eye piece. Measurements are made by means of cross-lines engraved on the ground glass screen. The screen can be rotated through 360° , the angle of rotation is read through an auxiliary eyepiece.



Uses of Tool Maker's Microscope

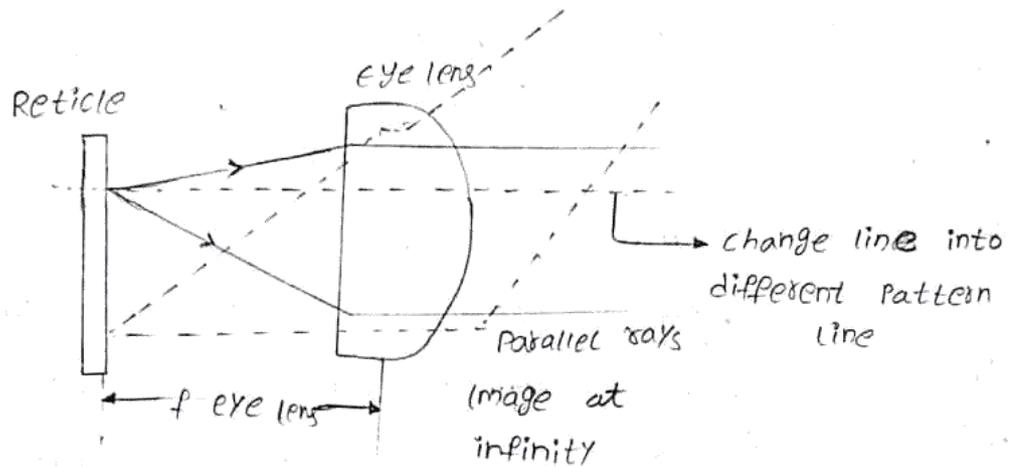
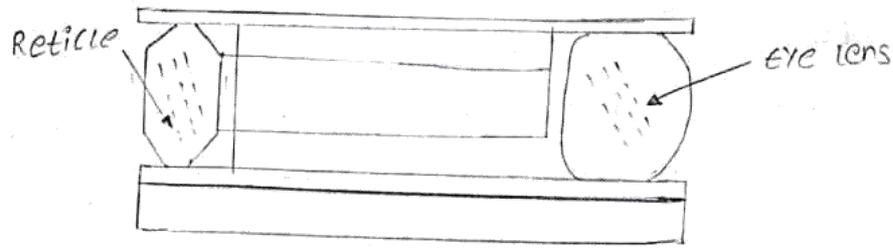
This is a highly versatile instrument and it is used in workshop and inspection areas like checking shoulder distance, radii, angles and form tools.

The tool maker's microscope may also be used to measure pitch diameter, major and minor diameters, pitch and lead. Lead-measuring and thread-measuring attachments extend the practical applications of this microscope. Some advanced models include a projection attachment that permits making contours and other precision measurements normally.

Collimator

(58)

Collimator is an optical instrument originated from the telescope. Collimators are assemblies of optical lens that receive convergent or divergent light rays as input and deliver parallel light rays as output.



Working

A reticle which is placed very close to the observer, is optically transferred to a position, infinitely distant from the observer. As there are two optical elements a reticle is placed on a ground glass window. The complete arrangement can be incorporated in a compact tube. The eye lens delivers parallel rays and it is called as a collimating lens.

The eye lens allows observations of the reticle at infinity for sighting the target. An opaque coating is applied inside the ground glass window, excluding an uncoated vertical line or centre cross through which diffused light can enter and viewed through the eye lens as a cross or vertical line.

Light. This cross or vertical line of light is called as a reticle. For infinity adjustments, the cross or vertical line of light is placed in the principle focal plane of the eye lens.

When Collimator Used as the Sighting device for a weapon, the amount of collimator levelling mechanism is employed with and Scales which allows the weapon to be situated at a particular location with relation to the line of sight developed by the collimator

Advantages:-

Light Standard defines length in terms of a standard

The advantages of light standards of wavelength are,

1. They are constant
2. They are reproducible anywhere in the world.
3. They do not depend on reference to some particular and possibly vulnerable metal piece.

Their advantages are a major criteria for any standard. It became possible, since, at a constant temperature and pressure each pure color of light from a vaporization element has a specific and constant wavelength

Advantages of Linear Measurement using optical instruments:-

The light beam has the following advantages,

1. Straightness
2. Weightlessness
3. No physical contact with the measurement (as in mechanical type).
4. Accuracy obtained through optical instrument is more, when compared with other measuring instruments.

5. As there is no physical contact between the optical instruments and the work is being measured, therefore no chance of spoilage of the work or the optical instrument.

6. Easy installation for inspection

7. Compact in size and the optical instruments are portable.

Limitations of using Optical Instruments

1. A point source can never give a point image due to diffraction of light. It instead gives an image in the form of a circular disc of an angular radius equal to λ/d .

where,

λ = Wavelength of light and

d = Diameter of the telescope or some other optical instrument.

2. Diffraction is the basic limitation on the resolving power of optical instruments like, microscopes and telescopes.

3. The lens of optical flat, it is difficult to control its way and there by orient the fringes to the best advantages.

4. The lens of optical instruments may fail due to chromatic aberration, spherical aberration and f -number.

In optical flat, the fringe pattern is not viewed from above directly, resulting obliquity which leads to errors in viewing and distortion.

Optical Projectors

The optical comparators which make use of the enlarged image principle are commonly known optical projectors. It is a versatile instrument widely used in many phases of Quality Control and production and has become almost a necessity in the well-equipped tool room.

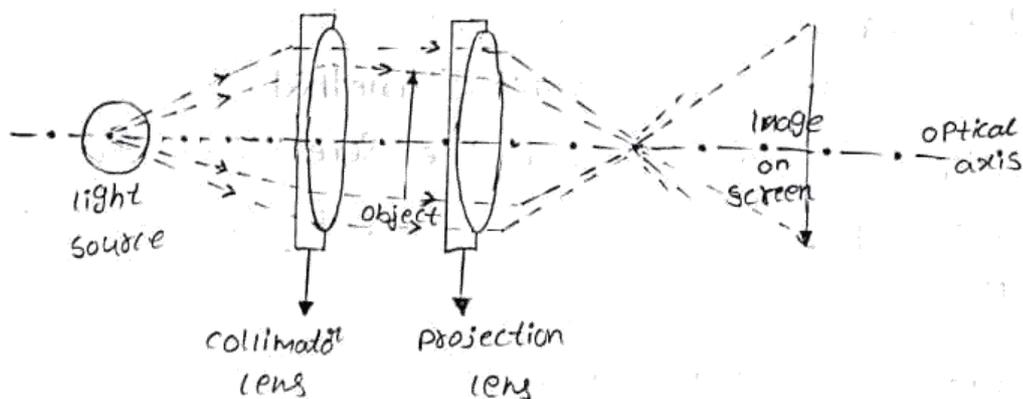
The various types of Optical projectors are as follows;

1. Contour projectors
2. Micro projectors etc.

All optical projectors, as defined, are fundamentally alike. They all display magnified image on an appropriate viewing screen, as an aid to more precise determination of dimension, form and occasionally physical characteristics of sample parts.

For precision measurements, the optical system must project images which are clear, sharp and dimensionally accurate. The mechanical design and function of the projector must also be compatible with the precision of the optical system.

Therefore, the following figure shows the basic working principle of optical system arrangement of all projectors. There are numerous arrangements of this simple system which sometimes give an air of refinement and fundamental difference to certain types of projector, but the method of optical image formation is always the same.



They are four essential elements in a projection system. They are source of light, collimating or condensing lens, projection lens and screen. The illumination required practically for all engineering projectors is a parallel beam, and

Carries a follower, which is projected by the light beam as it moves. This follower may be of three types.

- a) Probe
- b) Dot
- c) Reticule.

The probe and dot followers are used when the size of the part is less than view field of the projector at the given magnification. The reticule gauge follower is more versatile and is not restricted by part size (or) magnification.

Essential elements of the optical system

The optical projector is a versatile instrument widely used in many phases of Quality Control and production and has become almost a necessity in the well-equipped tool room. It has made possible the effective measurement of great numbers of components. Because of size, material composition, or dimensional characteristics, poses serious difficulties to other measurement methods.

The term "optical projector" here is used as a generic term to describe what have been variously called contour projectors, optical comparators, shadow graphs, lanterns, micro projectors, etc. No generally accepted nomenclature exists for this basic type of measuring equipment.

Optical projectors possess a special capability, that it is able to display a two-dimensional projection of a part rather than a single linear dimension as with most other gauging devices.

Industrial use of optical projectors involves three basic elements. They are,

1. The projector itself
2. A screen layout or chart-gauge for the comparison or

Important uses of Optical Projectors

(62)

The two basic applications or uses of Optical projectors. Are as follows,

Firstly the use of a projector for So-called tool room applications and single-piece inspection. Such a projector requires precision in the staging table mechanism and in the measuring devices associated with it. Since measurements are made with reference to a cross line on the center of the projector screen, just as in a tool maker's microscope, there is no prime requirement for a completely accurate image over the entire screen. A clear well defined image will suffice.

Thus, for tool room applications prime emphasis is placed on mechanical measuring, while for comparison application prime emphasis is placed on the accuracy of the optical system.

Chart gauges in Optical projectors

Chart gauges are of high importance for the effective use of the optical projectors. Point of reference for the operator is provided by them. These are generally processed on glass or plastic. Chart gauges are of three types. They are as follows.

1. Replacement type
2. Over-Screen type
3. Overlay type

1. Replacement type

The replacement chart gauges are used as a substitute for the standard viewing screen of a projector. Therefore, it must have all the required physical characteristics like thickness, flatness, surface, texture, etc., as of the original screen.

It should be properly and correctly positioned, the lines marked on the ground surface should face the operator.

5. A viewing Screen to receive the projected image.
6. Measuring devices were required

Aberrations

The Quality, Contrast and accuracy of an image produced by an optical projector are influenced by the aberrations in the optical system. These aberrations in optical elements make the light rays passing through them to deviate from the desired path, thereby reducing the image quality, contrast and accuracy.

The most common aberrations found in an optical projector are as follows.

(a) Distortion

It results due to non-uniform magnification from centre to edge of the screen

(b) Field Curvature

It is the out of focus from centre to edge due to spherical shapes of the screen.

(c) Chromatic Aberration

It is caused due to the dispersion of white light by optical system and inability to focus all the colours simultaneously in the plane of the screen.

(d) Lateral Color

It is caused by unequal magnification of blue and red colour in the image. Distinct blue or red fringes appear at the edges of images

(e) The image contrast is also influenced by viewing screen mirrors and mechanical mounting of the optical element to reduce flare and stray light.

The aberrations can be overcome by suitably selecting the light source, distance at which the lens is placed from the light source.

(63)
 If the path difference between reflected rays is even multiple of half wavelength they will be out of phase and of dark band. If the path difference is odd multiple of half wavelength there will be in phase with each other and will reinforce each other. So brightness will be observed. Alternate dark and bright bands as shown in figure. We will get depending upon the air gap and are due to interference of light.

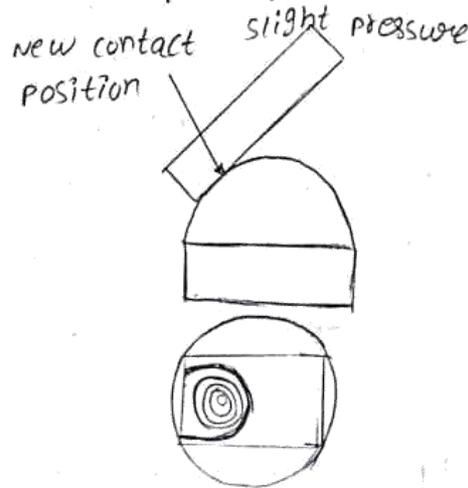
Contact is made at the central high point, resulting in a fringe pattern of concentric circles. If, now, each adjacent represents a change in elevation of the work surface relative to the optical flat of $\frac{1}{2}$, then

$$\frac{\lambda}{2} \times n = \text{Total change in elevation from point of contact of the outermost fringe}$$

Where,

λ = Wavelength of light used

n = Number of adjacent fringes observed.



Commonly, optical flats are used in normal daylight, the spectrum of which has a wavelength of approximately 0.5 mm. Thus, each fringe interval corresponds to a change in elevation of the surface of 0.25 mm.

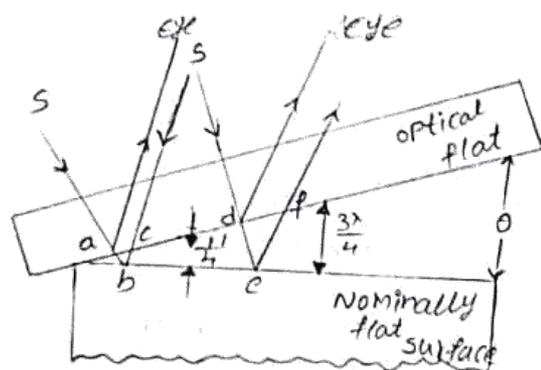
Suppose an optical flat to be laid onto a surface and the resulting fringe pattern is that

Such surfaces are normally produced by grinding followed by successive lapping operations until a high degree of flatness combined with a high surface finish is achieved. Virtually the use of light interference, using an optical flat as a reference plane

Optical flats are used to check the flatness of work pieces, gauges blocks, micrometer anvils etc. They are cylindrical pieces, from 25 by 88 mm to 300 by 70 mm.

These are made of a clear material, such as fused quartz and have two faces perfectly parallel to each other which are accurate within a few millionths of a centimeter. Some optical flats have both the parallel faces ground and lapped, other are truly only on one side.

The principle of an optical flat is illustrated in figure (1). The optical flat is placed over the work piece to be checked so that a thin work piece intervenes resting on a flat surface plate. Light is reflected along AB through the flat at B, a part of this light is reflected from the bottom face of the flat along BC and it leaves the flat at C.

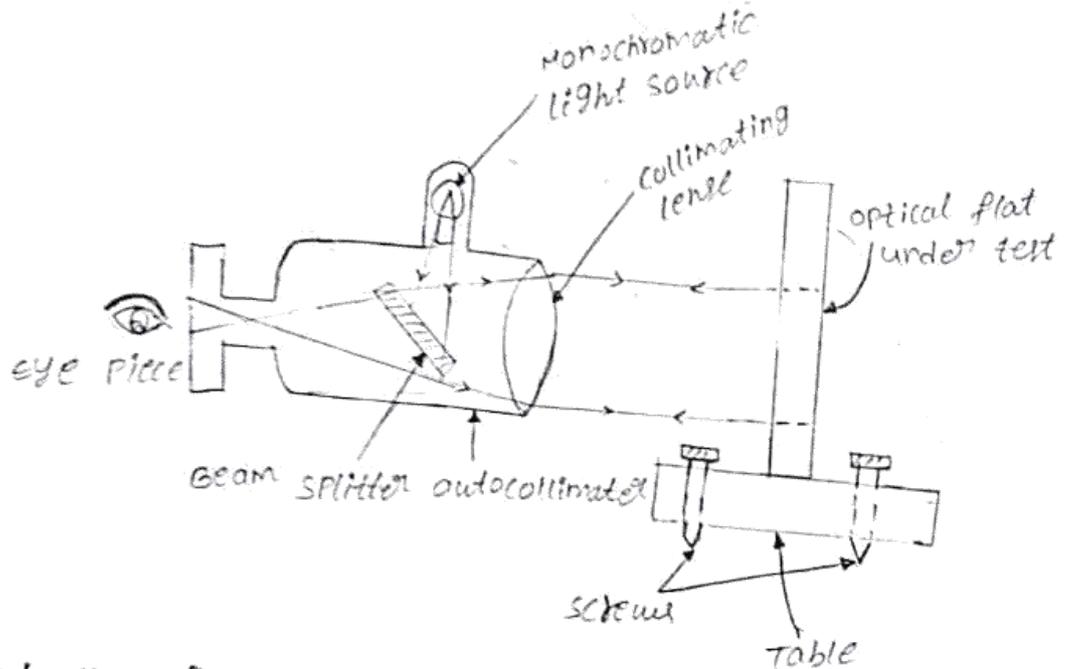


The second part of light travels an extra distance of $(BD + DC)$ than the first part of light. Also, it is given out of phase by π radians, which is reflecting from the work surface at D when light travelling in air along BD is reflected at the work surface, which is optically more dense than air, there

There is a change in phase π radius.)

Parallelism Test by Using Optical flats

To test the parallelism of working surfaces of type B optical flats, Fizeau interferometer method is used. The arrangement of Fizeau interferometer method is modified and shown in the figure.



Initially, the monochromatic light source is focussed onto the passed provide in the eye-piece, where it gets partially reflected by a beam splitter. The reflected light then strikes to the collimating lens and it gets collimated, and deliver it to the optical flat which is being under test.

The optical parallelism of two flat surfaces is given by,

$$\frac{\delta}{2} \times \frac{1}{\mu} \text{ (microns)}$$

where $\frac{\delta}{2}$ - Different between the thickness of Flat

μ - Refractive index of material

λ - wavelength of light.

flatness very accurately.

(66)

Advantages of Interferometers Over Optical Flats

1. The use of interferometers is faster and easier than that of optical flats.
2. With the use of interferometers high accuracies can be obtained.
3. Interferometers includes the refined arrangements which overcomes the disadvantages of optical flats.
4. With the use of interferometers, controlling of the lay of optical flat can be done.
5. Orientation of the fringes can be accomplished to the maximum advantages.

Interferometer

It is an optical instrument used for measuring flatness and determining the length of slip gauges by a suitable wave-length of light. It has a beam divider which detects the flatness very accurately.

Types of Interferometers

1. Michaleson interferometer
2. Multiple beam interferometer
3. Laser interferometer
4. Fabry - perot interferometer
5. fringe counting interferometer
6. NPL flatness interferometer
7. pitter NPL gauge interferometer
8. Zeiss gauge block interferometer.

Working principle of Michaleson Interferometer.

This is the oldest type of interferometer, which has subsequently, been modified in several respects and lot of

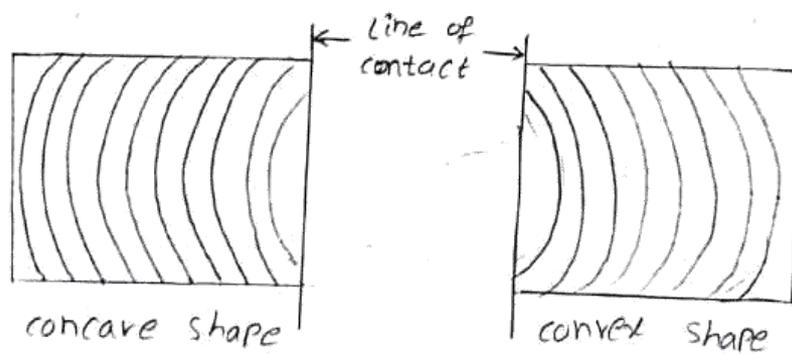
Whether the given surface is flat or curved.

The surface to be tested is placed with an optical flat, a monochromatic light is illuminated on the surface therefore, interference fringes are observed. The interference fringes are alternate bands and are formed by a thin layer of air gap between the bottom surface of an optical flat and top surface of test piece.

If the surface of test piece is not flat, then the fringe pattern of alternate bands are curve shaped and circular bands are observed at the point of contact with a central bright spot.

ii) whether the curved surface is convex or concave.

To find whether the surface is convex or concave shape, the surface of test piece is pressed with the finger at the edge tip. Thus, circular bands are disturbed and fringes gets closed, therefore the surface is convex shape.

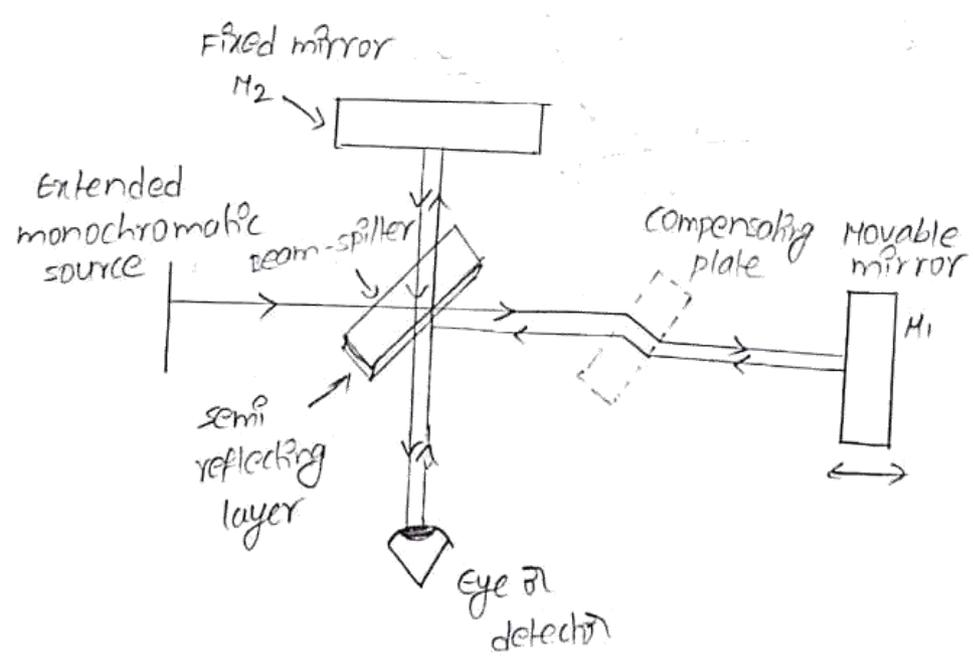


Interferometry - Interference of light - Michelson's Interferometer, NPL flatness Interferometer and NPL Gauge Interferometer.

It is an optical instrument used for measuring flatness and determining the length of slip gauges by a suitable wave length light. It has a beam divider which scatters the incoming ray into two parts. These scattered beam of rays are recombined in the same beam divider, which detects the

Sophistication introduced

Michelson interferometer utilizes monochromatic light from an extended source. The light falls on a beam splitter which splits the lights into two rays of equal intensity at right angles. One ray is transmitted to mirror M_1 , and other is reflected through beam splitter to mirror M_2 . From both these mirrors, the rays are reflected back. The mirror M_2 is fixed and the reflected ray from M_1 serves as reference beam. Every half wavelength of mirror travel produces a change in the measured optical path of one wavelength and the reflected beam from the moving mirror shifts through 360° phase change. When the reference beam reflected from the fixed mirror and the beam reflected from the moving mirror rejoin at the beam splitter, they alternately reinforce and cancel each other as the mirror moves. Thus each cycle of intensity at the eye represents $\lambda/2$ of the travel of mirror.

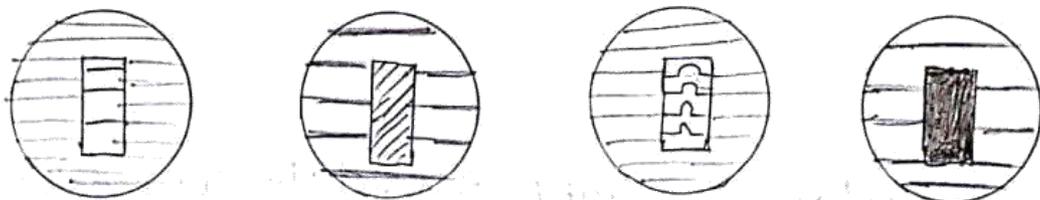
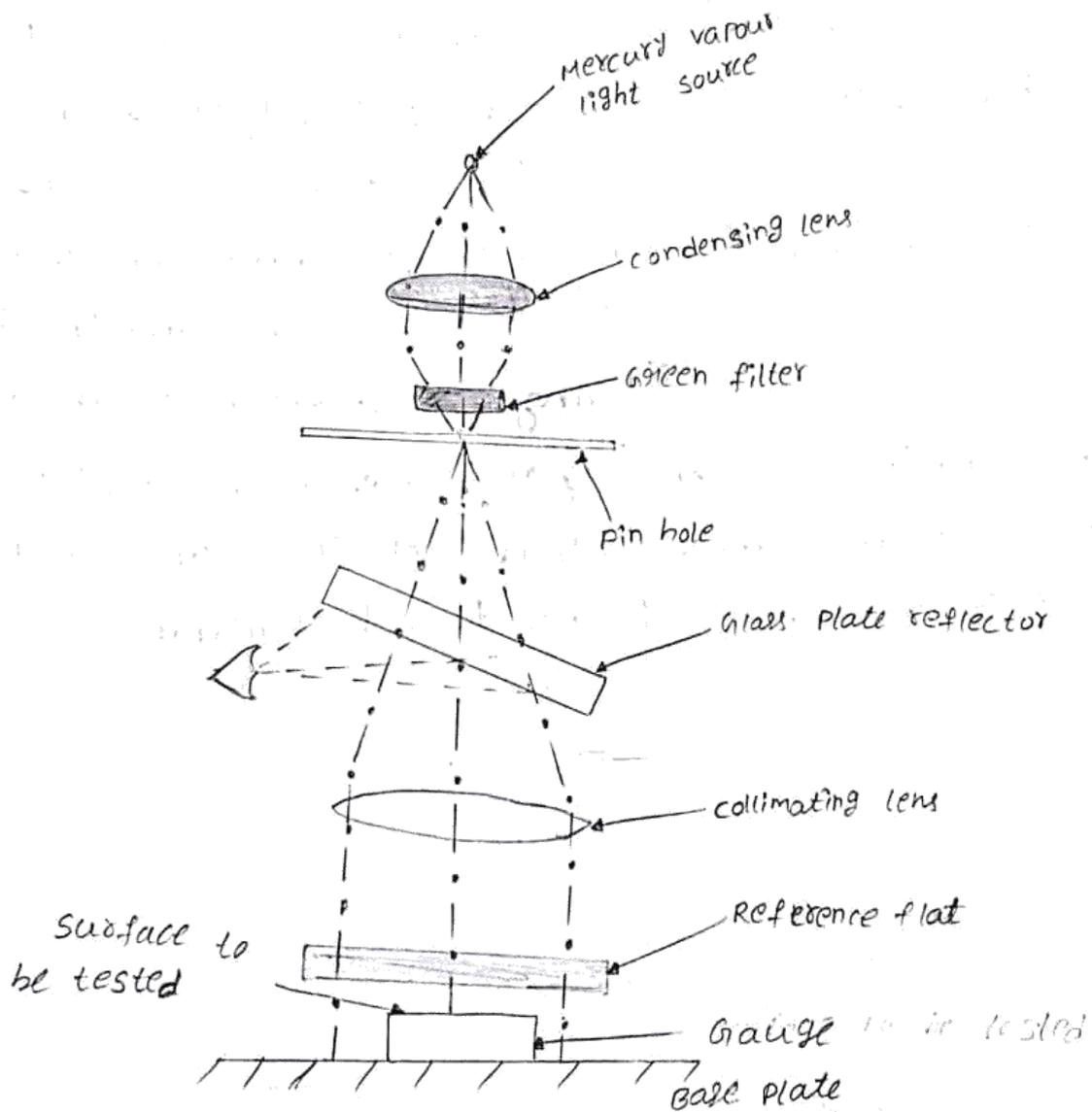


When monochromatic light is used to source, the fringes can be seen over a range of path difference that may vary

from a few to a million wavelengths, depending on the source. The wavelength are not important, but only their differences affect fringe formation.

NPL flatness interferometer.

The instrument shown in diagrammatic form in figure (a) was designed by the National Physical Laboratory and is manufactured commercially by Convery Cange and Tool Co. Ltd and higher and watts Ltd.



Optical Arrangement of Interferometer for Testing flatness of Surface

It consists essentially a mercury-vapour lamp whose radiations are passed through a green filter, thus removing all other colors and leaving a green monochromatic light whose wavelength is very close to 0.5mm. This light is focused onto a pinhole, giving an intense point source of monochromatic light, which is in the focal plane of a collimating lens and is thus projected as a parallel beam of light. This beam is directed onto the gauge to be tested through an optical flat so that interference fringes are formed across the face of the gauge, the fringes being viewed from directly above by means of a thick glass plate semi-reflector set at 45° to the optical axis.

An advantage of this instrument is that it can be also be used for testing the parallelism between gauge surfaces. Two methods are used,

- a) for gauges lesser than 25mm in length.
- b) for gauges greater than 25mm in length

If the gauge being tested is more than 25mm in length the fringe pattern on the base plate is difficult to observe but the base plate is rotary and its underside is lapped truly parallel with its working surface. Therefore, if a non parallel gauge is viewed the angle it makes with the optical will be as in figure.

Consider a gauge and 18 fringes in the second position. In figure(c), the distance between the gauge and the optical flat has increased by a distance δ_2 .

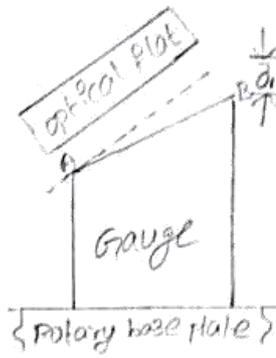


Fig (b)

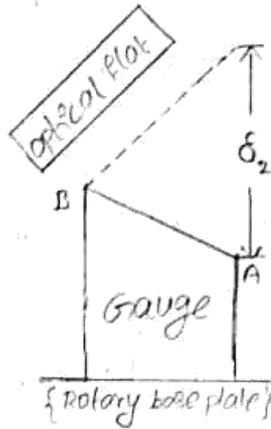


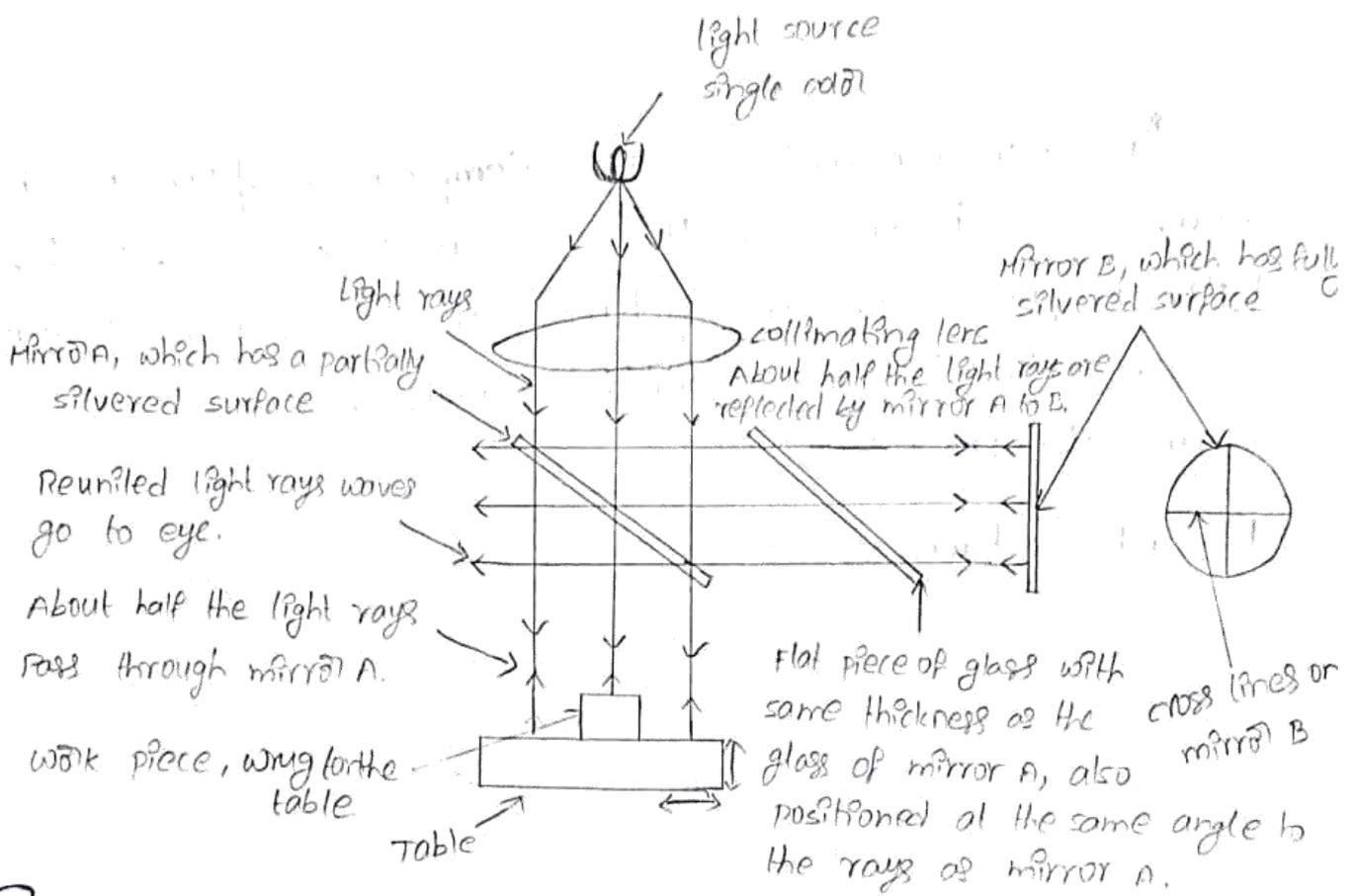
Fig (c)

Interferometers.

An interferometer is a measuring instrument, which also makes use of light-wave interference. The use of interferometers is faster and easier than that of optical flats and they are considered to be the most accurate measuring instruments available to day. Different kinds of interferometer have been designed, employing slightly different methods to accomplish the same results. A typical interferometer, illustrating the basic principles which are employed, is shown in figure (1)

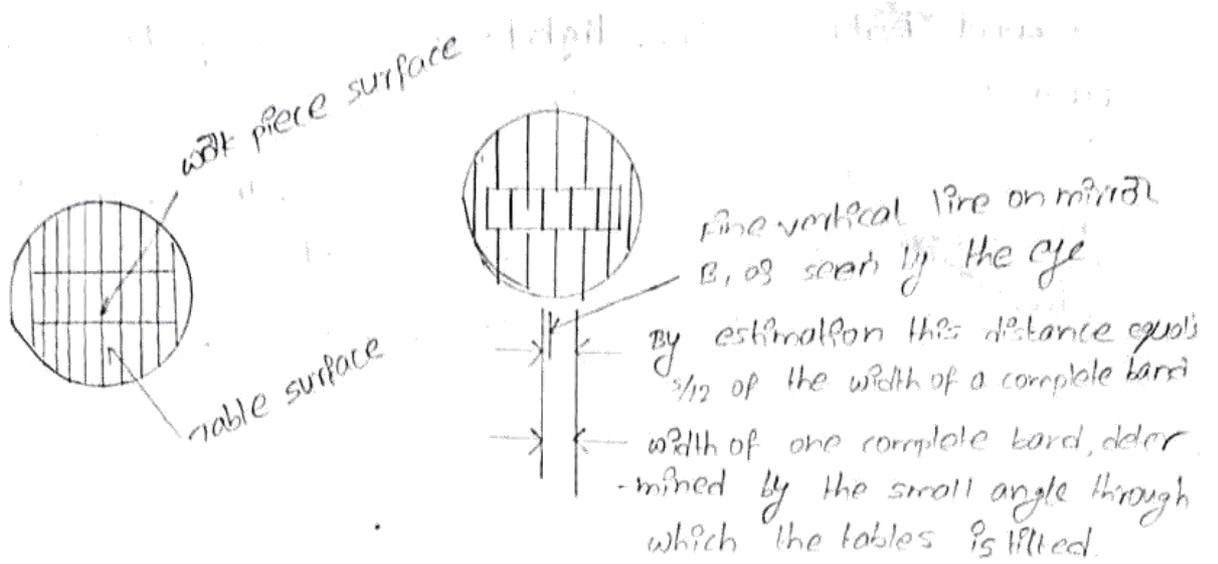
As shown in light ray from a single color light source are collimated into parallel ray by a lens. When these rays reach the partially silvered surface of mirror A,

About half of the light is reflected towards mirror B and the other passes through the silvered surface towards the work piece and table surfaces. Thus, the light rays have been divided and directed along two different paths. These divided light rays are then reflected back to mirror A.



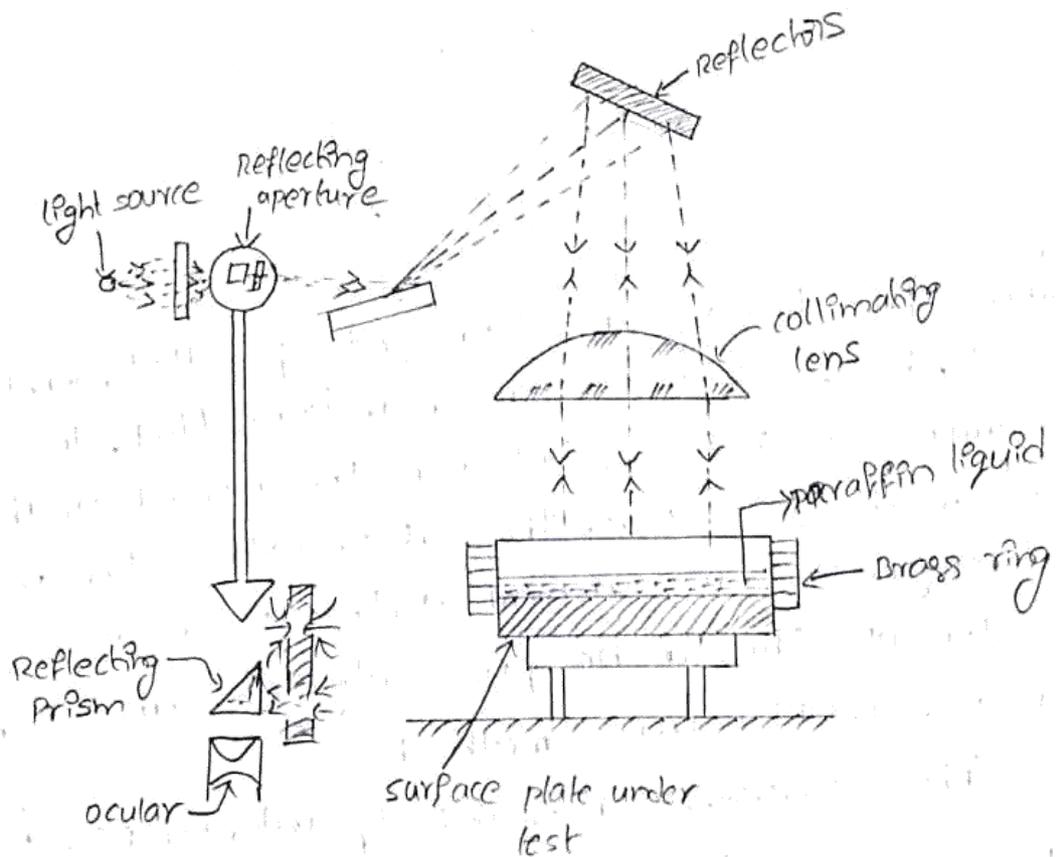
Since the bands are straight, parallel, and equally spaced, both surfaces are seen to be flat. In this example, a comparison is made between the height of the work piece and the height above the table, within the range of a half wavelength. The measurement to the nearest number of half wavelengths should be previously determined by a less precise measurement method.

This causes a series of interference bands to appear on the surfaces of the work piece as shown in fig (2)



Another example is the Comparison of the height of a worn gauge block with that of a master gauge block, where both heights are already known to be within a few millions of an inch. For this comparison, both of the gauge blocks are resting on the table.

Liquid Surface Interferometers.



(70)
The apparatus consists of a monochromatic light source, reflecting aperture, reflectors, collimating lens, brass ring, Paraffin liquid and the surface plate to be tested.

The given figure explains the testing of a surface plate. The surface plate is surrounded by a brass ring, containing paraffin liquid upto a height of 10mm. The upper surface of this liquid acts as the first reflecting surface.

If the surface plate is tilted with respect to the horizontal plane through a small angle, interference takes place between the incident rays on the surface of the paraffin liquid and those refracted and then reflected at the surface plate. The reflected light returns back through another aperture to be delivered in a reflecting prism to the ocular through which the interference fringes can be observed.

Understand by Moire fringes

The name given to the patterns whose formation is generated by overlapping of two layers of fine fabrics is known as Moire fringes. These are observed when the index grating is rotating slightly in its own plane, instead of being kept parallel to the scale grating. In this case, the intersection of the lines of two gratings are clearly visible as dark Moire fringes running at right angles to grating lines. If there is a transverse movement in the index position repeats itself after change of one grating period.

Moire fringes can be used for angular displacement by the use of radially ruled grating. Since one fringe pitch corresponds to a height change between optical flat and surface of one half-wave length.

Therefore, angles of 1mm pitch = $\frac{\delta}{2}$ radians = $\frac{1}{3932}$ radians

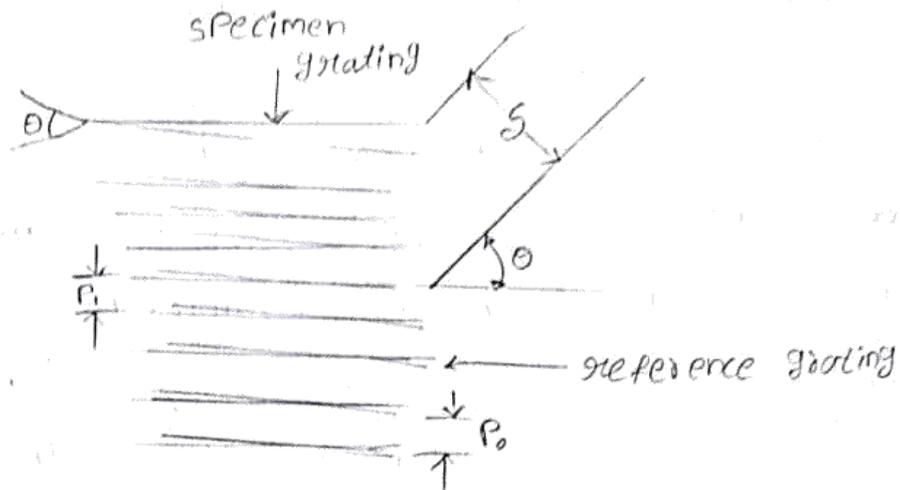


Figure:- The formation of Moiré fringes

The above figure demonstrates the formation of a Moiré fringes pattern.

Here

P_0 - The distance between the adjacent lines on the grating or specimen grating pitch

S - The distance between the adjacent Moiré fringes.

P_1 - Pitch of the Specimen grating

$$\therefore S = \frac{(P_0 \times P_1)}{[(P_0 \sin \theta)^2 + (P_0 \cos \theta - P_1)^2]^{1/2}}$$

where

θ - Angle between the two gratings.

In most practical situations gratings are aligned with θ close to 0.

$$\therefore S = \frac{P_0 P_1}{P_0 - P_1} \quad \text{or} \quad \infty$$

$$\frac{1}{s} \cdot \frac{P_0 - P_1}{P_0 P_1} = \frac{1}{P_1} - \frac{1}{P_0}$$

(21)

Here, $\frac{1}{s}$ is called Spatial frequency.

Fundamental difference between the length and flatness interferometers.

The length interferometer measures the gauges length from a specified point by first defining the wavelength. The measurement of length interferometer is regarded as the measurement of the wavelength of a spectral line passed.

- Through the gauge and fringe pattern observed in the telescope.

The flatness interferometer, measures the surface of a plate has undergone any irregularities or not. In testing flatness of a surface plate, the actual deviation from the true plane at various points is measured. The flatness interferometer detects the roughness of the surface and confirms whether the surface is flat or not by observing the interference fringes observed by using monochromatic light source, the incident rays from which may be either diffused or parallel.

The fundamental difference between the length interferometer and flatness interferometer is that a constant deviation prism is incorporated in a latter which divides the light into a large number of parallel beams. The individual parallel beam having a different and closely defined wavelength of known value.

Laser beam in interferometry

The following are the advantages of laser beam in interferometry.

geometrical quality related to the perfect plane. (22)

For testing of flatness of surface plate, the general practice is to measure the actual deviation from true planes at different points. The various methods of flatness testing are,

1. Spirit level method
2. Beam Comparator
3. Auto Collimator
4. Laser beam
5. Interference method.

The symbol for flatness is \square in drawings. Flatness symbol is shown and tolerance is mentioned as, $\square \quad 0.04$

b) Straightness

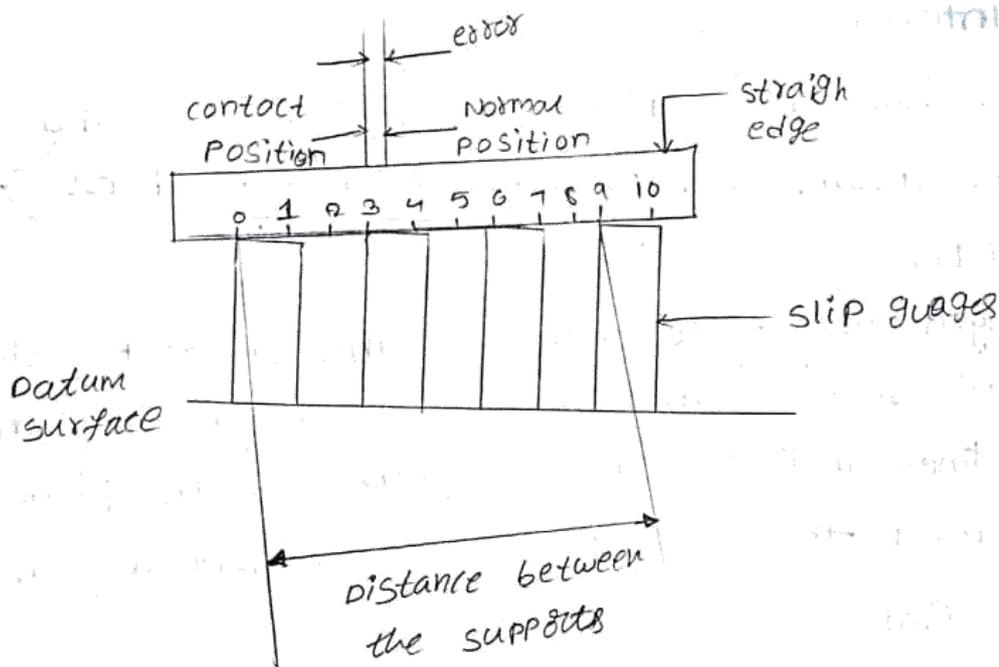
A straight line may be defined as the shortest distance b/w two points on the plane. The normal distance between the two straight lines indicates the straightness of the plane. The basic principle about the straightness measurement is given by Bryan

(c) Optical flat.

Optical flats are cylindrical in shape and the working surfaces of the optical flat is flat. Optical surfaces are of two types. i) Type A. ii) Type B. Type A optical flat has only one surface flat and type B has both are the surfaces flat. Type A optical flat is used for testing precision measuring surfaces of flats, whereas type B optical flats are used for testing measuring surface of micrometers. Optical flat gives precision and accuracy in measurement of flatness.

Flatness measurement using straight edges.

Straight edge is a measuring instrument or tool used to check the straightness and flatness of the parts. The basic principle involved for measuring straightness by a straight edge is wedge method. In this method, the straight edge is placed on the slip gauges of different lengths, with a slight inclination to the surface to be checked as shown in the figure below.



The distance between the gauges is divided into equal number of parts and are marked on the straight edge. When datum surface and straight edge are perfectly in a straight position, then the gap at each point will vary uniformly. Straight edges with a single edge are mainly used for checking straightness. For checking the straightness of an element at a cylindrical or taper surface, the straight edge is applied along the full length of the surface and is held before a bright background. The

Absence of light between the straight edge and work surface indicates the straightness of the element and vice versa. (23)

Utility of straight edge and surface plate in laboratories.

1. Straight edge is a measuring instrument or tool used to check the straightness and flatness of the parts in laboratories.
2. It is made up of steel or cast iron and widely used for testing machine tool slide ways.
3. They are heavily ribbed and bow shaped to prevent distortion.
4. Straight edges with a single edge are mainly used for checking straightness.
5. For checking the straightness of an element of a cylindrical or taper surface, the straight edge is applied along the full length of the surface and is held before a bright background.
6. For checking flatness, single edge as well as three and four-edged straight edges may be used.
7. It can be applied in different directions at different places on the surface to be tested.

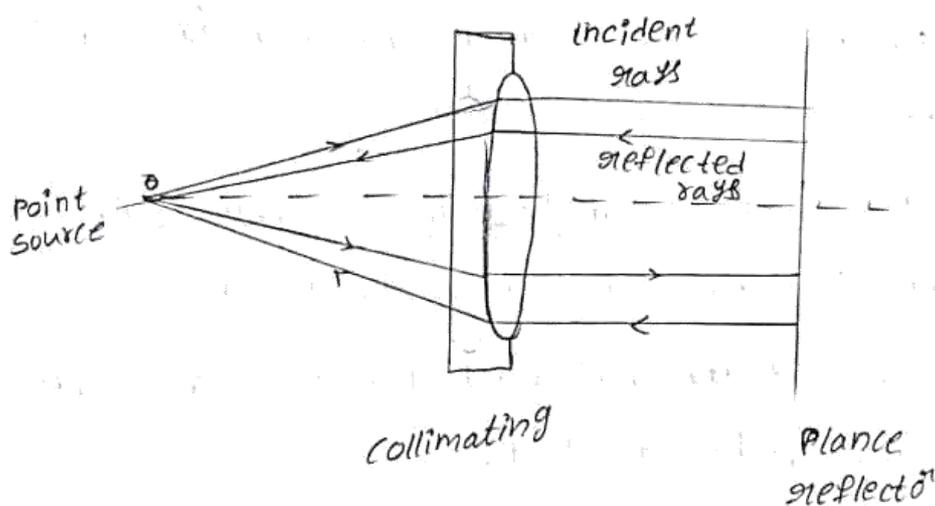
Utility of surface plate in laboratories

1. A surface plate or a plate has highly accurate flat surface.
2. It supplies a datum plane from which scribing, measuring or comparing vertical distances can be done.

3. For this, the distance plane is used as reference surface for mounting comparators, optimeters, sine bars, slip gauge blocks, vernier height gauges and soon
4. The plate is usually a good quality casting, heavily ribbed for rigidity and with a thick top.
5. These are massive and highly rigid in design, due to which they carry their own weight as well as the weights of heavy objects placed on them.
6. An heat treatment process is done to relieve internal stress.

Autocollimator

-Autocollimator is a type of optical instrument used to measure small angular inclinations. It is also used to check straightness, flatness and alignment of two plane surfaces or holes.



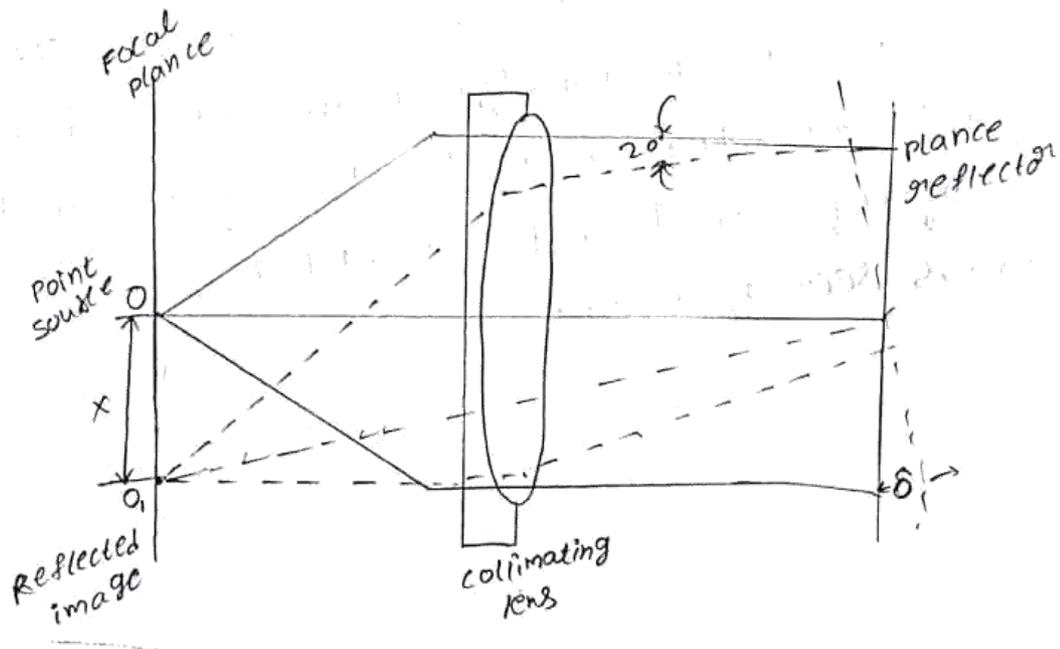
Working of principle

If a point source of light 'O' is placed at the principal focus of a collimation lens, it will be projected as a parallel beam of light. If this parallel 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 source S' as shown in the following fig(1).

Point Sources of light in focal plane of a collimating lens:

If the plane reflector is now tilted through some small angle δ , the reflected parallel beam will turn through 2δ and will be brought to a focus at point O' in the focal plane at a distance x' from O as shown in figure (2).



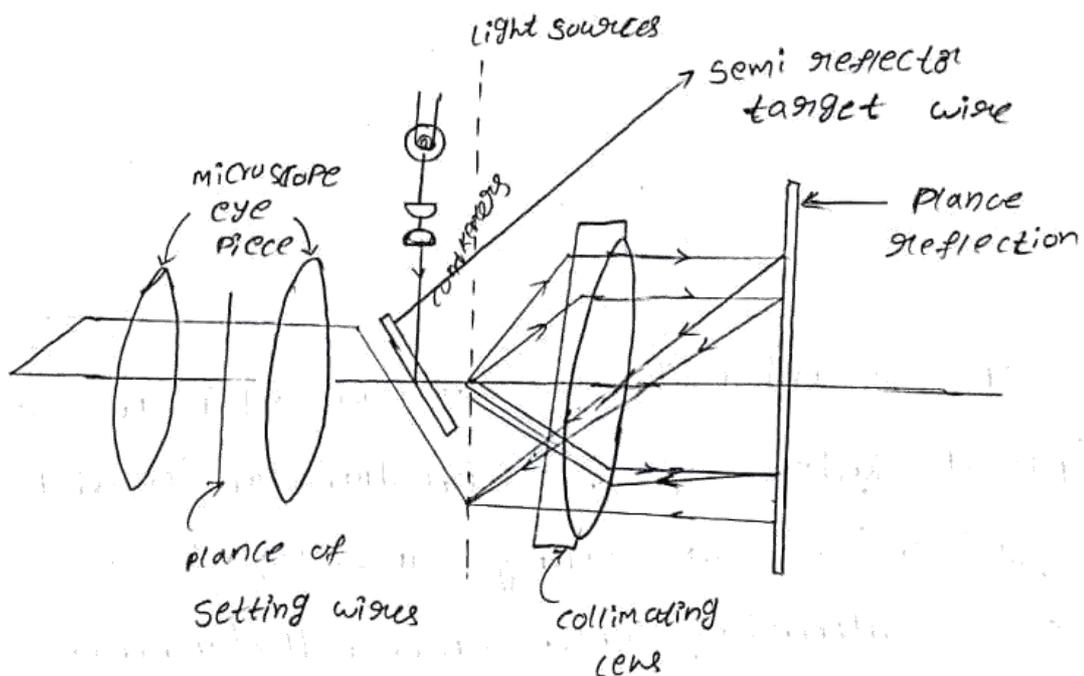
Autocollimator used for examination of plane surfaces.

Optical system of an autocollimator consists of a pair of target wires and setting wires, light sources, plane reflector, collimating lens, semi-reflector, microscope unit etc. A pair of target wires are placed at same axis on the focal plane. when collimating lens are illuminated

at the back side of target wires, an image is projected which is struck by the plane reflector. The projected image is brought to focal plane and can be viewed through microscope eye piece which is incorporated with scale and equipped with instruments. The scale can graduate 0.5 minute intervals.

In microscope unit, a pair of setting wires are placed which can be adjusted by micrometer.

The reading in micrometer is possible until the setting wires are extended on both sides of reflected images. The setting wires can move at 0.5 minutes per revolution by adjusting the micrometer drum and is divided into 60 equal parts. Thus, with the help of micrometer the value of reflector tilts 90° (i.e., right angle) can be found upto 0.5 second of arc.



Autocollimator

This instrument is used to measure small angular inclinations. It is used to check straightness, flatness and alignment as follows,

(a) Examinations of plane Surfaces

An autocollimator is commonly used for checking the plane surfaces such as beds of machine tools. For this, a test block is made. The base of the block is flat with its working surface square, flat and polished to form a reflecting surface. The test block is placed at one end of the surface to be checked with its reflecting surface normal to the collimator axis which is mounted on a rigid stand. The collimator is adjusted until the cross wire and its image coincide as seen through the eyepiece.

(b) Checking Squareness of Two Surfaces.

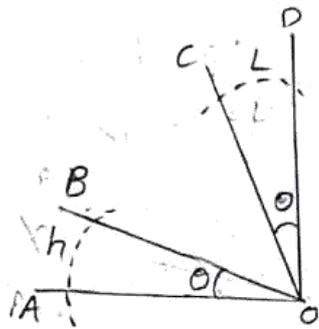
Suppose there are two machined surfaces at right angle to each other. Their squareness can be checked with the help of autocollimator to a high degree of accuracy in the same manner as explained above. The test block is first placed on the horizontal surface with its reflecting surface normal to the optical axis of the collimator and reading in the micrometer noted.

(c) Checking Alignment or Parallelism

Parallelism or alignment of two holes in a part can also be tested by the autocollimator. In this case, a test bar will be placed alternately in each hole and collimator reading is taken.

2. Spirit level

The spirit level comprises a sealed glass tube with is mounted on the base, a scale engraved on the top of this glass tube and a liquid filled in the tube. The inner surface of the tube is ground to a convex barrel shape that has a large radius. The precision level is solely dependent upon the accuracy of the radius of tube. If the spirit level is placed on a horizontal surface, then the bubble rests at the centre of the scale. Whenever the level i.e. OA and OB and corresponding positions of the bubble C and D respectively.



Consider

θ = Small angle through which the base is tilted

L = Distance travelled by the bubble.

h = Difference in heights between the ends of the base

L = Base length

R = Radius of curvature of the tube,

Then,

$$L = R\theta$$

$$\text{Also } h = L\theta \Rightarrow \theta = \frac{h}{L}$$

from equations (1) and (2) we get

$$L = \boxed{\frac{hR}{L}}$$

States the uses of

(26)

i. Uses of Tool Makers flat

- a) In the measurement of work of the highest precision, tool makers flats are used.
- b) It is used in inspecting of small components with precision gauge blocks.

ii Uses of Angle plate

- a) Angle plate is a work holding device which is used as fixture in metal working.
- b) As these plates possess excellent finishing and flatness they can be used along with granite surface plate accuracies.
- c) With the help of angle plate, work can be clamped or held in a vertical position.
- d) In workshops or inspection laboratories the cast iron angle plates are used with surface plates for the purpose of measurement.

iii Uses of V-Block.

- a) In workshop and inspection purpose V-block are used widely for checking the roundness of cylindrical workpieces.
- b) These are also used for holding the cylindrical workpiece for accurate centre marking.
- c) For supporting rectangular components at 45° to the datum surface, V-blocks are employed.

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 interchangeability 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 gauge 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.

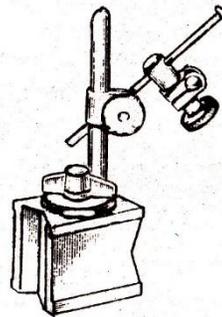
➤ **Mechanical Comparators:**

Principle of workings: A mechanical comparator employs 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 rising 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

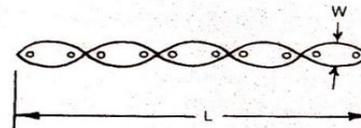
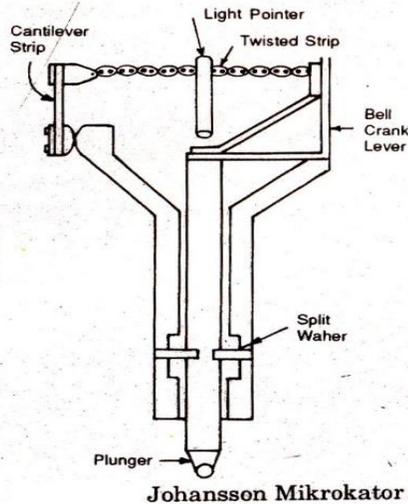
In its operation, the indicator is set to zero by the use of slip gauges representing the basic size of the part. The part to be checked is then placed below the measuring plunger of the indicator. The linear movement of the plunger is magnified by means of a gear and pinion train into a sizable rotation 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.



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 perforation 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:

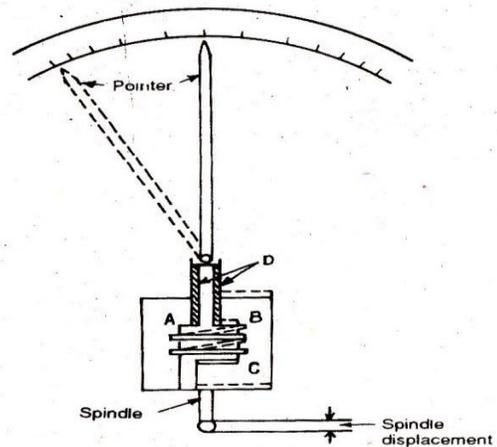
In reed type mechanical comparator, the gauging head is usually a sensitive, high quality, dial indicator. The dial indicator is mounted on a base supported by a sturdy column. Fig. 5.4 shows a read type mechanical comparator.

The reed mechanism is a frictionless 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 to swing through an arc.

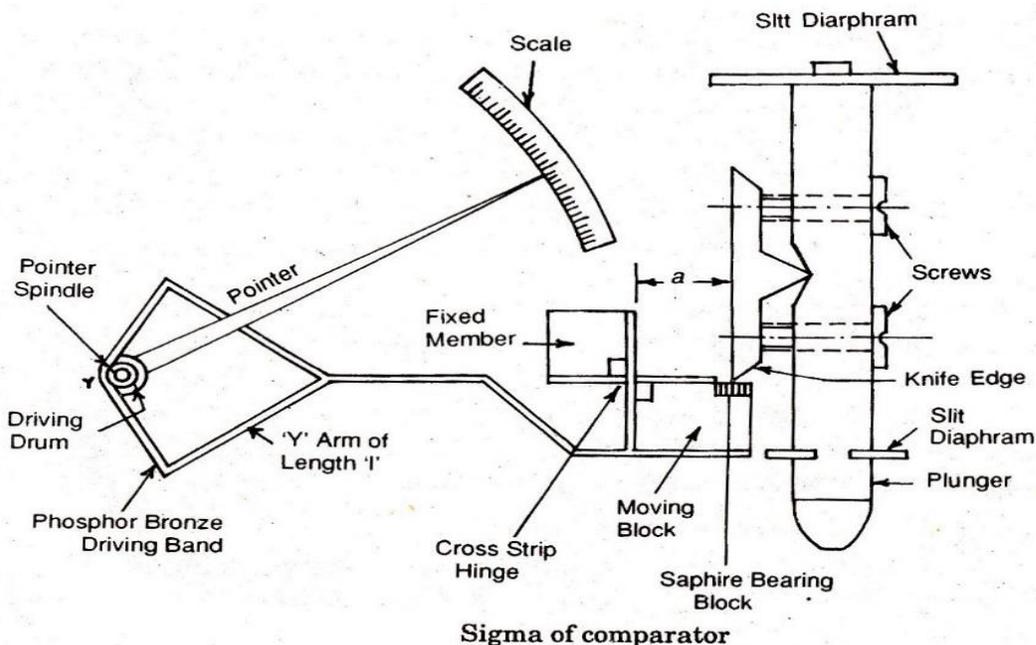
The scale may be calibrated by means of gauge block to indicate any deviation from an initial setting. The mechanical amplification is usually less than 100 but it is multiplied by the optical lens system. It is available in amplification ranging from 500 to 1000.



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

diaphragms). 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 $\times 300$ to $\times 5000$, 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

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.

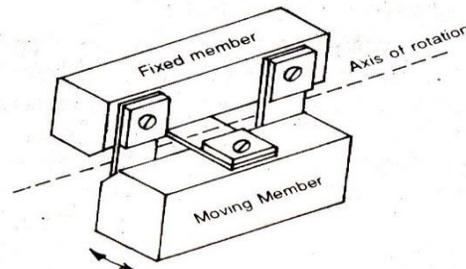


Fig. 5.6. cross strip liver used in sigma comparator.

Advantages of Mechanical Comparators:

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.

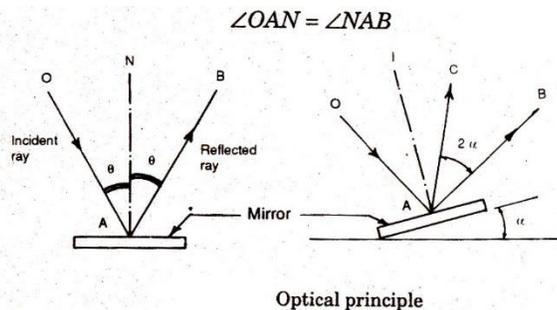
5. Portable: For ordinary workshop conditions, these instruments are very suitable and being portable can be issued from the stores.

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,



Now, if the mirror is tilted through an angle on the reflected ray of light has moved through an angle 2α . 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:

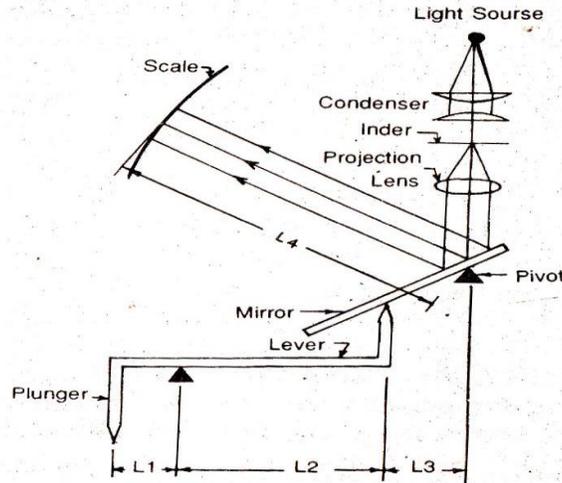


Fig. 5.8. Meeter optical comparator

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

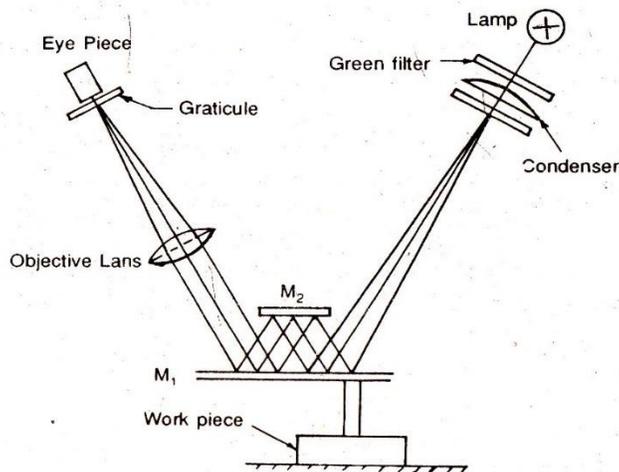
Now, if the movement of the plunger causes the mirror to tilt by an angle α , then the image will be tilted by 2α .

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 M_1 . It is then reflected to another fixed mirror M_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.

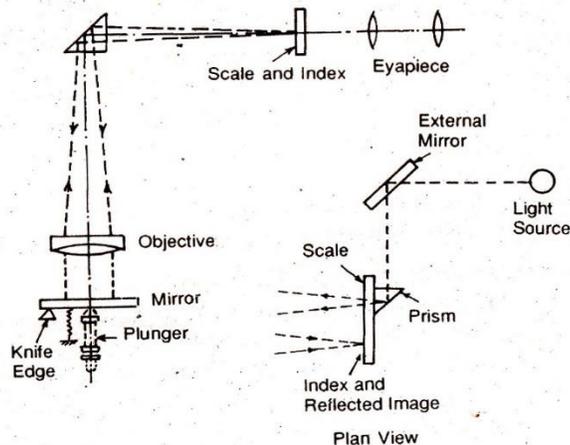
Magnification : If the distance from the plunger centre line to the first mirror pivot is x and the plunger moves a height h , then the angular movement of the mirror $\delta \theta = \frac{h}{x}$. If f be the focal length of the lens, then the movement of the scale is $2f \cdot \delta \theta$, i.e.,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

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

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

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:

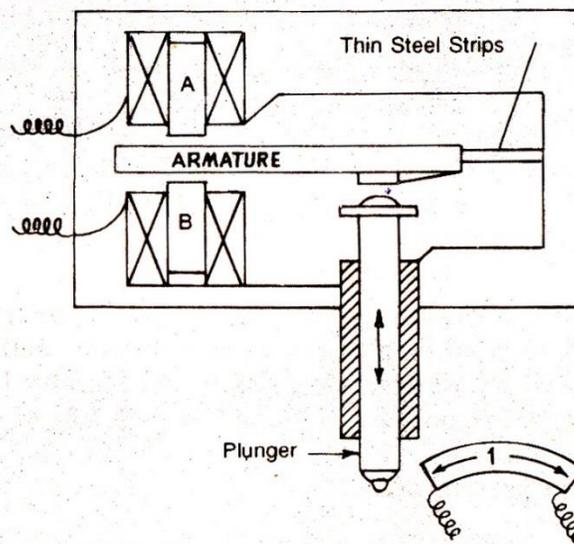
1. High accuracy: These comparators have very few moving parts and hence gives higher accuracy.
2. No parallax Error: The scale can be made past a datum line and thus have high range and no parallax error.
3. High magnification: Hence suitable for precision measurements.
4. Optical lever is weightless.
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.

➤ Electrical Comparators:

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 Gauging Heads

The purpose of the visual gauging 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.

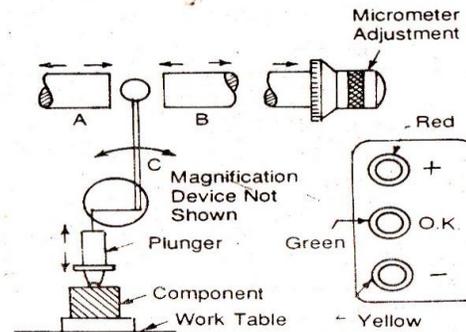


Fig. 5.12. Visual gauging head

Advantages of electrical and electronic Comparators:

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.

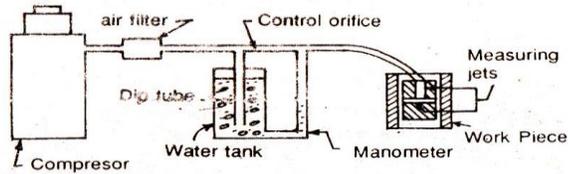


Fig. 5.15. Solex Pneumatic Gauge

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 orifice 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 inspected 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 workpiece
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 walled 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 comparator 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 Comparasator : 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 comparators, 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.

*****THE END*****