UNIT 4

LIMITS, FITS, TOLERANCES AND MEASUREMENT OF FLATNESS

Syllabus

Limits, fits and tolerances - Types of Fits, Unilateral and Bilateral tolerance system, Hole and Shaft basis system. Interchangeability and Selective assembly.

Limit Gauges : Taylor's principle, Design of GO and NO GO gauges, Measurement of angles using Bevel protractor and Sine bar. Measurement of flatness using Straight edges, Surface plates, Optical flat and Auto collimator.

LEARNING OBJECTIVES

On the completion of this unit, the student shall be able to understand the following concepts,

- Types of fits
- Unilateral and bilateral system
- Hole and Shaft basis system
- Interchangeability and selective assembly
- Design of GO and NO-GO gauges
- Measurement of angles by Sine bar and Bevel protractor
- Flatness measurement by straight edges and surface plate
- Optical flat and Autocollimator

INTRODUCTION

The word 'Metrology' is derived from Greek words, Metro (measurement) and Logy (science). Hence, it is defined as science of measurement, which deals with determining the unknown quantities by comparing it with the predetermined standards or by using various measuring instruments. The quantities that are measured may be mechanical, electrical, chemical, optical, physical etc.

In practice, it is impossible to manufacture a component to exact size repeatedly. Therefore, it is logical to consider the variations in the dimensions of the part as being acceptable, if its size is known to lie between a maximum and minimum limit. This difference between the size limits is called tolerance.

GO gauge and NO GO gauge, which inspect the upper and lower limits of the workpiece. Based on the form of surface to be tested, limit gauges are classified as, Plug gauge, Snap gauge, Ring gauge.

Angular measurement involves in measuring the inclination between surfaces. Precise angular measuring instruments help in navigation of ships and aeroplanes, also for determining the approximate distance between stars and planets. The instruments that measure angles include sine bar, angle gauges, autocollimator, clinometers, etc. Selection of instrument depends upon the type of component and accuracy required.

Flatness can be measured by using straight edges, surface plates, optical flat and autocollimator. Based on the type of surface and degree of accuracy required, the instrument is selected for measurement.

PART-B ESSAY QUESTIONS WITH SOLUTIONS

4.1 LIMITS, FITS AND TOLERANCES

4.1.1 Types of Fits – Unilateral and Bilateral Tolerance System

Q42. Define the terms,

(i) Allowance

(ii) Limits

(iii) Tolerance

(iv) Fits.

Answer :

Dec.-10, Set-4, Q1(a)

(i) Allowance

The prescribed difference between the dimensions of two mating parts (i.e, holes and shaft) for any type of fit is known as allowance.

Maximum allowance = Higher limit of hole – Lower limit of shaft

Minimum allowance = Higher limit of shaft – Lower limit of hole

The allowance may be positive or negative.

Thus, the allowance is positive for clearance fit and negative for interference fit as shown in below figure.

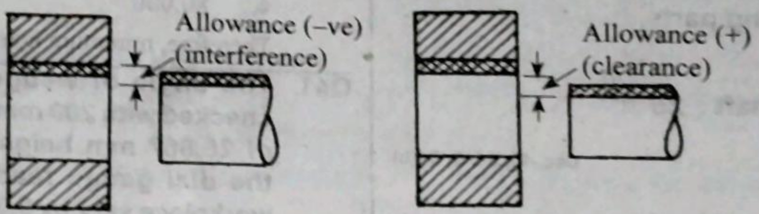


Figure (2): Negative Allowance

(ii) Limits

Limits are defined as the permissible variation in dimension, to account for variability. Usually in mass production, large number of components are to be made by different operators on different machines. Hence, it is impossible to make all components with exact dimensions. The difference in dimensions vary from machine to machine, operator to operator and quality of the components. The limits of a size are the maximum and minimum permissible sizes of the component.

(iii) Tolerance

The difference between upper limit and lower limit is known as Tolerance. In the figure below, the diameter of shaft is 40.00 mm which is known as the basic or nominal diameter. The shaft is accepted, if its diameter lies between 40.00 ± 0.05 = 40.05 mm and 39.95 mm. The dimension 40.05 mm is called the upper limit and the dimension 39.95 mm is called lower limit and the difference between these limits is called tolerance.

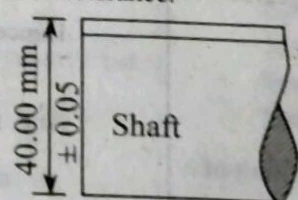


Figure: Tolerance

(iv) Fits

It is defined as the degree of looseness or tightness among two mating components, so as to assemble together and perform a specific function. A fit gives the relationship between two mating parts, i.e., shaft and hole which are assembled in accordance with their sizes. It can either provide a fixed joint or a movable joint.

Example: If the pulley is placed on the shaft, it forms a fixed type of joint. Whereas, when the shaft runs in a bearing, then there exists a relative motion between them forming a movable joint.

Depending upon the tolerance between the mating parts, fits can be classified into three basic types. They are,

1. Clearance fit
2. Transition fit and
3. Interference fit.

Q43. Draw the conventional diagram of limits and fits and explain the terms,

(i) Basic size

(ii) Upper deviation

(iii) Lower deviation

(iv) Fundamental deviation.

Answer : Dec.-10, Set-3, Q1(a)

Conventional Diagram of Fits

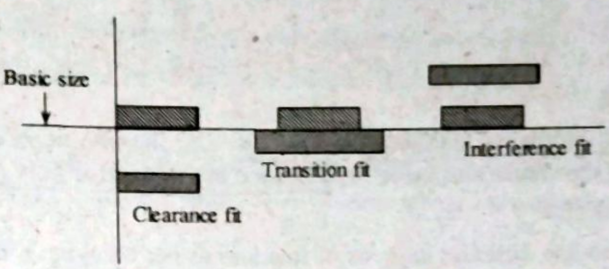


Figure (1) : Types of Fits

Conventional Diagram of Limits

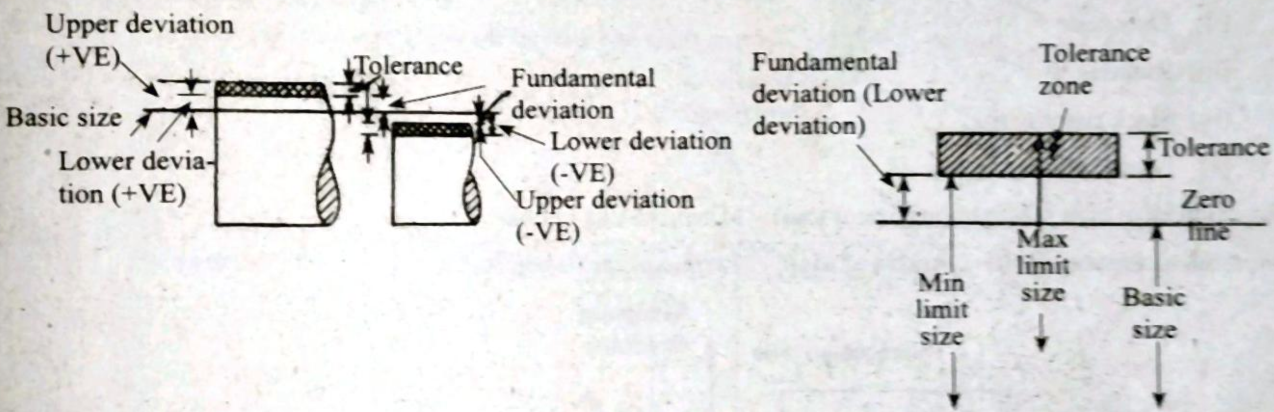


Figure (2): Limits

(i) Basic Size

It is the standard size of a part, in relation to which all limits of variation of size are determined. It is also known as nominal size of a part or dimension. The basic size is specified for both shaft and hole is same. It is the designed size obtained by calculation for strength.

(ii) Upper Deviation

It is the difference between the maximum limit of size and the corresponding basic size. It is a positive quantity, when the maximum limit of size is greater than the basic size, and negative when the maximum limit of size is less than the basic size.

(iii) Lower Deviation

It is the difference between the minimum limit of size and the corresponding basic size. It is positive, when the minimum limit of size is greater than the basic size, and negative when the minimum limit of size is less than the basic size.

(iv) Fundamental Deviation

It is the deviation, either upper or lower deviation, nearest to the zero line for a hole or a shaft. It fixes the position of the tolerance zone, in relation to the zero line.

Q44. What are the different types of fits and explain with neat sketches? Nov./Dec.-16, (R13), Q3(a)

OR

Define fit. What are the conditions of types of fits? Nov.-15, (R13), Q1(b)

OR

Define fit. State different types of fits and explain each of them with suitable sketches and examples.

Answer : [May-10, Set-4, Q2 | Model Paper-4, Q8(a)]

Fit is defined as the degree of tightness or looseness between two mating parts to perform a specific function in an assembly. A fit can be either a movable joint or a fixed joint.

Type of Fits

Depending upon the clearance (i.e., positive, zero or negative) , the fits are classified as,

1. Clearance fit
2. Interference fit.
3. Transition fit

1. Clearance Fit

In this fit, the diameter of shaft is always smaller than the hole, i.e., the minimum diameter of hole is greater than the largest permissible diameter of the shaft. The value of clearance in this type of fit is positive, i.e., the difference between the sizes of hole and shaft is positive.

The shaft can rotate or slide, and has different degrees of freedom as per the type of function served by the fit.

The most common fits of clearance type are,

(i) Slide fit
(ii) Easy slide
(iii) Running fit
(iv) Slack running fit
(v) Loose running fit.

Maximum clearance = Maximum size of shaft – Minimum size of hole.

Minimum clearance = Minimum size of shaft – Maximum size of hole

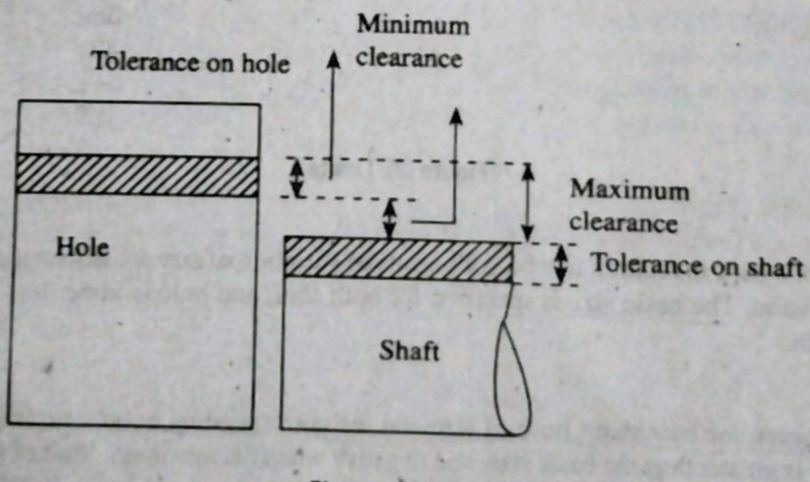


Figure : Clearance Fit

2. Interference Fit

In this type of fit, the minimum permissible diameter of the shaft is larger than the maximum allowable diameter of the hole. As the diameter of shaft is larger than the diameter of hole, the hole and shaft are intended to be attached permanently as a solid component.

Interference fits are classified as force fit, tight fit and heavy force and shrink fit.

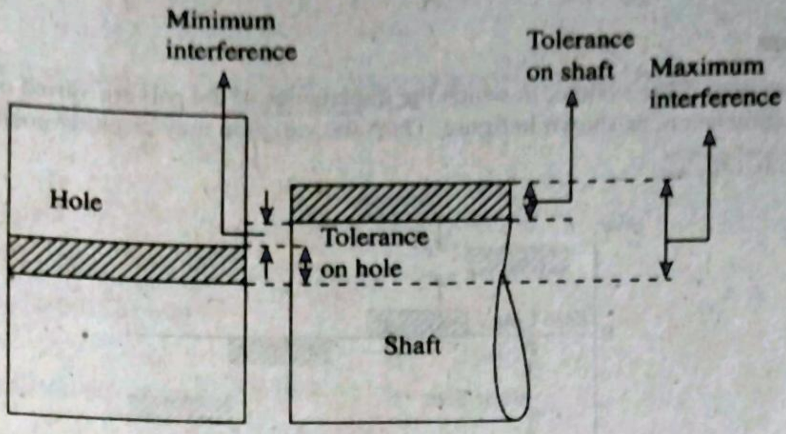


Figure : Interference Fit

Maximum interference = Minimum size of hole ± Maximum size of shaft

Minimum clearance = Maximum size of hole ± Minimum size of shaft.

3. **Transition Fit**

Transition fit is obtained, when the diameter of the largest allowable hole is greater than diameter of smallest shaft but the smallest hole is smaller than the largest shaft. Thus there is a small positive or negative clearance between the shaft and hole members.

They are of two types,

(i) Wringing fit and

(ii) Push fit.

In this type of fit the tolerance zones of the hole and shaft overlap completely or part

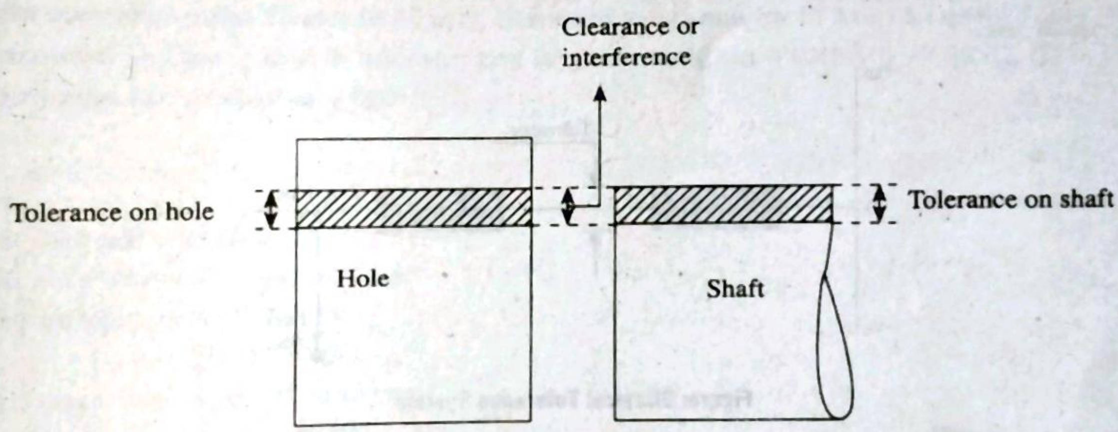


Figure : Transition Fit

Q45. Compare and contrast unilateral and bilateral tolerance system. Dec.-19, (R16), Q8(b)

OR

What is the difference between Unilateral tolerance and Bilateral tolerance? Which is the most suitable tolerance method and why? Nov.-15, (R13), Q3(a)

OR

Explain the unilateral and bilateral systems of writing tolerances with suitable examples. Which system is preferred in interchangeable manufacturing? Why?

[Dec.-10, Set-1, Q1(a) | Model Paper-II, Q8(a)]

OR

Explain unilateral system and bilateral system of tolerances.

Nov./Dec.-17, (R15), Q3(b)

Answer :

Unilateral Tolerance System

Unilateral tolerance system is the system, in which the dimensions of the part are varied only in one direction, it may be over or under the basic size dimension, as shown in figure. Thus, the variation may be either positive or negative.

Example: $30^{+0.04}_{+0.01}, 30^{-0.04}_{-0.01}, 30^{+0.04}_{-0.00}$

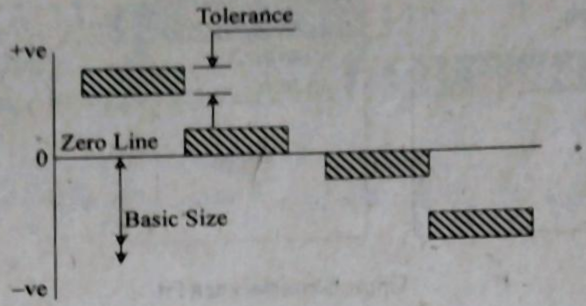


Figure: Unilateral Tolerance System

This system is used in interchangeable manufacture, due to the following reasons,

(i) It is simple and easy to find deviations,

(ii) 'Go' gauge end can be standardized, as the holes and shafts of different tolerance grades have the same lower and upper limits respectively.

(iii) It assists the operator, when machining is to be done. The operator machines hole to lower limit and shaft to upper limit, so that components can be machined further, to avoid rejection.

Bilateral Tolerance System

It is the system, in which the variation in the dimension is allowed on both sides of the basic size, i.e., the variation on either side of the basic size may not be equal. Thus, the variation will be both positive and negative.

The examples of this system are,

$20^{\pm 0.02}$, $20^{+0.02}_{-0.01}$, etc.

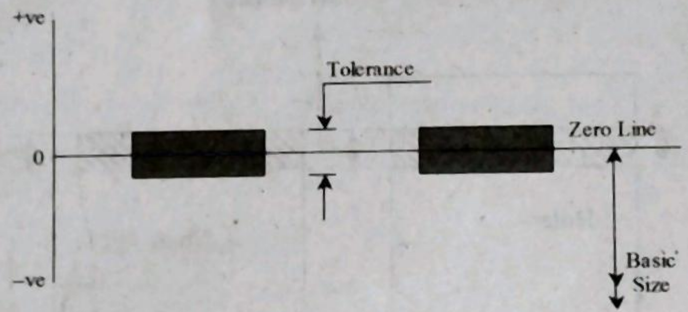


Figure: Bilateral Tolerance System

This system is useful for positioning of a hole. In this system, the machine setting is done for the basic size, hence it is used in mass production.

Unilateral tolerance system is preferred over the bilateral system because, in this system the tolerance can be revised without affecting the allowance or clearance, i.e., without changing the type of fit.

Q46. Calculate the tolerances, fundamental deviations and limits of size for the shaft designated as 40 H8/f7. Standard tolerance for IT 7 is 16i and IT 8 is 25i. Where 'i' is the standard tolerance unit. Upper deviation for 'f' shaft is – 5.5D$^{0.41}$, 40 mm lies in the diameter range 30–50 mm.

Answer :

Given that,

Hole and shaft pair = 40H8/f7

Basic size = 40mm.

Standard tolerances, IT7 = 16i

IT8 = 25i

∴ Upper deviation for shaft, 'f' = $-5.5D^{0.41}$

Range of diameter = 30 mm to 50 mm

Since, the basic size of shaft ranges from 30 to 50 mm, the geometric mean diameter is,

$\therefore D = \sqrt{30 \times 50} = 38.729$ mm

Standard tolerance unit,

$$i = 0.45\sqrt[3]{D} + 0.001D$$

$$= 0.45\sqrt[3]{38.729} + 0.001\,(38.729)$$

$$= 1.56 \text{ microns} = 0.001561 \text{ mm}$$

For Shaft

Upper deviation or fundamental deviation $= -5.5\,D^{0.41}$

$= -5.5\,(38.729)^{0.41}$

$= -24.629$ microns $= -0.0246$ mm

Standard tolerance for grade of IT 8 = 25 i

$= 25 \times 0.001561 = 0.03902$ mm

Maximum limit of shaft = Basic size + Fundamental deviation

$= 40 + (-0.0246)$ mm $= 39.975$ mm

Minimum limit of shaft = Maximum size – Standard tolerance

$= 39.975 - 0.03902 = 39.935$ mm.

Tolerance of shaft = Maximum limit – Minimum limit

$= 39.975 - 39.935 = 0.04$ mm

Q47. Calculate the limits for a hole shaft pair designated 25 H8/d9. Show graphically the disposition of tolerance zones with reference to the zero line. The lower deviation for a H type hole is zero. 25 mm lies in the diameter range 18 mm to 30 mm. Standard tolerance for IT 8 is 25 i and I'T 9 is 40i, where 'i' is the standard tolerance unit in microns and is given as i(μm) = $0.45\sqrt[3]{D} + 0.001D$, (D is in mm). The upper deviation for 'd' shaft is – $16D^{0.44}$.

Answer :

Given that,

Hole shaft pair = 25 H8/d9

Range of diameter = 18 mm to 30 mm

Standard tolerance for IT8 = 25i

for IT9 = 40i

Since, the range of basic size is 18 to 30 mm,

Geometric mean diameter, $D = \sqrt{18 \times 30}$

$\therefore D = 23.23$ mm

Standard tolerance unit,

$$i = 0.45\sqrt[3]{D} + 0.001D$$

$$= 0.45\,(23.23)^{\frac{1}{3}} + 0.001 \times 23.23$$

$$= 1.30 \text{ microns} = 0.0013 \text{ mm}$$

For Hole

For grade '8' of hole (H8), standard tolerance = 25 i = 25 × 0.0013 = 0.0325 mm

Lower deviation of hole(H) is zero

∴ Minimum size of hole = 25 mm

Maximum size of hole = 25 + 0.0325 = 25.0325 mm

Limits of hole = $25^{+0.0325}_{+0.000}$

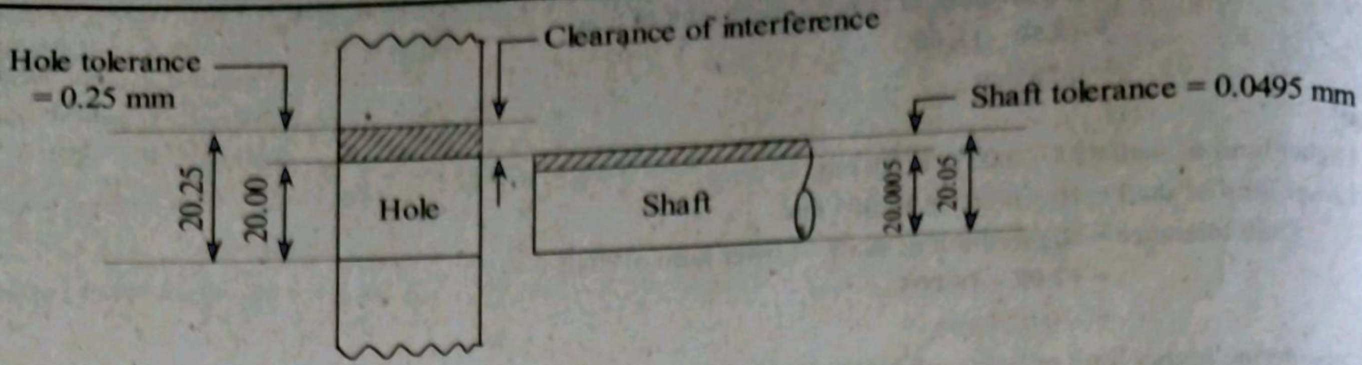


Figure (2): Transition Fit

4.1.2 Hole and Shaft Basis System

Q51. Differentiate between hole basis system and shaft basis system.

[Dec.-19, (R16), Q1(h) | May/June-13, (R09), Q1(b) | Dec.-11, Set-2, Q3(b)]

OR

Explain Hole basis system and shaft basis system.

[Nov./Dec.-18, (R16), Q9(b) | Model Paper-III, Q8(a)]

Answer :

Hole Basis System

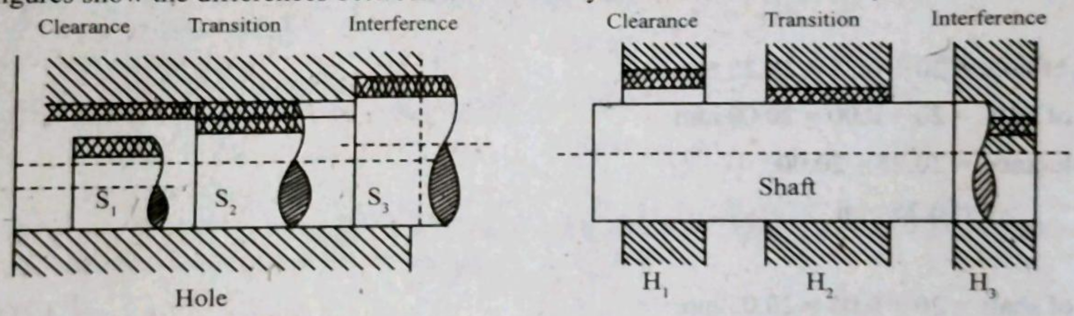
It is a system, in which the limits on the hole are kept constant and a series of fits are obtained by varying the limits on the shafts. In this system, the size of hole, where lower deviation is zero is assumed as the basic size.

In this system, it is easy to vary the shaft sizes, according to the fit required. Hence, it is preferred in mass production, as it is convenient and less costly, to make a hole of correct size, due to availability of standard drills and reams etc.

Shaft Basis System

It is a system, in which the limits on the shaft are kept constant and a series of fits are obtained, by varying the limits on the holes. In this system, the upper deviation of shaft is zero.

Following figures show the differences between hole based system and shaft based system.



Hole Basis System **Shaft Basis System**

Figure

Q52. Write short notes on converting a hole based fit into an equivalent shaft based fit.

Answer :

May-10, Set-1, Q7(b)

Hole basis system is employed for most general applications and some times shaft basis system is also used for design of fits. From Indian Standard (IS) system, the equivalent conversion of hole basis into shaft basis or vice versa are readily available as standards.

For clearance fit, the conversion of hole basis system equivalent to shaft basis system, for the size upto 500 mm is given as,

$$H7-d8 = D8-h7$$

$$H7-f6 = F7-h3$$

$$H11-c11 = c11-h11$$

The conversion for transition and interference fits is made if the tolerance grade for the shaft is same as that hole or one grade finer. Generally, for transition and interference fits with large total tolerance, grade of tolerance, used is same for both shaft and hole. Therefore, this is done for transition fits, *J, K, M, N* in grades above *IT*8, and for interference fits, *P* to *ZC* above *IT* 7.

If the total tolerance on interference and transition fit is not very large, one finer grade of tolerance is used for hole, than on the shaft. Thus, the value of 'Δ' is used to calculate the deviations of holes in conversion of hole basis to shaft basis system.

Consider an example of conversion of hole basis fit, i.e., H7 – p6 into shaft basis fit P7 – h6 for the size of 25 mm. Therefore, the upper limit (ES) for the hole is given as,

$$P7 = ei(p) + \Delta$$

For 25 mm size, the fundamental deviation for '*p*' can be taken from IS : 919 tables as – 22 microns. For grade of IT7, the value of deviation is 8 microns.

$$\therefore \text{ES}\ (P7) = -22 + 8 = -14 \text{ microns} = -0.014 \text{ mm}$$

Q53. Convert hole based fit Equivalent to the shaft based fit with neat sketch,

(i) 25 H_8c_7

(ii) 30 H_5n_9.

Answer :

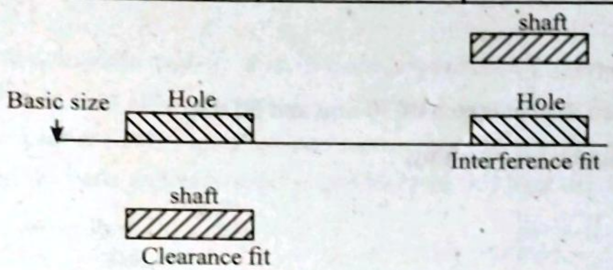
(i) 25 H_8c_7 Nov.-15, (R13), Q2(b)

The equivalent system i.e., shaft basis system of this fit is "25C_8h_7". Hence, the given fit is clearance fit.

(ii) 30 H_5n_9

The equivalent system i.e., shaft basis system of this fit is 30 N_5h_9. Hence, the given fit is interference fit.

S.No	Hole Basis	Shaft Basis	Type of Fit
1.	25 H_8c_7	25C_8h_7	Clearance fit
2.	30 H_5n_9	30 N_5n_9	Interference fit



Figure

Q54. A 50 mm diameter shaft is made to rotate in the bush. The tolerances for both shaft and bush are 0.050 mm. Determine the dimension of the shaft and the bush to give a maximum clearance of 0.075 mm with the hole basis system.

Answer : [Dec.-10, Set-1, Q1(b) | Model Paper-I, Q8(b)]

Given that,

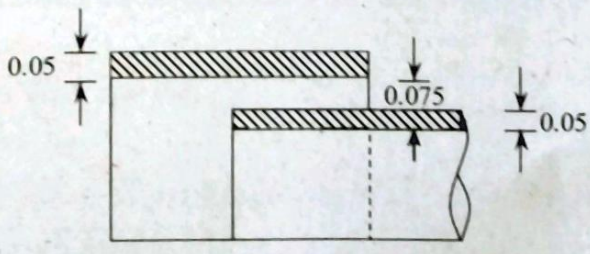
Tolerance for shaft = 0.050 mm

Tolerance for bush = 0.050 mm

Diameter of shaft = 50 mm

In a hole basis system, lower deviation of hole is zero.

$\therefore$ Lower limit of hole = 50 mm



Figure

Maximum size of shaft = 42 mm

Minimum size of shaft = 42 – 0.016 = 41.984 mm

Minimum size of hole = 42 mm

Maximum size of hole = 42 + 0.011 = 42.011 mm

Minimum clearance = Minimum size of hole – Maximum size of shaft

= 42 – 42

= 0

(i) Therefore, K5/h6 is a transition fit.

(ii) It is shaft based fit.

4.1.3 Interchangeability And Selective Assembly

Q56. How does selective assembly differ from an interchangeability with reference to manufacturing?

May-10, Set-2, Q5(b)

OR

Explain the principle of selective assembly and interchangeability in detail.

Nov.-15, (R13), Q2(a)

OR

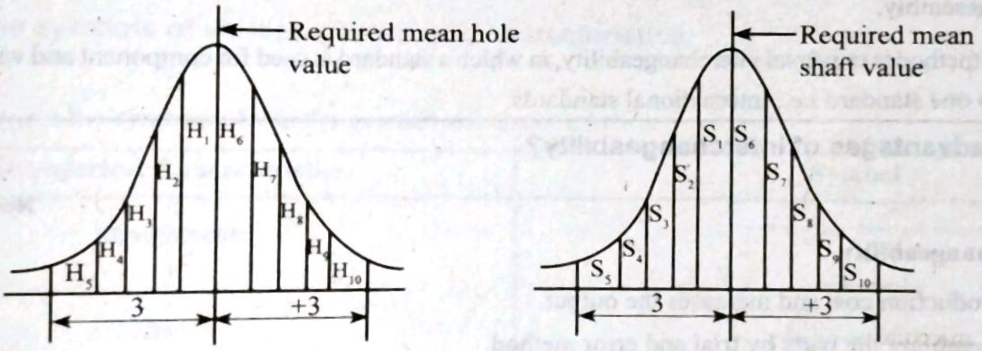
Explain briefly the difference between the interchangeable manufacturing and selective assembly.

Nov./Dec.-16, (R13), Q2(b)

Answer :

Selective Assembly :

The need of the consumer is not only the quality, precision and trouble-free products, but also the availability of products at economical prices. This is possible by automatic gauging for selective assembly. In this system, the parts are manufactured to wider tolerances and the products produced are classified into various groups, according to their sizes by automatic gauging. Classification is made for formatting the parts and only similar groups are assembled together.



Figure

If hole and shaft are to be produced within a tolerance of 0.02 mm and both are in the curve of normal distribution, then automatic gauging divides them into parts with a 0.002 mm limit for selective assembly of individual parts. Consider an example of piston with cylinder, whose size is 60 mm and the clearance of 0.12 mm is required for the assembly. Let the tolerance on bore and piston to be 0.04 mm. Then,

Dimension of bore diameter is $60^{\pm 0.02}$ mm and,

Dimension of piston is $59.88^{\pm 0.02}$ mm

The pistons and bores may be selected to give the clearance of 0.12 mm as given below,

Cylinder bore	59.98	60.00	60.02
Piston	59.86	59.88	59.90

Interchangeability

Interchangeability is a system of mass production, in which large number of mating parts are produced. In conventional method, single operator was confined with number of units and assemble it, which used to take long time and was not economical. So, to reduce the cost and time, mass production system was developed. In most production systems, the components are produced in one or more batches, by different operations on different machines.

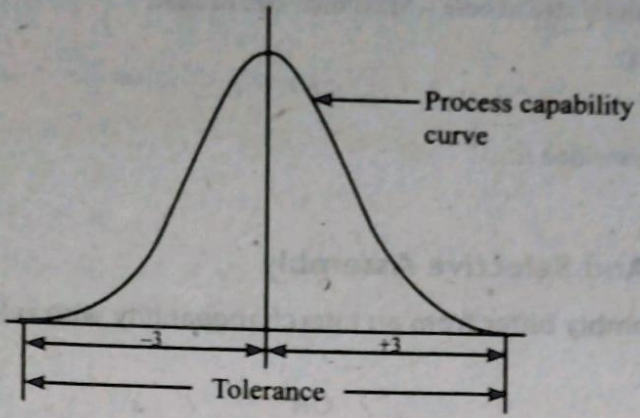


Figure ; Process Capability Curve

When this system is applied, a component is selected randomly with any other component. This system ensures reduced cost and increased output.

In this system, operator is concerned with a specific work repeatedly. The other work is taken care by operators of other batch, thus saving the time and simultaneously all the operations can be completed within a specified time. With the help of this method, parts which are worn or defected can be removed, replaced and assembled by other part very easily and the cost of maintenance is reduced and time required for it also reduced. Interchangeability can be applied only when certain standards are followed. The required fit is obtained by two ways. They are,

1. Full or universal interchangeability
2. Selective assembly.

The mostly used method is universal interchangeability, in which a standard is used for component and various manufacturing units are converted into one standard i.e., international standards.

Q57. What are the advantages of interchangeability?

Answer :

Nov./Dec.-16, (R13), Q2(a)

Advantages of Interchangeability

1. It reduces the production cost and increases the output.
2. It eliminates assembling the parts by trial and error method.
3. Worn out and defective parts can be easily replaced.
4. It is possible to produce mating parts at different places by different operators.
5. As there is a division of labour, the operator performs same operations number of times and becomes specialized in that particular operation, thus improving quality and saving the time for operations.
6. Maintenance cost and shut down period is reduced.

Q58. Explain the concept of selective assembly. Discuss its significance in manufacturing.

Answer :

May-10, Set-2, Q5(a)

For answer refer Unit-IV, Q56, Topic: Selective Assembly.

Significance of Selective Assembly in Manufacturing

1. It is the best and cheapest method in manufacturing.
2. It reduces manufacturing cost and gives high quality in assembly.

3. It reduces the scrap rate in manufacturing.
4. It produces tight tolerance of assembly, although the components are made with wide tolerances.
5. It reduces machining cost and defective assemblies.
6. It increases the efficiency of fit, without reducing the tolerance zone of component.

Q59. Describe principal features of the Indian standard system of limits and fits for plain work.

Nov./Dec.-17, (R15), Q2

OR

"Indian Deviation and 18 grades of Tolerances". Explain the statement in detail.

Answer :

In India, the Indian Standard (IS 919– 1993) is used for system of limits and fits. This system comprises of 20 different grades of fundamental tolerances (or grades of standard tolerance or grades of accuracy of manufacture), and 28 types of standard deviations. These standard deviations are indicated by letters (i.e., for holes: capital letters *A* to *ZC* and for shafts: Small letters *a* to *zc*)in diameter steps upto 500 mm. The designations of 28 deviations are represented as follows.

For holes: *A,B,C,CD, D,E, EF,F,G,H,I,J, JS,K,M,N, P,R,S,T,U,V, X, Y,Z, ZA, ZB, ZC*, and letters *I,L,O,Q* and *W* are not used.

For shafts: Small letters from *a* to *zc* is used.

By selecting the suitable combination of fundamental tolerances and fundamental deviations, a number of different fits ranging from extreme interference to those of extreme clearance are obtained. All fits can be obtained except very exceptional engineering requirements such as very coarse work to fine gauge manufacturing applications.

Generally, a unilateral hole basis system is recommended, but if necessary, bilateral shaft basis system also used.

For the convenience, the part is described with basics size, and the maximum and minimum limits are determined by its deviation from the basic size.

4.2 LIMIT GAUGES

4.2.1 Taylor's Principle, Design of GO and NO GO Gauges

Q60. What are the symbols of various geometrical characteristics.

Answer :

The following are the symbols of various geometrical characteristics.

Geometrical Characteristics	Symbol
Straightness	
Flatness	▱
Cylindricity	⌭
Roundness	○
Angularity	∠
Parallelism	//

Perpendicularity	⊥
Profile of line	⌒
Profile of surface	⌓
Position	⊕
Symmetry	≡
Concentricity	◎

Q61. State and explain the Taylor's principle of gauge design with neat sketch of Plug gauge and Snap gauges?

May/June-19, (R16), Q9(b)

OR

Explain the Taytor's principle applied in limits.

Nov./Dec.-18, (R16), Q8(a)

OR

State the Taylor's principle for the design of limit gauges.

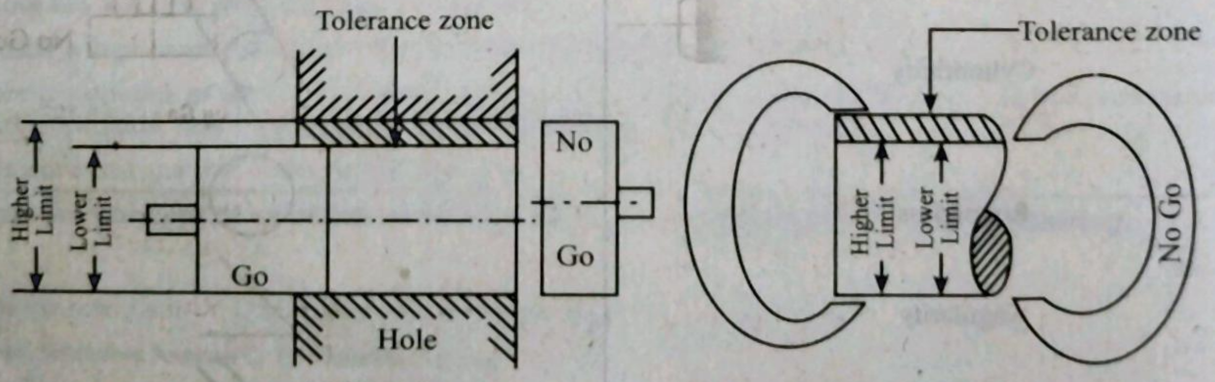
[Nov./Dec.-16, (R13), Q4(a) | Model Paper-II, Q8(b)]

Answer :

According to this principle, 'GO' gauge is designed to check the maximum material condition and 'NO GO' gauge is designed to check minimum material condition. The difference between 'GO' and NO GO' gauge sizes is equal to the tolerance of hole or shaft. Go gauges should ensure the checking of all the dimensions (location, size, roundness) in one pass, and NO GO gauge should check only one element of feature in a single pass.

In a plug gauge, the GO gauge corresponds to the lower limit of hole and NO GO gauge corresponds to the higher limit of the hole while in a snap gauge, the GO gauge indicates the higher limit of shaft and NO GO gauge indicates the lower limit of shaft.

The length of GO plug gauge should be equal to the length of hole, so that possible required dimensions such as diameter, alignability, straightness can be checked. The length of NO GO plug gauge is short compared to GO plug gauge and it measures the variation in the shape of hole.



(a) Plug Gauge **(b) Snap Gauge**

Figure

Q62. Discuss in detail about the various types of limit gauges with neat diagram.

Answer :

Gauges are inspection tools, to check the measurement of manufactured components. They are used to inspect the size of component is within the specified limits or not.

Limit Gauges: These are used in industries. It has GO gauge and NO GO gauge, which inspect the upper limit and lower limit of the workpiece. The materials used are high carbon steel and alloy tool steels. GO gauges inspect the maximum material limit (MML) and NO GO gauges inspects minimum material limit (LML) of shaft and hole.Limit gauges are also used for checking interference of fits.

	GO gauge (MML)	NO-GO gauge (LML)
Hole	Lower limit	Upper limit
Shaft	Upper limit	Lower limit

Based on the form of surface to be tested, limit gauges are classified as follows,

1. Plug gauge
2. Snap gauge
3. Ring gauge.

1. **Plug Gauge:** Plug gauges are used to check the holes, in which 'GO' gauge is the size of the lower limit of the hole and the 'NO GO' gauge corresponds to the higher limit of hole. Generally, these gauges are made up of suitable wear-resisting steel and the handles can be made of any suitable steel. The commonly used various types of plug gauges are.

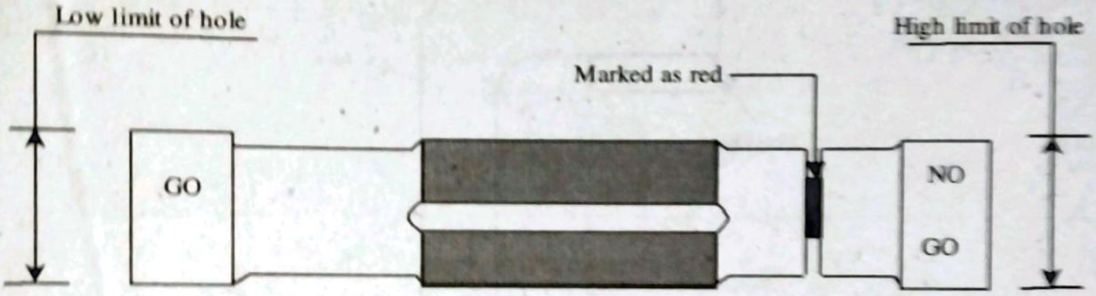
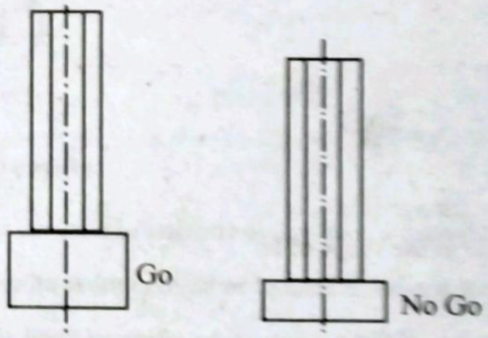
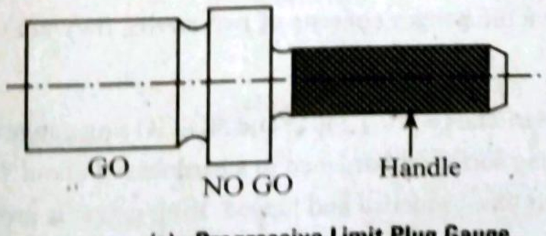


Figure (1): Solid Type Plain Plug Gauge (upto 10mm)

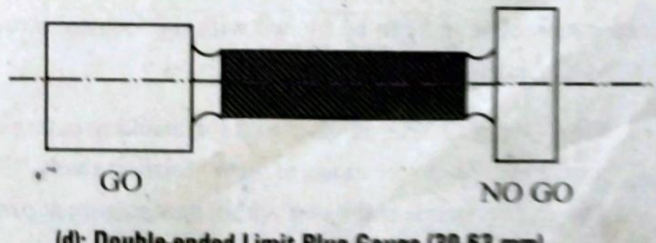
(a) : Standard Plug Guage



(b) : Single Ended Limit Plug Gauge (63-100 mm)



(a) : Progressive Limit Plug Gauge



(d): Double-ended Limit Plug Gauge (30-63 mm)

Figure (2): Types of Plug Gauges

2. **Snap Gauge:** These gauges are used for gauging shafts, spindles i.e., used for checking external diameters. The 'GO' snap gauge corresponds to the maximum material limit of the shaft, while the 'NO GO' gauge corresponds to the minimum material limit. Snap gauges are of three types,

(i) Single ended progressive type gauge

(ii) Double-ended gauge

(iii) Adjustable snap gauge.

Single ended gauges are non-adjustable gauges and the suitable for work size of 100-250 mm. Double ended gauges are easy and convenient to use for works of size 3-100mm. The gauging surfaces of the snap gauge is hardened and suitably grounded and lapped.

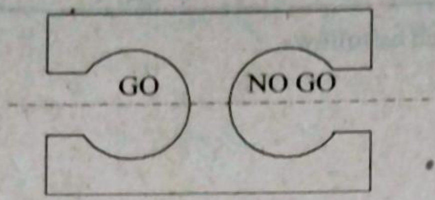


Figure (3) : Double Ended Snap Gauge

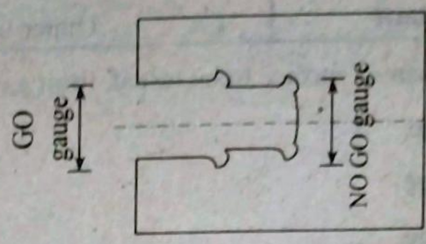


Figure (4) : Single End Progressive Gauge

Adjustable Snap Gauge

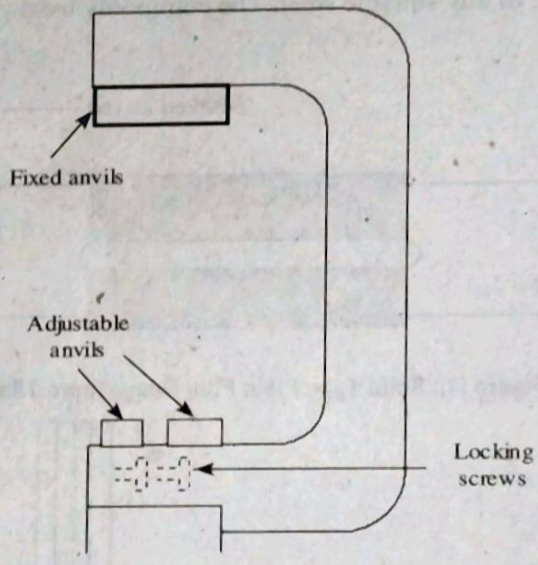


Figure (5) : Adjustable Snap Gauge

The adjustable snap gauge consists of a frame, which is designed for the structural rigidity, less weight and balance. This type of gauges are manufactured in large number of sizes with the openings that ranges from $\frac{1}{4}$ to 12 inches.

It consists of fixed anvils at the upper end and adjustable anvils at the lower end as shown in figure. The surfaces of these anvils are hard chrome plated, for reducing the errors due to wear. The adjustable anvils at the lower end can be adjusted to the desired dimensions and can be locked with the locking screws. When the gauges consists of two anvils, they are called as GO and NO-GO gauges.

3. **Ring Gauge:** These are also used for checking external diameter. The GO ring gauge and NO-GO ring gauge are designed separately. These are made of wear resisting steels. The gauging surface is hardened to a hardness of about 720 H.V. The gauging surface is stabilized with a heat treatment process and then grounded and lapped. Ring gauge is provided with a hole of size corresponding to the diameter of component. The range of gauge varies from 3-70 mm in 10 steps and 70-250 mm in 17 steps.

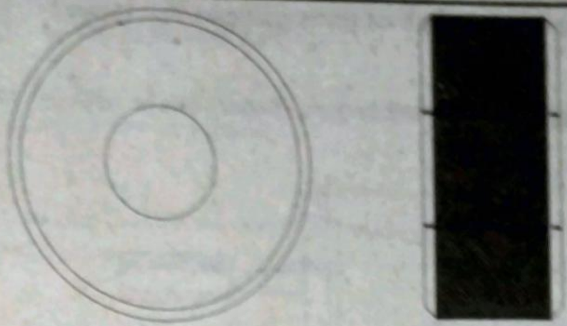


Figure (6) : Ring Gauge

The other types of limit gauges are as follows:

Combined Limit Gauge: The plug gauge combined with GO and NO GO dimensions to check both upper and lower limits of work, is known as combined limit gauge. It is usually used for gauging cylindrical holes. This gauge is formed by arranging a spherical ended gauge of equal diameter as lower limit of hole. A spherical projection (P), as shown in figure, is provided at the outer edge of spherical member. The distance between the spherical projection to its diametrically opposite side is equal to maximum limit of dimension.

For measuring the hole for minimum limit (i.e., GO-position), the gauge is inserted into the hole such that it is parallel to the axis of hole, whereas, for measuring maximum limit (i.e., NO GO position), the gauge should be tilted such that spherical projection is normal (perpendicular) to the hole.

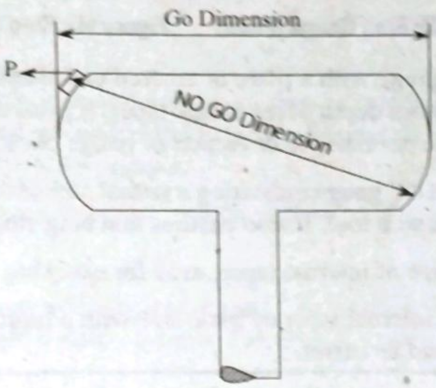


Figure (7) : Combined Limit Gauge

Position Gauges: Position gauges are used to inspect the location of different features on workpiece with respect to the reference surface, such as, distance of a hole, distance between the holes etc. Many types of position gauges are designed depending on the shape of the workpiece. Position gauges are designed based on two methods,

(i) Principle of sighting

(ii) Method of feel.

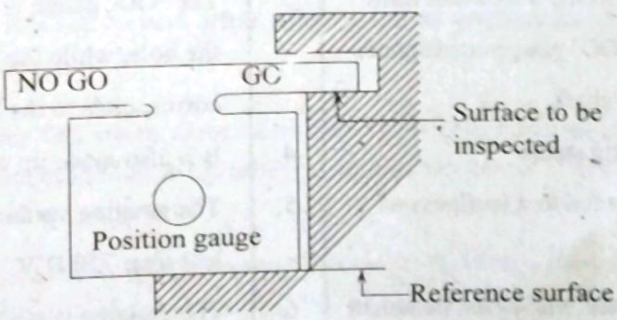
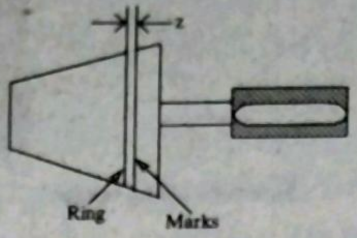


Figure (8) : Position Gauge

Q63. Enumerate and explicate various types of limit gauges for tapers.

Answer :

A taper is measured by using taper plug and ring gauges. Tapers can be both internal as well as external. The various types of limit gauges for tapers are,



Figure(1): Plug Gauge (Plain)

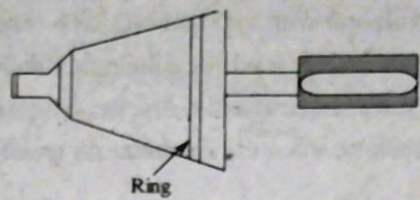
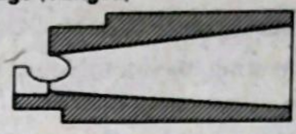


Figure (2): Plug Gauge (Tanged)



Figure(3): Ring Gauge (Plain) Figure (4): Ring Gauge (Tanged)

Plug Gauge (Plain): It is a full form 'GO' gauge with a plain or tapered end shank. It has two rings, one ring marked on gauge plane and another ring to represent the minimum depth of the inside taper. It is used for checking internal taper of corresponding size. The distance between the rings (z) is the permissible deviation of gauge plane position.

Plug Gauge (Tanged): It is also a full form 'GO' gauge indicating a virtual size of the shank of basic size having a tang employed to verify the internal tapers or sockets of machine tool. It also ensures that tang slot should be able to accept the tang.

Ring Gauge (Plain): It indicates the basic size of internal taper, used for checking the taper of tapped or plain end shank.

Ring Gauge (Tanged): It corresponds to an internal taper of basic size with a limit step, which checks the length of shank from gauge plane and effect of thickness of tang and its offset.

Q64. Compare between ring and plug gauges?

Answer :

	Ring Gauges		Plug Gauges
1.	It is used for gauging shafts, spindles, etc.	1.	It is used to check the holes.
2.	It is designed as 'GO' and 'NO GO' ring gauges.	2.	It is designed in two ways i.e., 'GO' and 'NO GO' plug gauges.
3.	The GO gauge corresponds to the maximum limit of the shaft, while the 'NO GO' gauge corresponds to the minimum limit of the shaft.	3.	The 'GO' gauge is the size of the lower limit of the hole, while the 'NO GO' plug gauge corresponds to the higher limit of hole.
4.	It is made up of wear resisting steels.	4.	It is also made up of wear resisting steels.
5.	The gauging surface is hardened to a hardness of about 720 H.V.	5.	The gauging surface is hardened to about or less than 750 H.V.
6.	The gauging surface is stabilized with a heat treatment process and then grounded and lapped.	6.	The gauging surface is stabilized, grounded and lapped.

Q65. What are the common materials used for gauges?

Answer :

The common materials used for gauges are as follows,

High Carbon Steels

Generally gauges are made of cast steel which are hardened with oil or water. Gauge plates and silver steels are made by using this material. Oil hardening is mostly used, to avoid cracking of material. Plug gauges of different sizes are made of different steels, such as,

Guages of diameter 15-32 mm – Made of cast steel.

Gauges of smaller diameter – Made of silver steels.

Guages of bigger diameter – Made of case hardening steels.

During hardening process, the steel is heated to 730°C and subjected to quenching in water. A temperature of 200°C (tempering temperature) should be retained for about 7 to 10 hrs for stability and reduced brittleness.

Mild Steel

Gauges made of mild steel are commonly subjected to case hardening process. They are heat treated either by carburising or cyaniding process. Minimum depth of case hardening should be done about 0.75 mm, in order to permit for grinding and finishing. The gauge is maintained at a temperature range of 150°C to 160°C for about 5 hrs and followed by slow cooling, to reduce the inner stresses. Mild steel possess good machinability and is available at low cost.

Oil Hardened Steel

It is used in the mass production of gauges. Gauges made of this steel are surfaced with the carbide at contact points, to increase the gauge life.

Plated Gauges

Chromium plating is done, which helps in making the surface of gauge hard and wear and corrosion resistant. While manufacturing a gauge, it is machined, plated, grounded and lapped to desired size. The coating thickness is about 0.2 to 0.3 mm. Chromium plating is also done to recover the worn gauged.

To inspect the work materials like aluminium, etc., which possess abrasive action, gauges with stellite ribs are used.

Cast Irons

These are used in manufacturing gauges of large sized bodies. The working faces are made of tool steel or cemented carbide. A closed grain structure of iron, free from blow holes, is used. This iron is mades table to relieve the stresses, due to casting and then subjected to final machining.

Glass

The gauges made of glass are used in least cases due to their brittle nature. They are resistant to corrosion and abrasion and have low thermal expansion.

Invar

It consists of 36% nickel, having low coefficient of expansion i.e., less than 1×10^{-6}/°C, but it is not used for long periods.

Elinvar

It has 42% nickel with coefficient of expansion as 8×10^{-6}/°C and is more suitable than invar.

Q66. Elucidate terms, gauge tolerance and wear allowance as assignable to limit gauges.

Answer :

Gauge Tolerance or Manufacturing Tolerance: Generally, gauges can not be manufactured to exact sizes. Also, some variations in size cannot be eliminated due to imperfections in the process, skills of worker etc. Therefore, some allowance must be provided while manufacturing gauges.

The gauge tolerance is also called as gauge maker's tolerance. Basically, the gauge tolerance should be kept as small as possible, but this will increase the cost of manufacturing the gauges. There is no accepted policy for standard policy gauge tolerance. Generally, gauge tolerance on limit gauges, is 10% of work tolerance, on inspection is generally 5% of work tolerance and on reference or master gauge, it is 10% of work tolerance.

Wear Allowance: Due to constant rubbing of the measuring surfaces of GO gauges against the surface of the work piece, wearing is enhanced on the measuring surface of gauges. As a result, the original size of gauge varies. The size of 'GO plug' gauge is reduced due to wear and that of ring or snap gauge 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, whereas in ring or snap gauges, it is subtracted. For 'NO GO' gauges, wear allowance is not provided as they are not subjected to much wear as GO gauges. Wear allowance is usually taken as 5% 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.

Q67. What are the advantages and limitations of GO and NO GO gauges?

Answer : May/June-19, (R16), Q8(b)

Advantages of Limit Gauges

1. These are portable and requires no power supply.
2. More than one dimension can be checked in a single pass of gauge.
3. Inspection is done at a faster rate.
4. Various dimensions of the components can be controlled.
5. Operation can be performed by a semi-skilled labour
6. Work is carried out with high flexibility.

Disadvantages of Limit Gauges

1. These do not specify the exact size of the component
2. These are difficult to manufacture with close (fine) tolerances.
3. Due to the wear and tear, the accuracy of the gauges is effected.
4. These are economical, if used for only similar products.

Uses of Limit Gauges

1. Mostly employed in mass production
2. Plug gauge – checks hole dimensions
3. Snap gauge – checks shaft dimensions
4. Taper gauge – inspects the taper dimensions
5. Thread gauge – checks the threading of the part
6. Profile gauge – checks the form or contour of the part.

Q68. Write a short note on the various aspects for deciding the limits on the limit gauges.

Answer : Nov./Dec.-16, (R13), Q4(b)

The various aspects considered for deciding the limits on limit gauges are as follows,

1. Cost of production
2. Gauge tolerance and
3. Gauge wear

1. Cost of Production

The cost of production of a gauge increases with increase in accuracy to which gauge is manufactured. Therefore, high accuracy should be maintained only wherever it is necessary.

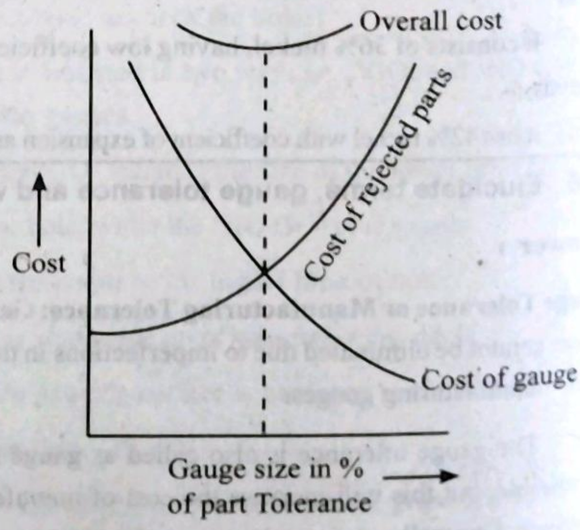
2. Gauge Tolerance

An attempt to manufacture a fixed size gauge to an exact dimension involves higher costs. The variation on gauge dimension may be restricted to small values, but, an allowable amount of tolerance is necessarily provided on gauge.

3. Gauge Wear

Suitable provisions are given for gauge wear as it is unavoidable. The GO and NO-GO gauges undergoes wear, but wear in GO-Gange is higher. Wear is permissible to certain extent but excessive wear results in rejection of components which are above the minimum metal conditions. Thus, it is required to set, gauge wear limit which is economical.

The below graph shows the method to find the variation which gives the minimum cost.



Figure

Q69. Design the general type of GO and NO-GO gauge for components having 20H7/f8 fit. i (microns) = 0.45 (D 1/3) +0.001 D, upper deviation of "f" shaft = –5.5 $D^{0.41}$, 20 mm falls from the diameter step of 18-30, IT7 = 16i, IT8 = 25i, wear allowance = 10% of gauge tolerance.

Answer :

[Nov./Dec.-16, (R13), Q5 | Model Paper-III, Q8(b)]

Given that,

Designation of fit = 20 H7/f8

Basic size = 20 mm

Standard tolerance, IT7 = 16 i

IT8 = 25 i

Upper deviation to shaft = $-5.5\ D^{0.41}$

Wear allowance = 10% of gauge tolerance

The range of diameter is 18 mm to 30 mm.

$\therefore D = \sqrt{18 \times 30} = 23.23$ mm

The standard tolerance unit (i) is given as,

$i = 0.45\ (D)^{1/3} + 0.001\ D$

$= 0.45\ (23.23)^{1/3} 0.001\ (23.23)$

$= 1.30$ microns

$\therefore \quad i = 0.0013$ mm

For Hole

Tolerance grade, IT7 = 16 i

$= 16 \times 0.0013 = 0.0208$ mm

Lower deviation of hole (H) = 0

$\therefore$ Limits of hole = $20^{+0.0208}_{+0.000}$

Gauge tolerance = 10% of standard tolerance of hole (work tolerance)

$= 0.1 \times 0.0208 = 0.00208$ mm

$\therefore$ Wear allowance = 10% of gauge tolerance

$= 0.1 \times 0.00208 = 0.000208$ mm

For Shaft

Tolerance grade, IT8 = 25 i

$= 25 \times 0.0013 = 0.0325$ mm

Upper deviation of shaft = $-5.5D^{0.41}$

$= -5.5\ (23.23)^{0.41}$

$= -19.932$ microns $= -0.01972$ mm

Maximum limit of shaft = Basic size + Upper deviation

$= 20 + (-0.01972) = 19.980$ mm

Minimum limit of shaft = Basic size + Upper deviation – Tolerance grade

= Maximum limit of shaft – Tolerance grade

$= 19.980 - 0.0325 = 19.9475$ mm

$\therefore$ Limits of shaft = $20^{-0.02}_{-0.053}$

Gauge tolerance = 10% standard tolerance of shaft

$= 0.1 \times 0.0325 = 0.00325$ mm

Wear allowance = 10 % of gauge tolerance

$= 0.1 \times 0.00325 = 0.000325$ mm.

Gauge Limits for Hole (Plug Gauge)

For Go gauge :

Upper limit = 2 + 0.00208 + 0.000208 = 20.00228 mm

Lower limit = 20 + 0.00208 = 20.00208 mm

$\therefore$ Limits of hole = $20^{+0.00228}_{+0.00208}$

For NO GO gauge :

Upper limit = 20.0208 + 0.00208 = 20.0228 mm

Lower limit= 20.0208 + 0.000 = 20.0208 mm

$\therefore$ Limits of hole = $20^{+0.0228}_{+0.0208}$

Gauge Limits for Shaft (Ring Gauge)

For GO gauge :

Upper limit = 19.980 – 0.000325 = 19.979 mm

Lower limit = 19.980 – 0.00325 – 0.000325 = 19.976 mm

$\therefore$ Limits = $20^{-0.021}_{-0.024}$

For NO GO gauge :

Upper limit = 19.947 – 0.000 = 19.947 mm

Lower limit = 19.947– 0.00325 = 19.943 mm

$\therefore$ Limits = $20^{-0.053}_{-0.057}$

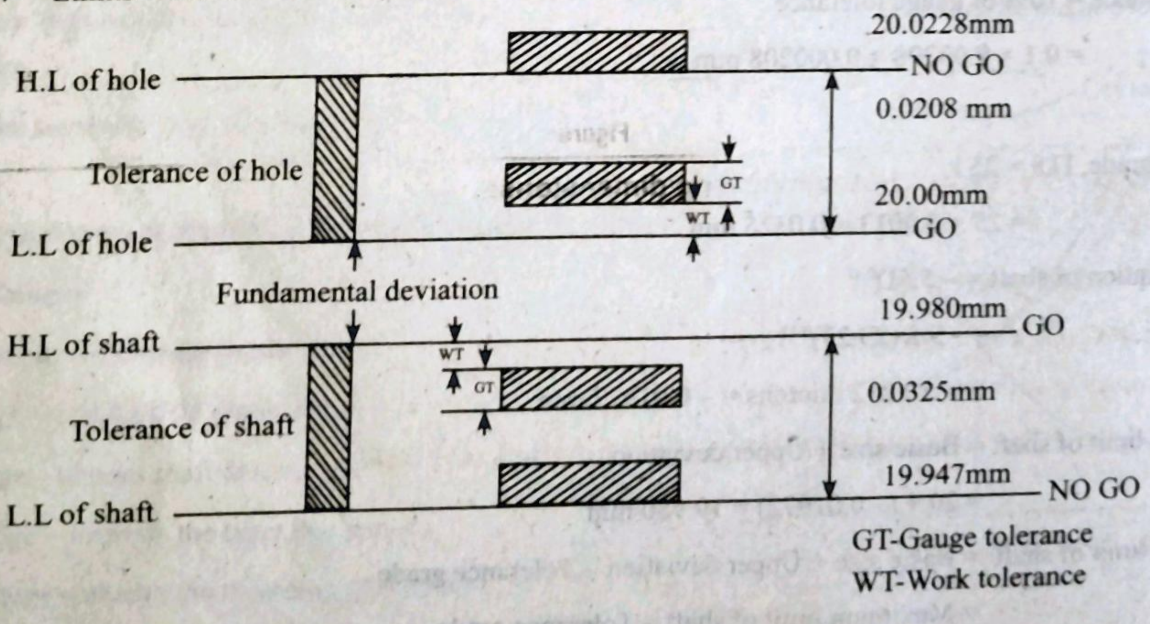


Figure: Graphical Representation of Tolerance

Q70. Shafts of 75 ± 0.02 mm diameter are to be checked by the help of GO and NO-GO ring gauges. Design the Gauge, sketch it and show GO size and NO-GO size dimensions. Assume normal wear allowance and Gauge maker's tolerance.

Answer : Nov.-15, (R13), Q5(b)

Given that,

Diameter of shaft = 75 ± 0.02 mm

Maximum size of shaft = 75 + 0.02 = 75.02 mm

Minimum size of shaft = 75 − 0.02 = 74.98 mm

∴ Tolerance = maximum size − minimum size

= 75.02 − 74.98 = 0.04 mm

Gauge maker's tolerance = 10% of work tolerance

= 0.1 × 0.04 = 0.004 mm

Wear allowance = 0.1 × 0.004 = 0.0004 mm

Go Gauge:

H.L = 75.02 − 0.0004 = 75.0196 mm

L.L = 75.02 − 0.0004 − 0.004 = 75.0156 mm

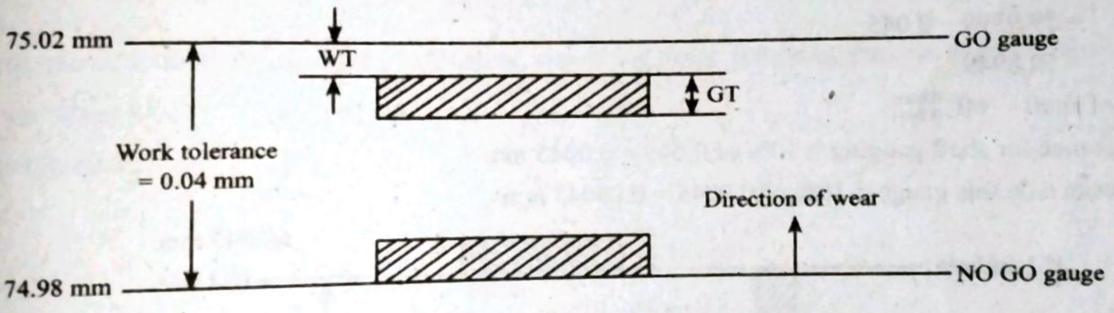
$\therefore$ Limits of gauge = $75^{-0.0196}_{-0.0156}$

No-Go Guage

H.L = 74.98 − 0.000 = 74.980 mm

L.L = 74.98 − 0.004 = 74.976 mm

$\therefore$ Limits of gauge = $74^{-0.980}_{+0.976} = 75^{-0.020}_{-0.024}$



Figure

Q71. A hole and shaft system had the following dimensions:

60 H 8 /c 8

The multiplier of grade 8 is 25.

The fundamental deviation for 'C' shaft is – (9.5 + 0.8 D).

The diameter slip is 50 – 80.

Design the suitable 'GO' and 'NO-GO' gauges for shaft and hole.

Answer : Dec.-19, (R16), Q9

Given that,

Basic size = 60 mm

Diameter range = 50 mm to 80 mm

Gauge Limits for Hole (i.e., Plug Gauge)

For Go Gauge

Upper Limit = 60 + 0.0045 + 0.0004 = 60.0049 mm

Lower Limit = 60 + 0.0004 = 60.0004 mm

$\therefore$ Limits = $60^{+0.0049}_{+0.045}$

For No Go Gauge

No Go Gauge = $60.045^{+0.0045}_{-0.0000}$ mm

Gauge Limits for Shaft (i.e., Ring Gauge)

Go Gauge :

Upper limit = 59.9399 – 0.0045 – 0.0004

= 59.935 mm

Lower Limit = 59.9399 – 0.0004

= 59.9395

$\therefore$ Go Gauge = $59.9395^{-0.0045}_{-0.000}$

= $60^{-0.065}_{-0.0605}$

No Go Gauge :

Upper limit = 59.8949 – 0.000

= 59.8949

Lower Limit = 59.8949 – 0.0045

= 59.8904 mm

No Go Gauge = 59.8949 – 0.0045 – 0.1051

= $60^{-0.1051}_{-0.1096}$

4.2.2 Measurement of Angles, Using Bevel Protractor and Sine Bar

Q72. Explain the construction and working of a bevel protractor.

Answer : [Nov./Dec.-17, (R15), Q4(a) | May/June-13, (R09), Q2(b)]

Construction

A bevel protractor is an angle measuring instrument, consisting of the following parts as shown in figure.

1. A fixed measuring blade
2. An adjustable blade
3. Body and
4. Turret.

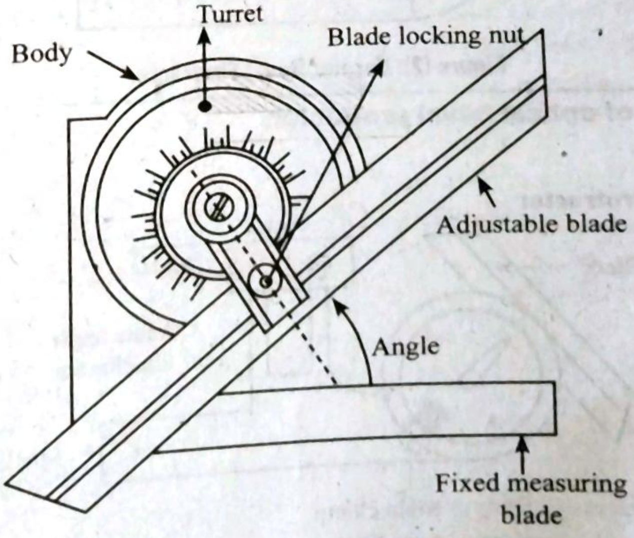


Figure: Bevel Protector

Working

A bevel protractor is used to measure angle between the two faces of a component. The fixed measuring blade and the adjustable blade is set along the faces of the component whose angle is to be measured, as shown in figure. The blades are then locked by a locking nut, to tighten the component for accurate measurement. The body consists of a circular scale and extends to form one of the blades. The circular scale can measure angles upto 360 degrees. The adjustable blade also slides and can be locked at any position along its length, to the rotating turret mounted on the body. Thus, accurate angular measurements of any component can be easily done by a bevel protractor.

Q73. Explain about vernier bevel protractor.

Answer :

The vernier principle is also applied in angular measurements. It is an instrument used to measure angle to an accuracy of 5 minutes (5') or 1/12 of one degree. The vernier protractor includes number of attachments, that make it possible far wide range of measurements.

The main scale is graduated in degrees. On some instruments, this scale is on the body of the instrument itself while on other instruments the graduations are on the rotating turret. The vernier scale has 24 divisions, 12 divisions are on each side of the zero index line. The 24 vernier scale divisions are numbered from 60 to 0 and 0 to 60, as shown in figure (1). Each vernier scale graduation represents 5' i.e., least count of the instrument is 5'.

In angular measurements, it is important to read vernier scale reading. When the angle is an exact degree, the index line on the vernier scale, coincides with graduation on the main scale. However, if the angle is more than an exact number of degrees, the fractional value (in 5' increments) is read on the vernier scale.

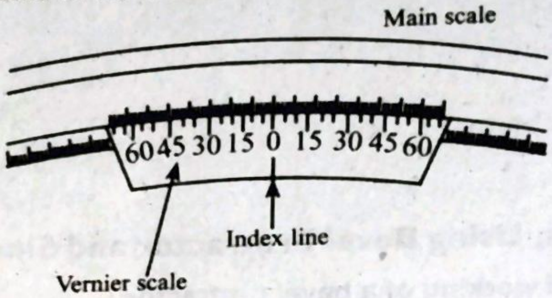


Figure (1): Vernier Scale

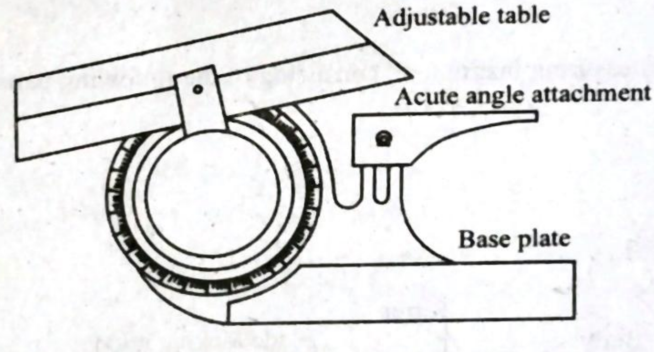


Figure (2): Vernier Bevel Protractor

Q74. Explain the construction of optical bevel protractor.

Answer :

Construction of an Optical Bevel Protractor

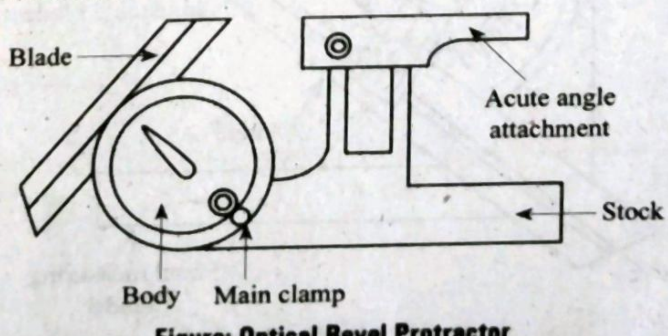


Figure: Optical Bevel Protractor

The main components of optical bevel protractor are,

1. **Body:** The body of an optical bevel protractor should be flat on its back, without any projections on it. It should be noted that, while placing the back of bevel protractor on the surface plate there should be no visible rock present on it. The flatness of the body and stock's working edge is tested, by checking the squareness of blade with respect to stock, by setting the blade at an angle of 90°.

2. **Stock:** The stock of protractor should be designed such that its working edge should be straight. The length and thickness of the working edge is about 90 mm and 7 mm. Any small variation in its straightness causes the formation of concavity, which will be available in the highest order of 0.01 mm.

3. **Blade:** The length of the protractor varies from 150 mm to 300 mm. The width and thickness of blade is 3 mm and 2 mm. It can be rotated at an angle of 45° and 60° along with an accuracy of 5 minutes. The straightness and parallelism of working edge is designed upto 0.02 mm and 0.03 mm, along the entire length of blade, i.e., 300 mm. The blade can be moved in the reverse direction throughout its length and can be able to clamp in any direction.

4. **Acute Angle Attachment:** This attachment is easily fitted into the body and can be clamped in any direction. The flatness of working edge should be in the range of 0.005 mm and it should be parallel to the stock's working edge.

Q75. Explain how the measurements are made with optical bevel protractor.

Answer :

Optical bevel protractor is a modified form of vernier bevel protractor. This instrument consists of glass circle, adjustable blade, working edge, etc., as shown in figure. The glass circle is fitted inside the main body and is divided into ten intervals through the circumference of 360°. A small microscope is incorporated on a rotating member to view the circular graduations. The adjustable blade is attached to rotating member and aids to record readings.

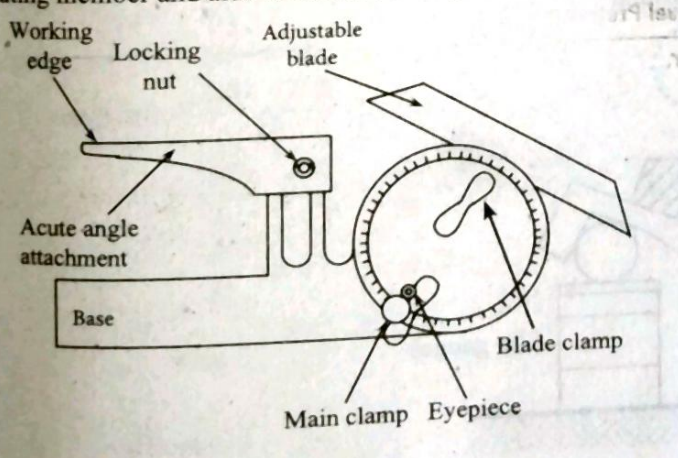


Figure: Optical Bevel Protractor

It can be used for wide range of applications. The general use is the angle measurement. The fixed and adjustable blades are set along the faces of the component whose angle is to be measured. The blades are locked by locking nut, to tighten the component for accurate measurement. The adjustable blade also slides and can be locked at any position along its length.

Optical bevel protractor comprises of a lens in the form of an eye piece for easy reading of protractor divisions. It can be also used for measuring flatness, acute angles, and checking the geometrical properties of the materials. The accuracy of the optical bevel protractor is upto 2 minutes.

Q76. Explain the use of sine bar for setting a component for a given angle.

Dec.-19, (R16), Q8(a)

OR

Explain the in detail the working of sine bar and what are its limitations? **May/June-19, (R16), Q9(a)**

OR

Describe the measuring method by using sine bar. **Nov./Dec.-18, (R16), Q9(a)**

OR

Discuss the construction, working principle, and applications of any one angular displacement measuring instrument.

Model Paper-I, Q9(a)

Answer :

Sine bar is an angular measuring instrument. It is made of high chromium corrosion resistant steel, high carbon. It is hardened, grounded and stabilised. Sine bar consists of steel following parts,

1. Rollers
2. Steel bar
3. Slip gauges
4. Surface plate.

The rollers are made of same diameter and are attached at each end of bar so that their axis are parallel to each other. The slip gauges are used with sine bar and are arranged based on the angle to be measured.

Principle: The operating principle of sine bar is based on trigonometric laws.

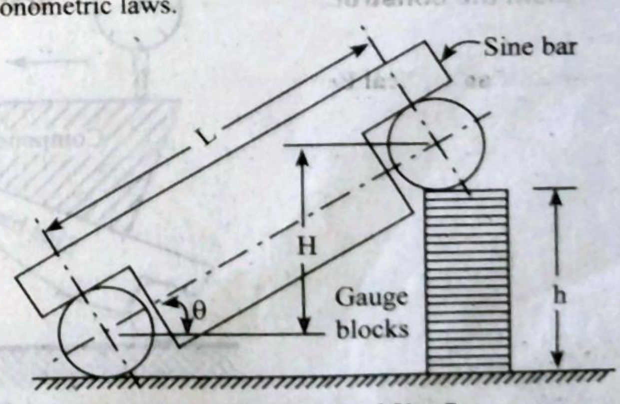


Figure (1): Principle of Sine Bar

In order to set a given angle, one roller is placed on the surface plate, and the other roller is placed over the slip gauges. Let 'H' be the height of the slip gauges and 'L' be the distance between the centres of steel rollers. Then,

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

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

Thus, angle is measured by indirect method as a function of trigonometric sine. Due to this, the instrument is known as sine bar.

Applications of Sine Bar

1. **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. As it consists of two rollers, at each end of the sine bar one roller, is placed on the surface plate and the other roller is placed over the slip gauges, as shown in figure (2).

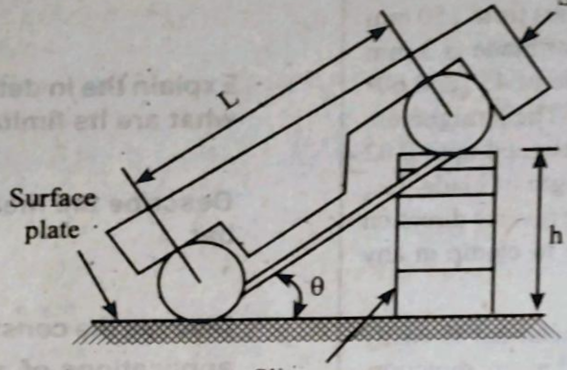


Figure (2)

Where,

H – Height of the slip gauges

θ – The angle at which sine bar is set

L – The distance between centre of the rollers.

For accurate results, rollers should be placed on slip gauges of height H_1 and H_2 respectively.

$$\therefore \sin\theta = \frac{H_2 - H_1}{L}$$

2. **Checking Unknown Angles, when the Component is of Small Size**

Initially, the angle is measured with the help of a bevel protractor. Then, sine bar is set up at desired angle and slip gauges are 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 figure (3).

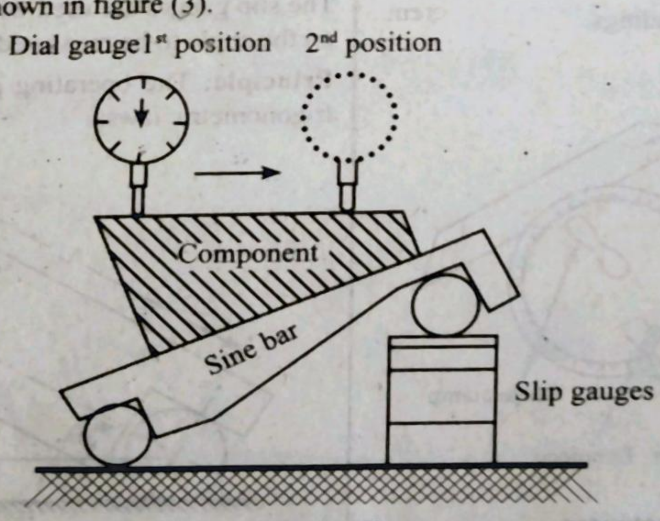


Figure (3)

Therefore, the angle of component can be calculated as,

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

3. **Checking of Unknown Angles, when the Component is of Large Size**

During measurement, the sine bar is placed on the component which is to be checked, and while the component is placed over the surface plate, as shown in figure (4).

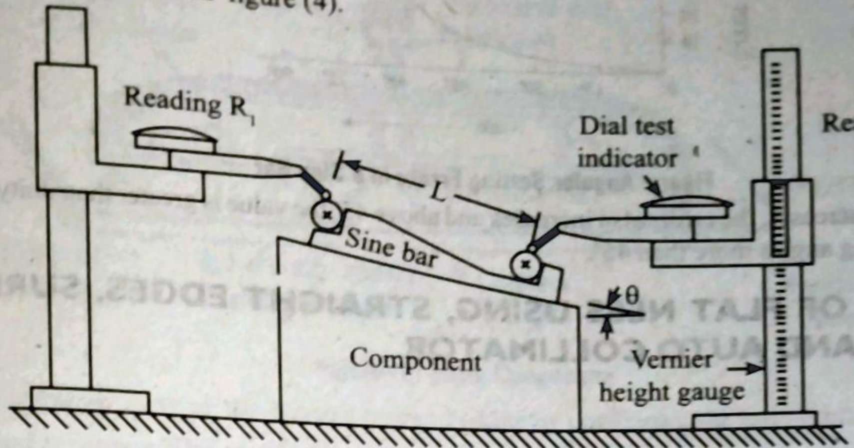


Figure (4)

The height above the rollers can be measured with the help of vernier height gauge, with dial test indicator mounted on the anvil. The the angle of component is by,

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

Where,

H – Difference in heights

L – Distance between the roller centres.

Limitations of Sine Bar

For answer refer Unit-IV, Q 27.

Q77. Explicate reasons for not to use sine bar for measuring angles more than 45°.

OR

Why sine bar is not suitable for measuring angles for more than 45°?

Answer : **Nov.-15, (R13), Q1(d)**

The relationship between the angular setting accuracy ($d\theta$) and any error present in the combination of slip gauges (dH) or the spacing of the rollers (dL) can be obtained by differentiating the equation $\sin\theta = H/L$

$$\sin\theta = H/L$$

$\therefore$ By differentiation,

$$\cos\theta . \, d\theta = \frac{LdH - HdL}{L^2}$$

$$= \frac{dH}{L} - \frac{HdL}{L^2} = \frac{dH}{H} \times \frac{H}{L} - \frac{HdL}{L^2}$$

$$= \frac{dH}{H}\sin\theta - \frac{dL}{L}\sin\theta$$

$$= \sin\theta\left[\frac{dH}{H} - \frac{dL}{L}\right]$$

$$\therefore \quad d\theta = \tan\theta\left[\frac{dH}{H} - \frac{dL}{L}\right]$$

Thus, any error in spacing of rollers or combination of slip gauges is the function of the tangent of the angle 'θ'.

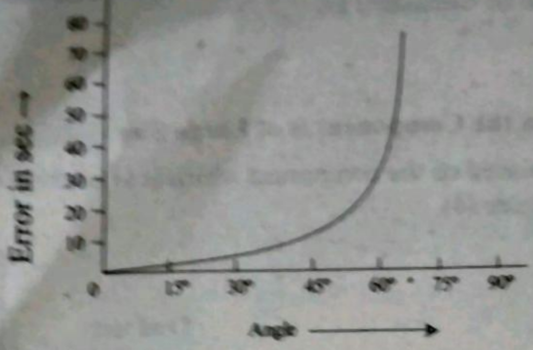


Figure: Angular Setting Errors in a Sine Bar

Therefore, as the angle increases, the errors also increases and above 45° the value is greater than unity. Hence, it is preferable not to use sine bar for measuring angles more than 45°.

4.3 MEASUREMENT OF FLAT NESS USING, STRAIGHT EDGES, SURFACE PLATES, OPTICAL FLAT AND AUTO COLLIMATOR

Q78. Enunciate,

(a) Flatness

(b) Straightness

Answer :

(a) Flatness

It is defined as the distance between the two parallel planes containing the surface. It is a geometrical quality of a perfect plane.

Flatness is determined by measuring 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 '⏥' and in drawings flatness symbol with tolerance is mentioned as,

⏥	0.04

(b) • Straightness

The normal distance between the two straight lines indicates the straightness of the plane. Straightness can be checked, by using a straight edge, dial indicator or autocollimator. The guideways of lathe are made straight, in order to move the tool in straight path for making cylindrical surfaces.

Q79. What are the methods used for measuring the flatness and explain with neat sketches.

Answer :

[Nov./Dec.-16, (R13), Q6 | Model Paper-II, Q9(a)]

1. **Flatness Comparators:** A beam comparator is used to measure the flatness of a surface. This method is highly accurate and rapid. The principle of checking the flatness involves in comparison of surface to be tested with a straight edge or a master plate, whose size is larger or similar than the test surface.

Since, there is no necessity for the master plate to be accurate, its flatness error must be known, for consideration during flatness testing.

Generally, a beam comparator instrument consists of a light beam body with three supports, where one support is fixed and is provided at the centre. The other two supports that are adjustable and are placed at the ends of the beam. Another supporting foot is also provided to prevent the falling or rolling of the beam over the surface. At the central part of the beam a sensitive dial indicator is fixed, in such a way that the line of action of plunger is same as that of the adjustable supports.

The flatness of a surface is checked multiple times and for each turn, the length of the movable feet (supports) are adjusted at various points on the surface and flatness is checked. Initially the readings are noted from the dial indicator by keeping the instrument over a reference master plate and then on the test surface and the process is repeated. Thus, the flatness error is known, when there exists a difference between the readings of master plate and test surface.

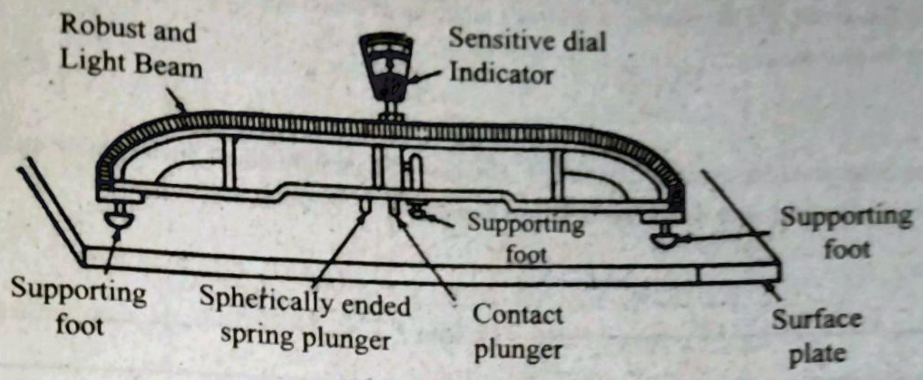


Figure (1): Beam Comparator

2. **Liquid Method:** In liquid method, the flatness testing is done by comparing the test surface with a liquid surface, which serves as a standard reference. This method is very quick and accurate. It is also suitable for checking the flatness of large work surfaces.

Mercury or dilute soda solution is filled in two cylinders which are connected at the base with a tube made up of rubber. These two cylinders are provided with micrometers, which are placed vertically over them, as shown in figure. To check the flatness, one cylinder is positioned at the centre of the surface and fixed. The other movable cylinder is positioned at various points over the test surface.

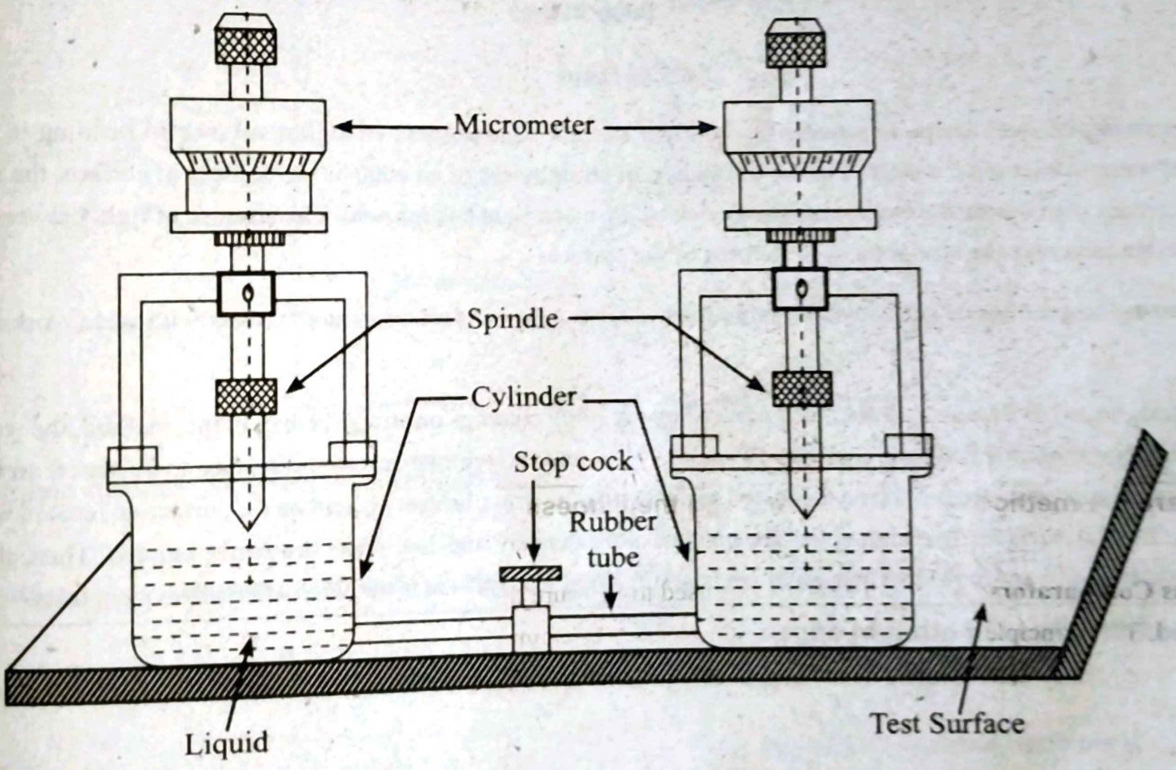


Figure (2) : Liquid Comparison Method

Then, by moving the spindles, till they touch the liquid surface, readings are noted for each position.

Thus, the error in flatness at each position can be known from the difference in two micrometer readings. It is necessary to check that there are no air bubbles present in the tube, while testing flatness. To restrict the flow of liquid from movable cylinder to fixed cylinder during testing, a stop cock is equipped in the tubing, as shown in figure (2).

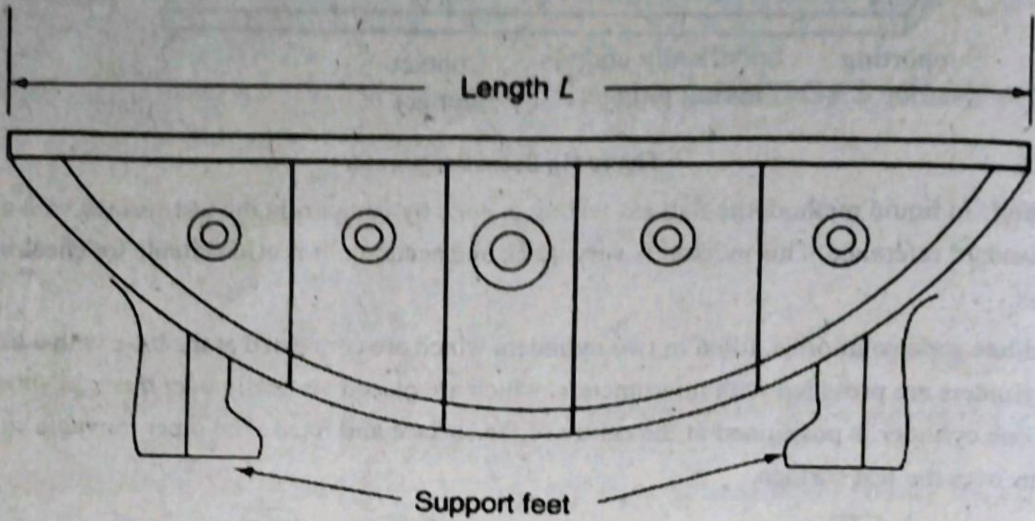
Q80. Explain briefly how straight edges are used for checking straightness or flatness

Answer :

For checking straightness or flatness, the straight edges are used in conjunction with surface plates and spirit levels. It is narrow or thin, deep and flat-sectioned measuring instrument made up of steels and cast irons. The length of straight edges varies from several millimeters to few meters.

For Example

Straight edges made up steel are available up to 2 m, and cast iron straight edges are available up to 3 m. These are ribbed heavily and manufactured in bow shapes as shown in below figure.



Figure

The narrow and deep shape is provided so that the straight edge possess enough resistance to bending in the plane of measurement without excessive weight. For the estimation of straightness of an edge or the flatness of surface, the straight edge is placed in contact with the surface to be tested and viewed against a light background. The absence of light between the surface and straight edge indicates the straightness or flatness of the surface.

For testing large areas of surfaces with large intermediate gaps or recesses, straight edges with wide working edges are used.

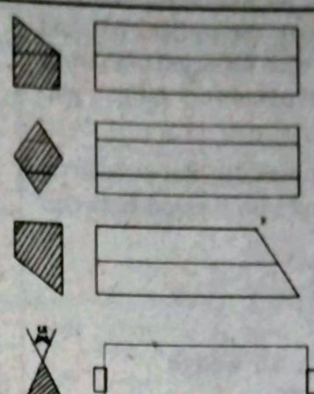
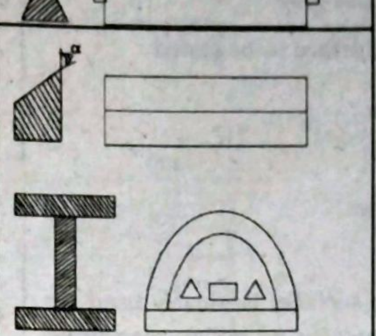
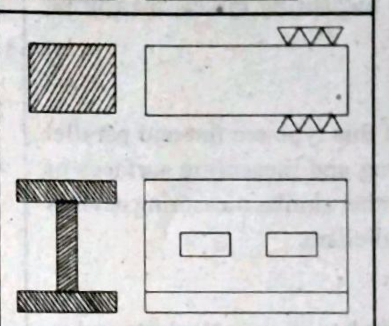
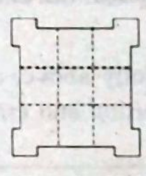
The straightness or flatness can also be measured by applying coatings on straight edge. In this method, the working edges of straight edge is applied with a light coating of Prussian blue, and then drawn across the surface to be tested. In this way, the trace of marking compounds are rubbed on the tested surfaces and the irregularities present on the surface are coated with different densities than the flat surface. The high spots are painted more densely and low spots are partly painted. Then, the surface is scraped or ground until a uniform distribution of spots on the complete surface is obtained after subsequent tests.

Q81. Mention the types of straight edges.

Answer :

The straight edges are classified as,

1. Tool maker's straight edges
2. Angle straight edges
3. Wide-edge straight edges
4. Box straight edge.

Type	Figure
Toolmaker's straight edges	
Angle straight edges	
Wide-edge straight edges	
Box straight edges	

Figure

Q82. Explain optical flat types and its limitations. Nov./Dec.-16, (R13), Q7(a)

OR

With a neat sketch explain the working of optical flat. Nov./Dec.-16, (R13), Q7(b)

OR

What is optical flat? What are their types? State the limitations of optical flat.

[Nov.-15, (R13) Q6(a) | Dec.-10, Set-4, Q3(a) | Model Paper-III, Q9(a)]

Answer :

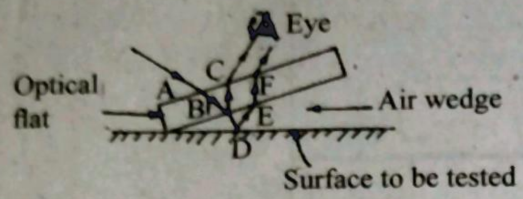
Optical Flat

Optical flat provides precision and accuracy in the measurement of flatness.

Usually optical flats are cylindrical pieces of 25 mm to 300 mm in diameter and of thickness about $\frac{1}{6}$ th of the diameter. Optical flats are made up of transparent materials such as quartz, glass, sapphire, etc. The quartz optical flats are wieldy used because of its hardness, low coefficient of expansion, high corrosion resistance and longer life.

Generally, it is used for checking the flatness of a surface. To check the flatness the optical flat is placed on the surface. The monochromatic light passes through the optical flat and strikes the workpiece. The light wave is then reflected both from optical flat and surface being tested, through a very thin air gap between the two surfaces.

If an optical flat is laid on a normally flat reflecting surface, a wedge shaped air passage may be formed between the surfaces.



Figure

Types of Optical Flats

Optical flats are of two types,

Type A

It has single flat working surface. Basically used for testing the flatness of precision measuring tables, measuring surfaces of flats, slip gauges, etc.

Type B

Both working surfaces of this type are flat and parallel to each other. It is used for testing and measuring surfaces of anvils, meters, micrometers, and other similar measuring devices used for testing flatness and parallelism.

Limitations of Optical Flat

1. It is not easy to control the lay of an optical flat and to orient the fringes to its optimal use.
2. The fringe pattern is not viewed directly above, and resulting obliquity can cause the distortion and errors in viewing.

Q83. By using optical flat and monochromatic light explain the procedure to determine whether the given surface is flat or curved.

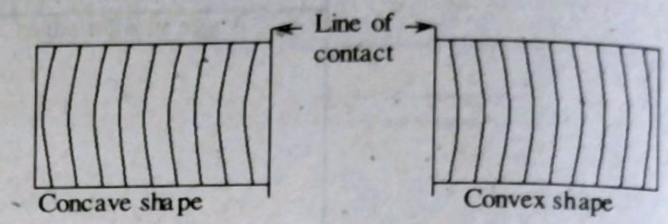
Answer : May-10, Set-2, Q7(a)

The surface to be tested is placed under an optical flat and a monochromatic light is illuminated on the optical flat Therefore, interference fringes are observed. The interference fringes are alternate bands (i.e., dark and bright) and are formed by a thin layer of air gap between the bottom surface of an optical flat and top surface of testpiece.

When the surface of test piece is perfectly flat, then the fringe pattern of alternative bands are dark, straight, parallel and equispaced on the surface. At this point, if light pressure is applied at any edge of surface, then no changes occurred in the fringe pattern.

If the surface of testpiece 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.

To find whether the surface is convex or concave shape, the surface of testpiece is pressed with the finger at the edge tip. Thus, circular bands are disturbed and fringes gets closed, therefore the surface is convex shape. If circular bands are not disturbed by light pressure at the edge tip, then pressure is applied at the center of surface. Thus, the number of circular bands are reduced and move apart from the edge tip, this shows that surface is concave shape.



Figure

Q84. What is the difficulty in using the optical flat alone? How do you overcome this difficulty in the interferometer?

Answer : Nov./Dec.-17, (R15), Q7(b)

Limitations of Optical Flat

1. It is not easy to control the lay of an optical flat and to orient the fringes to its optimal use.
2. The fringe pattern is not viewed directly above, and resulting obliquity can cause distortion and errors in viewing.

An interferometer overcomes these problems, by means of refined arrangements. In interferometers, the lay of the optical flat can be controlled, and fringes can be oriented to the best advantages. An arrangement is provided so that it is possible to view the fringes directly from top and above the fringes.

Q85. With neat sketch explain the working principle of auto collimator. Nov-15, (R13), Q6(b)

OR

Explain the optical system of an auto collimater used for examination of plane surfaces. May-10, Set-1, Q8(b)

OR

Explain with a neat sketches, the principle and working of an auto collimator and also list its applications.

OR

Explain the construction and working principle of an autocollimator with a neat diagram.

Answer :

Model Paper-I, Q9(b)

Autocollimeter is an optical instrument, which performs the functions of both optical tools (collimator and telescope). It is used for determining small angles with high degree of accuracy. Also it is used for checking straightness, flatness and parallelism.

Basic Working Principle

Autocollimator works on the principle that if a beam of light is projected on plane reflector which is perpendicular to the optical axis, the beam is reflected back along the same path as illustrated in figure (1). But, a slight change in the position of the plane reflector, will change the path of the light beam and is focused at a new point as shown in figure (2).

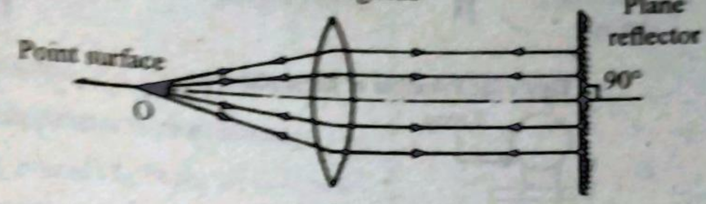


Figure (1)

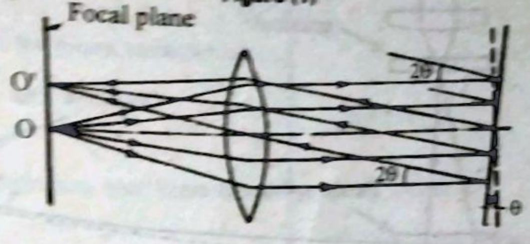


Figure (2)

The distance from OO' is given as,

$$x = 2.\phi.f$$

Where,

θ = Angle of inclination of the plane reflector.

f = Focal length.

Construction and Working

An autocollimator is equipped with the following components.

1. Cross line graticule at focal plane
2. Beam splitter
3. Objective lens
4. Plane reflector
5. Measuring/setting graticule.

Since, autocollimator is the combination of the telescope and collimator, it works on the principles of both the tools.

As Collimator: Initially, the light from the light source (lamp) illuminates the cross line graticule which is placed at the focal plane of objective lensor collimator lens and the diverged light rays from the graticule reaches the beam splitter, where they are reflected on to the objective. The light rays turn into parallel steam and projects onto the plane reflector, which is exactly perpendicular to the optical axis.

As Telescope: The parallel stream of light rays, which incident on the reflector are deflected back, where they intersect with the plane of target graticule. They, the light rays reaches the eyepiece through the beam splitter. This part of working of autocollimator illustrates a telescope.

When the plane reflector is not perpendicular to the optical axis (i.e., if rotated about an angle, θ) the stream of light rays also deflect at a certain angle, equal to the twice the angle of tilt. And the distance between two focus points (i.e., O and O').

$$x = 2.\phi.f$$

Thus, the distance between the two focus points (OO') is directly proportional to the tilt angle of the reflector.

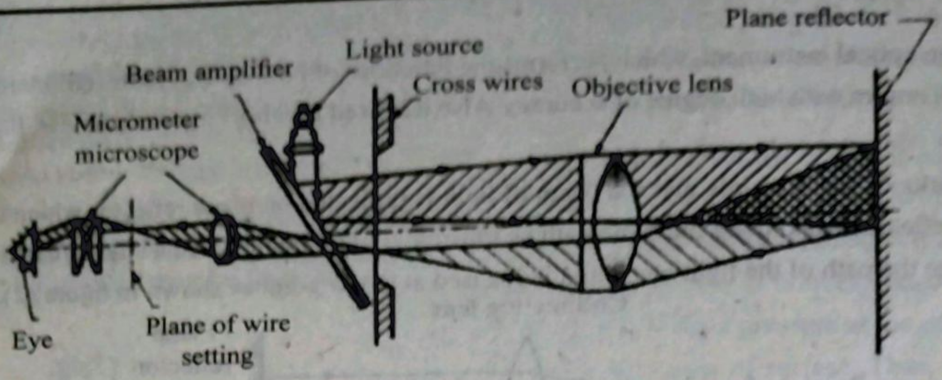


Figure (3): Principle of Autocollimator

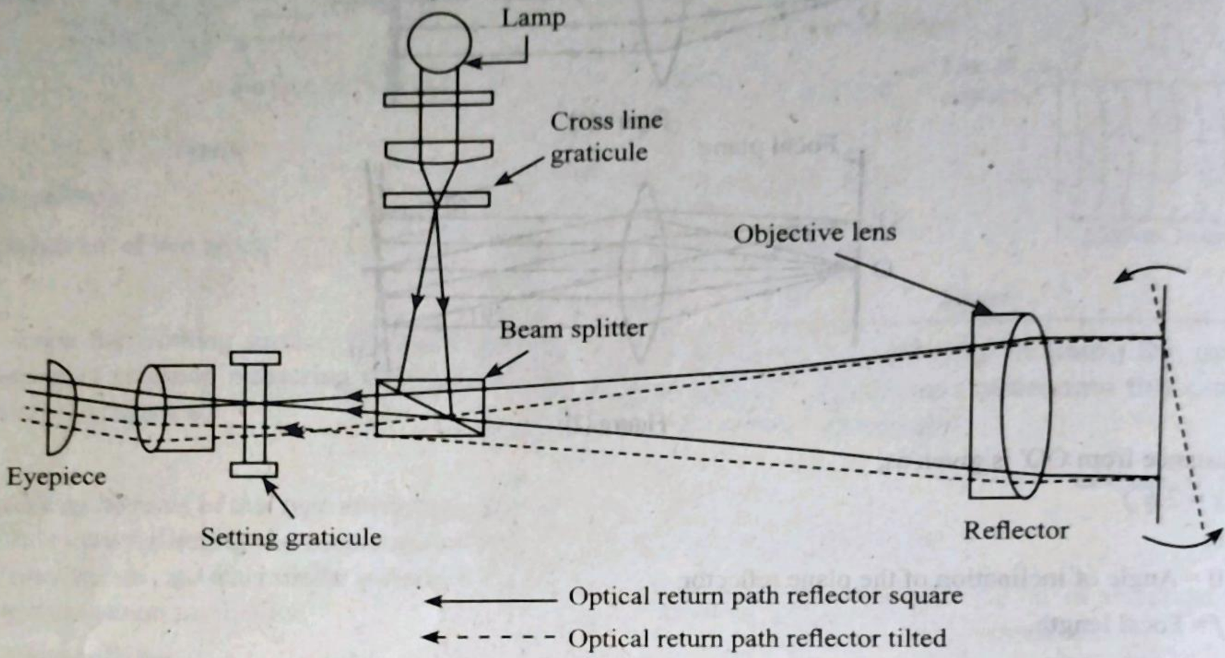


Figure (4): Line Diagram of Autocollimator

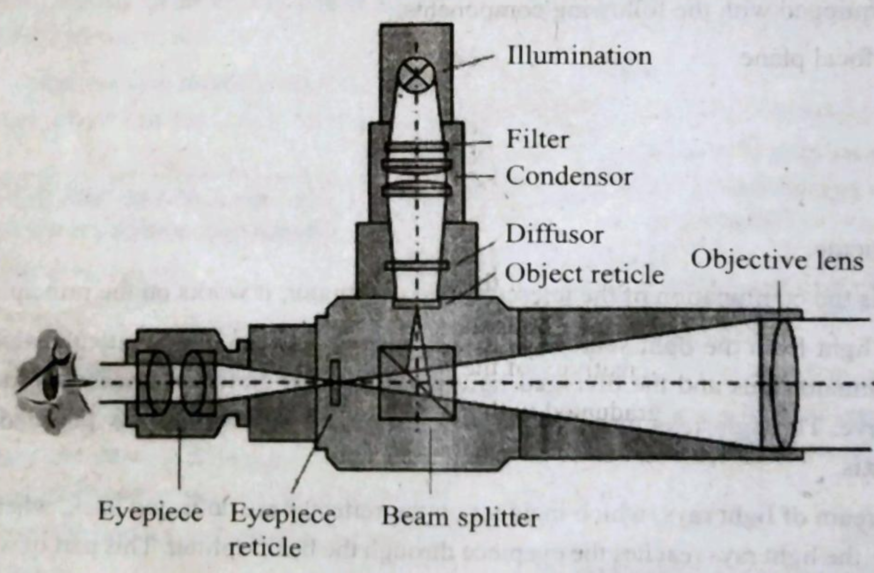


Figure (5): Visual Autocollimator

Characteristics of Autocollimator

1. Any other equipment is not required for focusing.
2. It does not respond to any external factors, except to the tilt of the reflector.
3. High repeatability can be achieved, when the autocollimator and target remain unchanged.

Factors Affecting the Performance of Autocollimator

Among many factors, focal length (f) and effective aperture of objective lens are the two factors which affect the performance of autocollimator. Sensitivity, angular measurement range and displacement of graticule image are dependent on the focal length, whereas working distance (distance between autocollimator and reflector) is regulated by the aperture of objective lens. For more working distance, large reflector must be used.

Disadvantages of Autocollimator

1. The designing of autocollimator is complicated.
2. The final readings are altered due to the air in between the reflector and autocollimator.
3. The flatness and reflectivity of the plane reflector also leads to errors.

Applications

1. It is used for measuring straightness and flatness of surfaces.
2. For evaluating the squareness and parallelism of components.
3. Autocollimator combined with polygons is used for precise angular indexing.
4. Autocollimator is also used in machine tool adjustments.
5. With the aid of master angles, it is used for comparative measurement of components.
6. To measure small linear dimensions.

Q86. Discuss the method of testing the straightness by spirit level and auto collimator.

Answer : [Nov./Dec.-17, (R15), Q7(a) | Model Paper-II, Q9(b)]

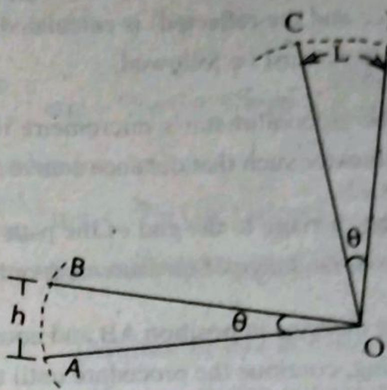
Spirit level mainly comprises of an enclosed glass tube which is attached to a cast iron base. The inner surface of the tube is finished to a large radius convex shape. This radius of curvature of the tube affects the precision or sensitivity of the spirit level. The upper surface of the tube is graduated with a scale. A small bubble of air or vapour is formed inside the tube by filling it with ether or alcohol.

Working Principle

It indicates the flatness of the surface with the position of the bubble i.e., if the spirit level is kept on a horizontal surface, the bubble settles at the middle of the scale. This is because the bubble tends to settle at the highest point in the tube and the centre point is its highest point.

When it is moved by an angle, the bubble starts moving along the tube by a distance through its radius with respect to the angle made by the base.

Figure represents two positions of the base of spirit level i.e., OA and OB and respective bubble positions C and D.



Figure

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,

$$l = R\theta \quad \text{... (1)}$$

And, $h = L\theta$

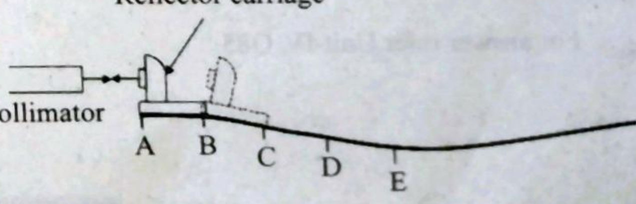
$$\theta = \frac{h}{L} \quad \text{... (2)}$$

From equations (1) and (2),

$$1 = h.\frac{R}{L}$$

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

2. **Autocollimator**



Figure

Measurement of Straightness

Consider a path ABCDE as shown in the figure. Initially, the reflector is placed on the carriage and is positioned on the path AB. Then the carriage is allowed to move to successive positions BC, CD etc. The gap between the points A, B, C... etc is equal to the length of the carriage which is equal to 50mm. If the path is not straight, the carriage will tilt at an angle. This angle is determined by the autocollimator and the difference in height of the two ends or extremes of the carriage (or distance between the point source and the reflected) is calculated for every position of the carriage. In order to check the straightness of the path the following steps must be followed.

1. Place the autocollimator's micrometre nearby carriage to measure vertical displacements. Then adjust the base of the autocollimator such that distance source and reflected image is nearly zero.

2. Move the carriage to the end of the path and check the reflected image through the eyepiece to ensure that the reflected image is in the range of measurement or not. If it is not in range then make fine levelling to the collimator.

3. Place the carriage in position AB and note the reading of autocollimator. Then move the carriage to position BC and take the reading, continue the procedure until the carriage reaches the end of the path.

4. Repeat the same in reverse direction i.e., moving the carriage from the end position to initial position.

5. Determine the average of readings at each position.

Q87. Bring out the importance and utility of straight edge and surface plats in laboratories.

Answer : [Nov./Dec.-17, (R15), Q6(b) | Model Paper-II, Q9(b)]

Straight Edge

For answer refer Unit-IV, Q80.

Surface Plate

For answer refer Unit-IV, Q33.

Surface plate forms the basis of a measurement. These are widely used in workshops and metrological laboratories, where inspection is carried out.

Q88. Describe a method used to check the flatness of a surface plate.

Answer : Nov.-15, (R13), Q5(a)

For answer refer Unit-IV, Q79. Topic: Flatness Comparators.

Q89. Explain the principle of optical flat and auto collimator.

Answer: Nov./Dec.-18, (R16), Q8(b)

Optical Flat

For answer refer Unit-IV, Q82, Topic: Optical Flat.

Autocollimator

For answer refer Unit-IV, Q85.