MODULE 2

SYSTEM OF LIMITS, FITS, TOLERANCE AND GAUGING

CONTENTS

OBJECTIVES

Students will be able to

1 Understand the basic principles of fits and tolerances,

2 Explain various types of fits and their applications,

3 Analyses the various types of tolerances and applications, and

4 Know the fundamental of the systems of fits.

2.1 Definition:

Limits

The maximum and minimum permissible sizes within which the actual size of a component lies are called Limits.

Tolerance:

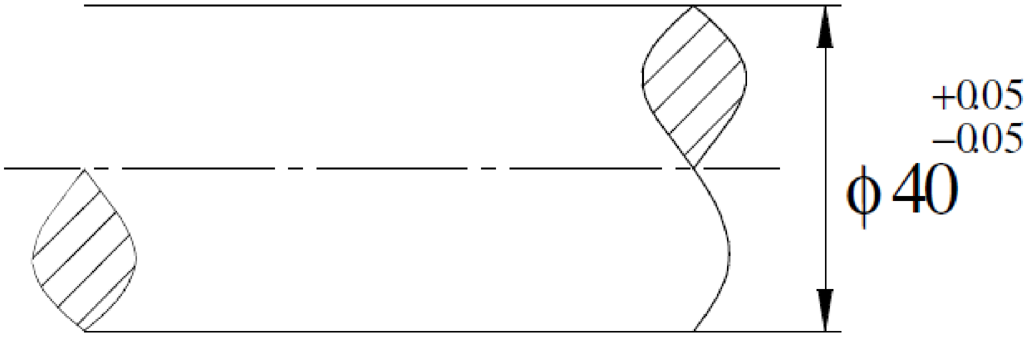
It is impossible to make anything to an exact size, therefore it is essential to allow a definite tolerance or permissible variation on every specified dimension.

Why Tolerances are specified?

· Variations in properties of the material being machined introduce errors.

· The production machines themselves may have some inherent inaccuracies.

· It is impossible for an operator to make perfect settings. While setting up the tools and workpiece on the machine, some errors are likely to creep in.



Consider the dimension shown in fig. When trying to achieve a diameter of 40 mm (Basicor Nominal diameter), a variation of 0.05 mm on either side may result.If the shaft is satisfactory even if its diameter lies between 40.05 mm & 39.95 mm, thedimension 40.05 mm is known as Upper limit and the dimension 39.95 mm is known asLower limit of size. Tolerance in the above example is (40.05-39.95) =0.10 mmTolerance is always a positive quantitative number.

Unilateral Tolerance:

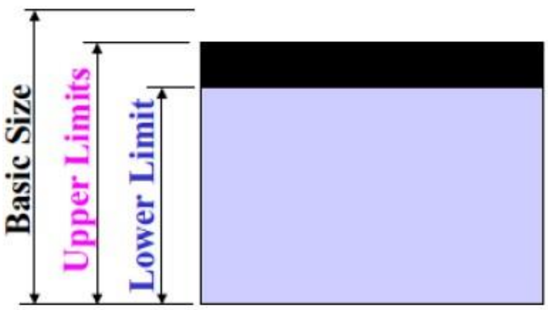
· Tolerances on a dimension may either be unilateral or bilateral.

· When the two limit dimensions are only on one side of the nominal size, (either aboveor below) the tolerances are said to be unilateral.

· For unilateral tolerances, a case may occur when one of the limits coincide with thebasic size.

e.g. $Ø25^{+0.18}_{+0.10}$

Basic Size = 25.00 mm
Upper Limit = 25.18 mm
Lower Limit = 25.10 mm
Tolerance = **0.08 mm**

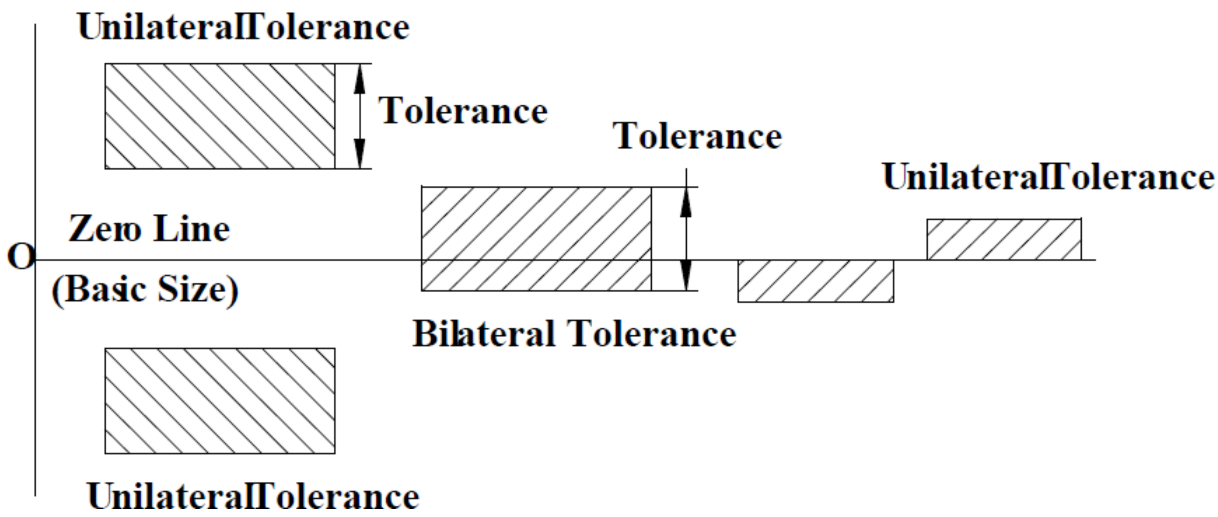


e.g. $Ø25^{-0.10}_{-0.20}$

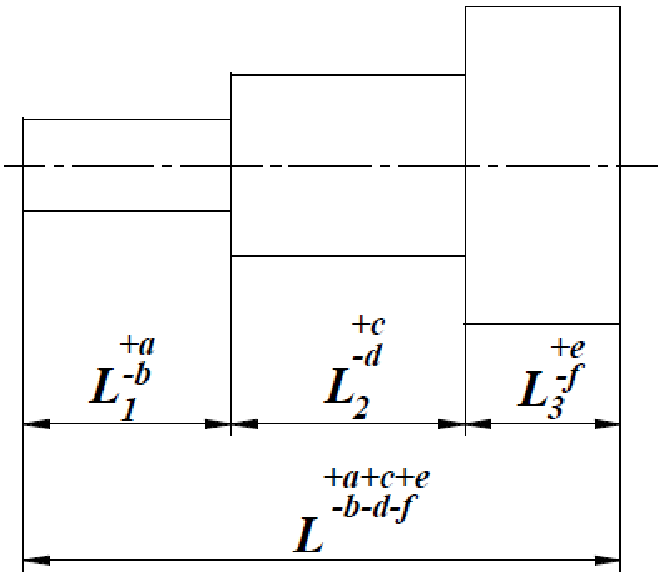
Basic Size = 25.00 mm
Upper Limit = 24.90 mm
Lower Limit = 24.80 mm
Tolerance = **0.10 mm**

Bilateral Tolerance: When the two limit dimensions are above and below nominal size,(i.e. on either side of the nominal size) the tolerances are said to be bilateral.Unilateral tolerances, are preferred over bilateral because the operator can machine to theupper limit of the shaft (or lower limit of a hole) still having the whole tolerance left formachining to avoid rejection of parts.

Schematic representation of tolerances:



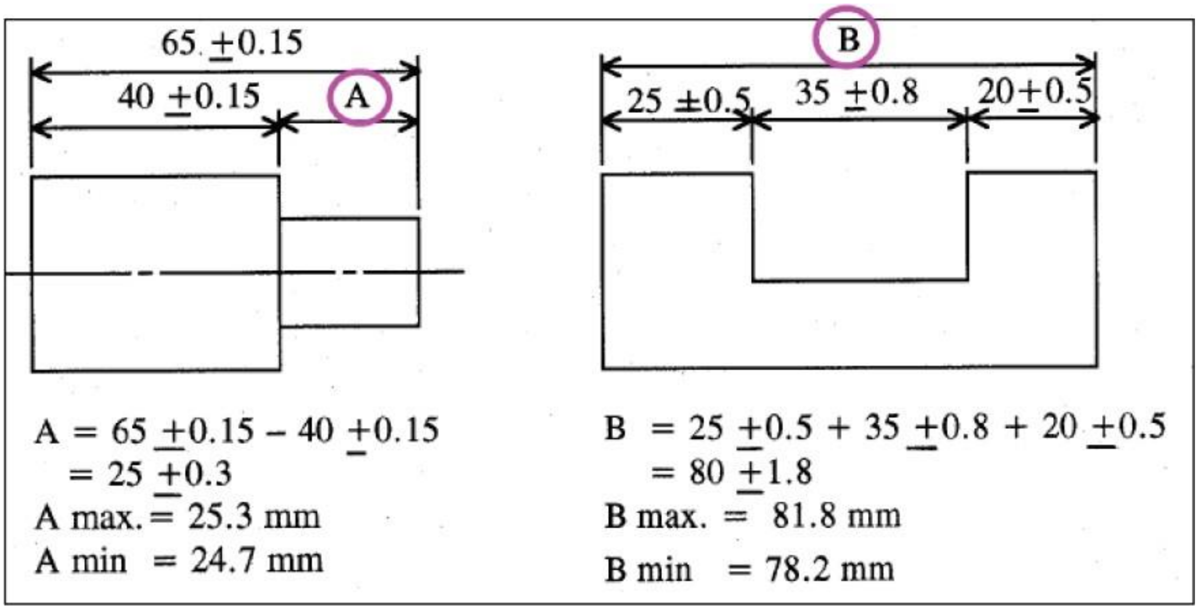
Tolerance Accumulation (or) Tolerance Build up:



If a part comprises of several steps, each step having some tolerance specified over itslength, then the overall tolerance on the complete length will be the sum of tolerances on individual lengths.

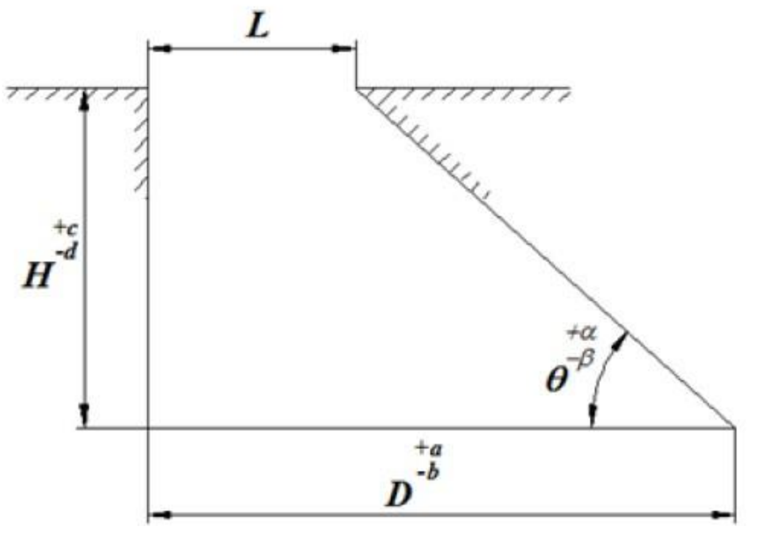
The effect of accumulation of tolerances can be minimized by adopting progressive dimensioning from a common datum.

Another example of tolerance build up is shown below.



Compound Tolerances:

A compound tolerance is one which is derived by consideringthe effect of tolerances on more than one dimension.



For ex, the tolerance on the dimension L is dependent on the tolerances on D, H & q.

The dimension L will be maximum when the base dimension is (D+a), the angle is (q+a),and the vertical dimension is (H-d).

The dimension L will be minimum when the base dimension is (D-b), the angle is (q-b),and the vertical dimension is (H+c).

2.2 LIMITS OF SIZE & TOLERANCE

Terminology of limit systems:

Limits of size: The two extreme permissible sizes of a component between which the actual size should lie including the maximum and minimum sizes of the component.

Nominal size: It is the size of the component by which it is referred to as a matter of convenience.

Basic size: It is the size of a part in relation to which all limits of variation are determined.

Zero Line: It is the line w.r.t which the positions of tolerance zones are shown**.**

Deviation: It is the algebraic difference between a limit of size and the corresponding basic size.

Upper Deviation: It is the algebraic difference between the maximum limit of size and the corresponding basic size. It is denoted by letters ***'ES'*** for a hole and ***'es'*** for a shaft.

Lower Deviation: It is the algebraic difference between the minimum limit of size and the corresponding basic size. It is denoted by letters ***'EI'*** for a hole and ***'ei'*** for a shaft.

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

Allowance: It is the intentional difference between the hole dimensions and shaft dimension for any type of fit.

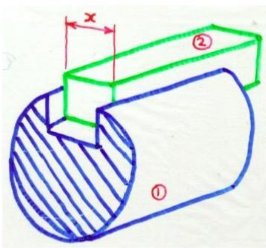
Size of tolerance: It is the difference between the maximum and minimum limits of size.

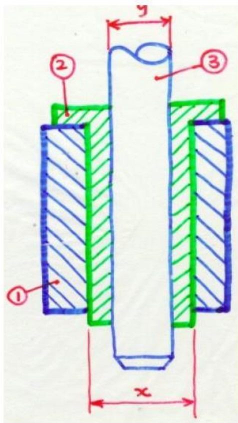
2.3 SYSTEM OF FITS

Fit is an assembly condition between 'Hole' & 'Shaft'

Hole: A feature engulfing a component.

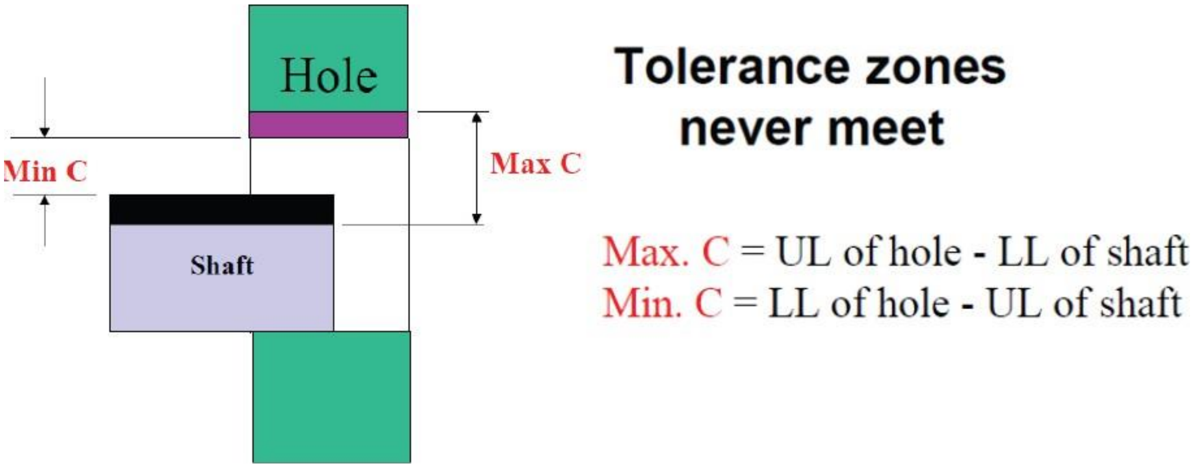
Shaft: A feature being engulfed by a component.





Clearance fit:

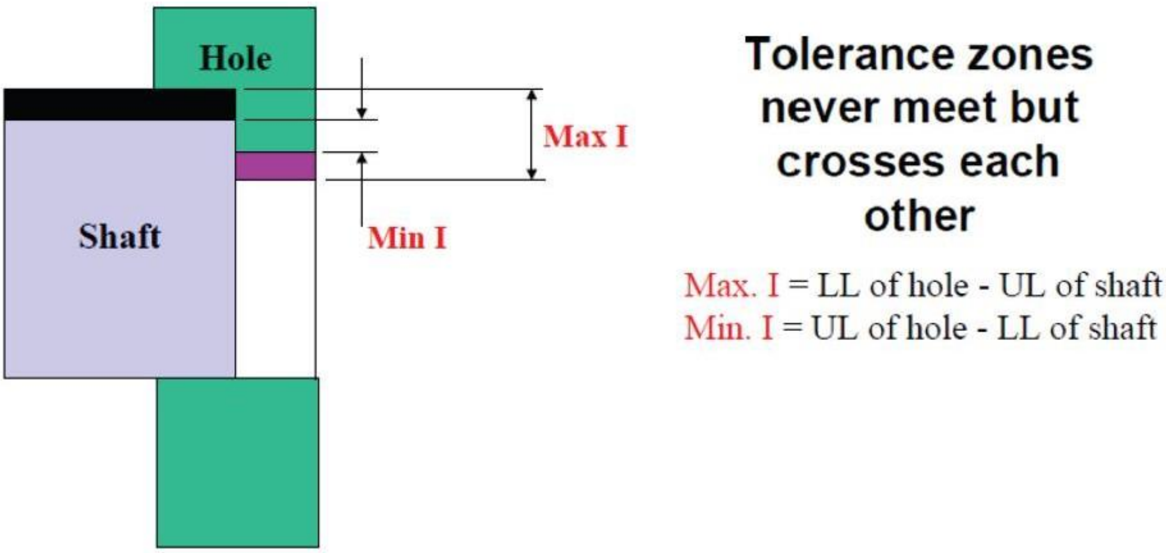
In this type of fit, the largest permitted shaft diameter is less than the smallest hole diameter so that the shaft can rotate or slide according to the purpose of the assembly.



Interference Fit:

It is defined as the fit established when a negative clearance exists between the sizes of holes and the shaft. In this type of fit, the minimum permitted diameter of the shaft is larger than the maximum allowable diameter of the hole. In case of this type of fit, the members are intended to be permanently attached.

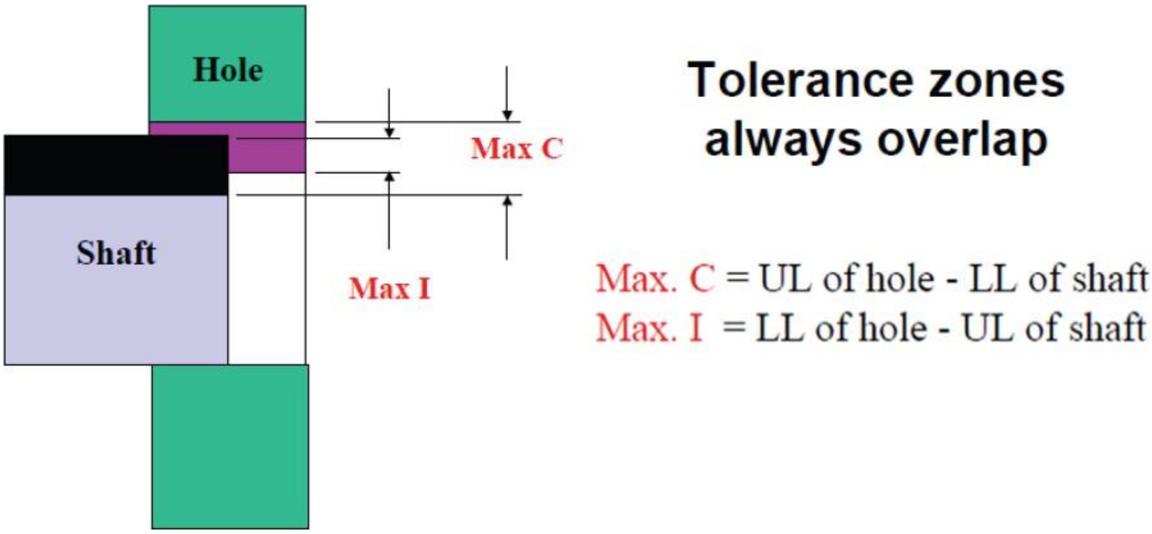
Ex: Bearing bushes, Keys & key ways



Transition Fit:

In this type of fit, the diameter of the largest allowable hole is greater than the smallest shaft, but the smallest hole is smaller than the largest shaft, such that a small positive or negative clearance exists between the shaft & hole.

Ex: Coupling rings, Spigot in mating holes, etc.



Interchangeability:

Interchangeability occurs when one part in an assembly can be substituted for a similar part which has been made to the same drawing. Interchangeability is possible only when certain standards are strictly followed.

Universal interchangeability means the parts to be assembled are from two different manufacturing sources.

Local interchangeability means all the parts to be assembled are made in the same manufacturing unit.

Selective Assembly:

In selective assembly, the parts are graded according to the size and only matched gradesof mating parts are assembled. This technique is most suitable where close fit of twocomponents assembled is required.

Selective assembly provides complete protection against non-conforming assemblies and reduces machining costs as close tolerances can be maintained.

Suppose some parts (shafts & holes) are manufactured to a tolerance of 0.01 mm, then an automatic gauge can separate them into ten different groups of 0.001 mm limit for selective assembly of the individual parts. Thus high quality and low cost can be achieved.

Selective assembly is used in aircraft, automobile industries where tolerances are very narrow and not possible to manufacture at reasonable costs.

2.4 Geometrical Tolerances:

It is necessary to specify and control the geometric features of a component, such as straightness, flatness, roundness, etc. in addition to linear dimensions. Geometric tolerance is concerned with the accuracy of relationship of one component to another and should be specified separately.

Geometrical tolerance may be defined as the maximum possible variation of **form** or **position of form** or **position of a feature.**

Geometric tolerances define the shape of a feature as opposed to its size. There are three basic types of geometric tolerances:

Form tolerances:

Straightness, flatness, roundness, cylindricity

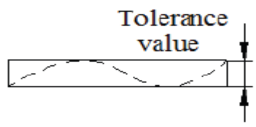
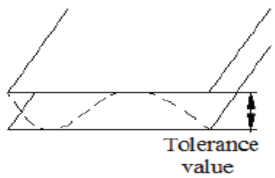
Orientation tolerances:

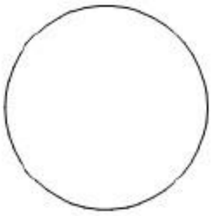
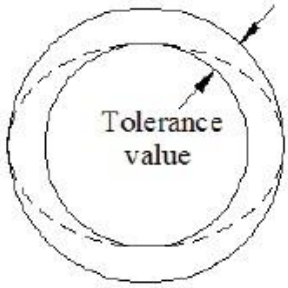
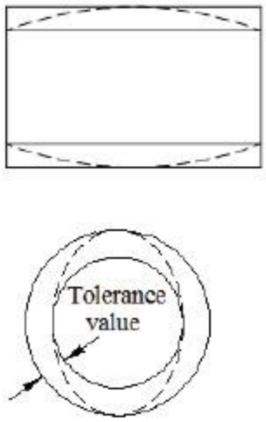
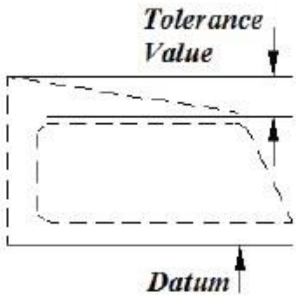
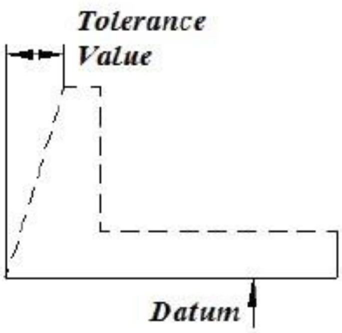
Perpendicularity, parallelism, angularity

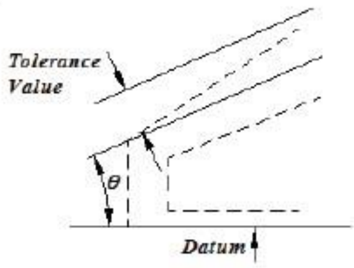
Position tolerances:

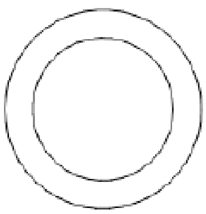
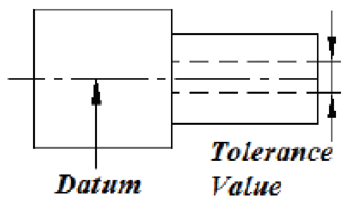
Position, symmetry, concentricity

FORM TOLERANCES

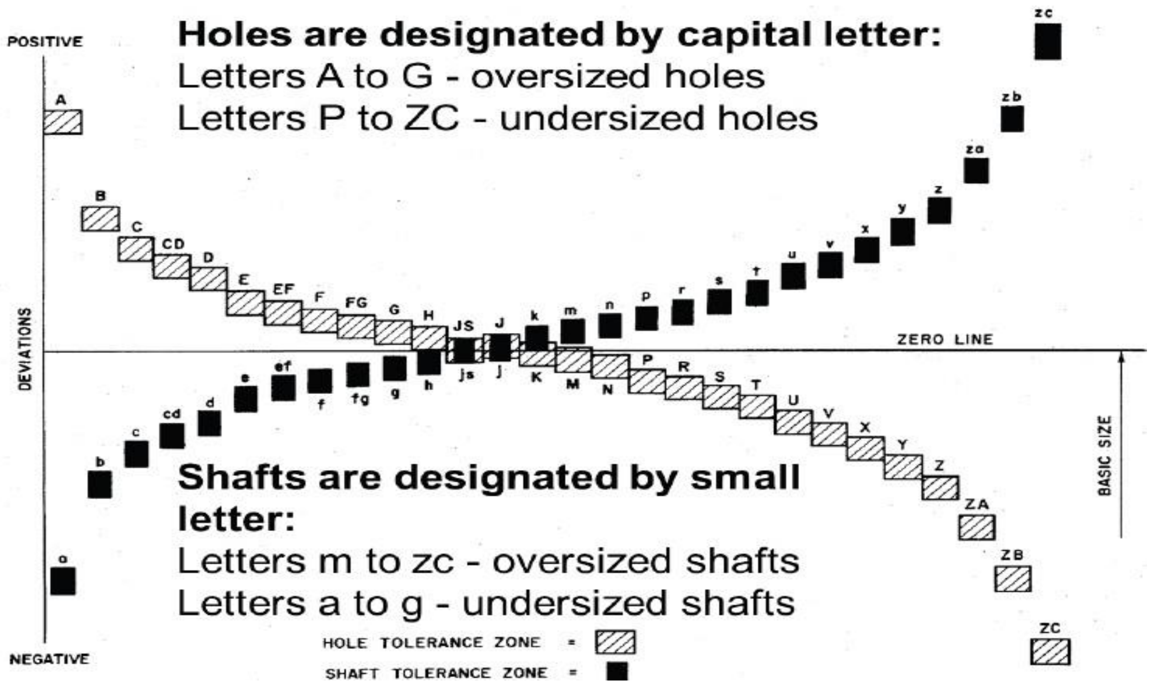
Characteristic or symbol	Function of geometric tolerance	Tolerance zone	Typical example
Straightness	To control the straightness of the line on a surface.	Area between two parallel straight lines in the plane containing the considered line or axis, Tolerance value is the distance between them.	
Flatness 	To control the flatness of a surface.	Area between two planes. Tolerance value is the distance between them.	

Roundness 	To control the errors of roundness of a circle in the plane in which it lies.	Area between two concentric circles. Tolerance value is the radial distance between them.	
Cylindricity 	To control combination of roundness, straightness, and parallelism of a cylindrical surface.	Annular space between two cylinders that are co axial. Tolerance value is the radial distance between them.	
ORIENTATION TOLERANCES			
Parallelism 	To control the parallelism of a line or surface w.r.t some datum.	Area between two parallel lines or space between two parallel lines which are parallel to the datum	
Squareness 	To control the perpendicularity of a line or surface w.r.t a datum.	Area between two parallel lines or space between two parallel lines which are perpendicular to the datum.	

Angularity 	To control the inclination of a line or surface w.r.t a datum.	Area between two parallel lines or space between two parallel lines which are inclined at a specified angle to the datum.	

POSITIONAL TOLERANCES			
Concentricity 	To control the deviation of the position of the position of the center or axis of the toleranced circles or cylinders.	Center or axis to lie within the circle or cylinder. Tolerance value is the diameter of such a circle or cylinder.	

2.5 SYSTEM OF TOLERANCES



'H' is used for holes and 'h'is used for shafts whose fundamental deviation is zero.

Basic shaft: It is a shaft whose upper deviation is zero. i.e. the maximum limit of shaftcoincides with the nominal size.(zero line). Eg: shaft 'h'

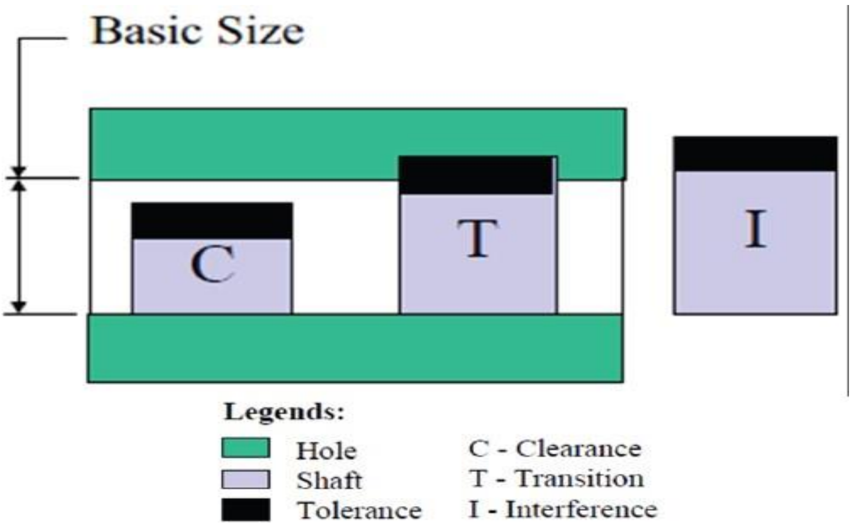
Basic hole: It is a hole whose lower deviation is zero. i.e. the minimum limit of holecoincides with the nominal size.(zero line). Eg: shaft ‘H’

Hole Basis: In this system, the basic diameter of the hole is constant while the shaft sizeis varied according to the type of fit.

Significance of Hole basis system: The bureau of Indian Standards (BIS) recommendsboth hole basis and shaft basis systems, but their selection depends on the productionmethods. Generally, holes are produced by drilling, boring, reaming, broaching, etc.whereas shafts are either turned or ground.

If the shaft basis system is used to specify the limit dimensions to obtain various typesof fits, number of holes of different sizes are required, which in turn requires tools ofdifferent sizes.

Hole basis system:



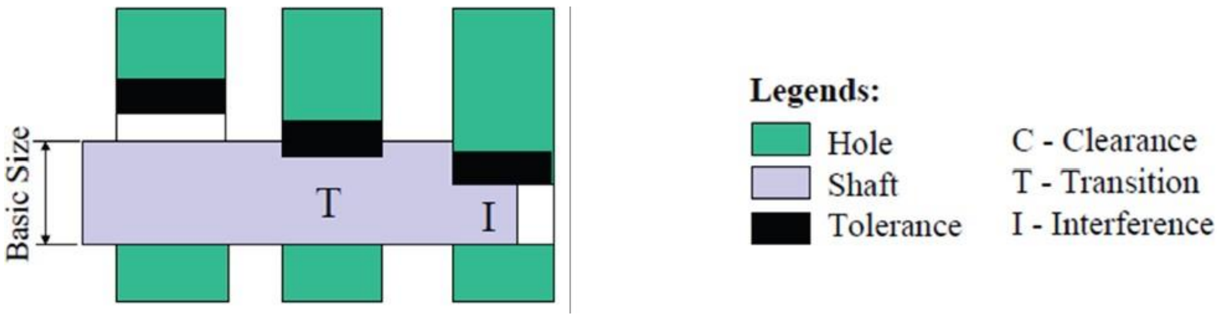
If the hole basis system is used, there will be reduction in production costs as only onetool is required to produce the ole and the shaft can be easily machined to any desiredsize. Hence hole basis system is preferred over shaft basis system.

Shaft Basis system:

In this system, the basic diameter of the shaft is constant while the hole size is varied according to the type of fit.

It may, however, be necessary to use shaft basis system where different fits are required along a long shaft.

For example, in the case of driving shafts where a single shaft may have to accommodate to a variety of accessories such as couplings, bearings, collars, etc., it is preferable to maintain a constant diameter for the permanent member, which is the shaft, and vary the bore of the accessories.



GRADES OF TOLERANCES

Grade is a measure of the magnitude of the tolerance. Lower the grade the finer thetolerance. There are total of 18 grades which are allocated the numbers IT01, IT0, IT1,IT2 T16.

Fine grades are referred to by the first few numbers. As the numbers get larger, so the tolerance zone becomes progressively wider. Selection of grade should depend on the circumstances. As the grades get finer, the cost of production increases at a sharper rate.

TOLERANCE GRADE

The tolerance grades may be numerically determined in terms of the standard tolerance unit '***i***' where ***i***in microns is given by (for basic size up to and including 500 mm) and(for basic size above 500 mm upto and including 3150 mm), where D is in mm and it is the geometric mean of the lower and upper diameters of a particular step in which the component lies.

The above formula is empirical and is based on the fact that the tolerance varies more or less parabolic ally in terms of diameter for the same manufacturing conditions. This is so because manufacture and measurement of higher sizes are relatively difficult.

The various diameter steps specified by ISI are:1-3, 3-6, 6-10, 10-18, 18-30, 30-50, 50-80, 80-120,180-250, 250-315, 315-400, and 400-500 mm. The value of 'D' is taken as the geometric mean for a particular range of size to avoid continuous variation of tolerance with size.

The fundamental deviation of type d,e,f,g shafts are respectively $-16D^{0.44}$, $-11D^{0.41}$, $-5.5D^{0.41}$ & $-2.5D^{0.34}$

The fundamental deviation of type D,E,F,G shafts are respectively $+16D^{0.44}$, $+11D^{0.41}$,$+5.5D^{0.41}$& $+2.5D^{0.34}$.

The relative magnitude of each grade is shown in the table below;

Tol. Grade	IT 5	IT 6	IT 7	IT 8	IT 9	IT 10	IT 11	IT 12	IT 13	IT 14	IT 15	IT 16
	7i	*10i*	*16i*	*25 i*	*40 i*	*64 i*	*100 i*	*160 i*	*250 i*	*400 i*	*640 i*	*1000 i*

It may be noted that from IT 6 onwards, every 5th step is 10 times the respective grade.i.e. IT 11=10xIT6=10x10i=100 i, IT12=10xIT7=10x16i=160 i, etc.

Numerical Problem 1:

Calculate the limits of tolerance and allowance for a 25 mm shaft and hole pair designated by H_8d_9. Take the fundamental deviation for 'd' shaft is $-16D^{0.44}$.

Numerical Problem 2

Determine the tolerances on the hole and the shaft for a precision running fit designated by 50 H_7g_6, given;

50 mm lies between 30-50 mm

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

Fundamental deviation for 'H' hole=0

Fundamental deviation for g shaft =$-2.5D^{0.34}$

IT7=16i and IT6=10i

State the actual maximum and minimum sizes of the hole and shaft and maximum and minimum clearances.

Numerical Problem 3:

Calculate all the relevant dimensions of $35H_7/f_8$ fit, dimension 35 mm falls in the step of 30-50 mm. The fundamental deviation for f shaft is – $5.5D^{0.41}$. i (in microns)=$0.45(D)^{1/3}+0.001D$, IT7=16i and IT8=25i.

LIMIT GAUGES

A ***Go-No GO*** gauge refers to an inspection tool used to check a workpiece against itsallowed tolerances. It derives its name from its use: the gauge has two tests; the checkinvolves the workpiece having to pass one test (Go) and fail the other (No Go).

It is an integral part of the quality process that is used in the manufacturing industryto ensure interchangeability of parts between processes, or even between different manufacturers.

A Go - No Go gauge is a measuring tool that does not return a size in the conventional sense, but instead returns a state. The state is either acceptable (the part is withintolerance and may be used) or it is unacceptable (and must be rejected).

They are well suited for use in the production area of the factory as they require little skill or interpretation to use effectively and have few, if any, moving parts to be damaged in the often hostile production environment.

PLAIN GAUGES

Gauges are inspection tools which serve to check the dimensions of the manufactured parts. Limit gauges ensure the size of the component lies within the specified limits. They are non-recording and do not determine the size of the part. Plain gauges are used for checking plain (Unthreaded) holes and shafts.

Plain gauges may be classified as follows;

According to their type:

(a) Standard gauges are made to the nominal size of the part to be tested and have the measuring member equal in size to the mean permissible dimension of the part to be checked. A standard gauge should mate with some snugness.

(b) Limit Gauges These are also called **'go'** and **'no go'** gauges. These are made to the limit sizes of the work to be measured. One of the sides or ends of the gauge is made to correspond to maximum and the other end to the minimum permissible size. The function of limit gauges is to determine whether the actual dimensions of the work are within or outside the specified limits.

According to their purpose:

(a) Work shop gauges: Working gauges are those used at the bench or machine in gauging the work as it being made.

(b) Inspection gauges: These gauges are used by the inspection personnel to inspect manufactured parts when finished.

(c) Reference or Master Gauges: These are used only for checking the size or condition of other gauges.

According to the form of tested surface:

Plug gauges: They check the dimensions of a hole

Snap & Ring gauges: They check the dimensions of a shaft.

According to their design:

Single limit & double limit gauges

Single ended and double ended gauges

Fixed & adjustable gauges

LIMIT GAUGING

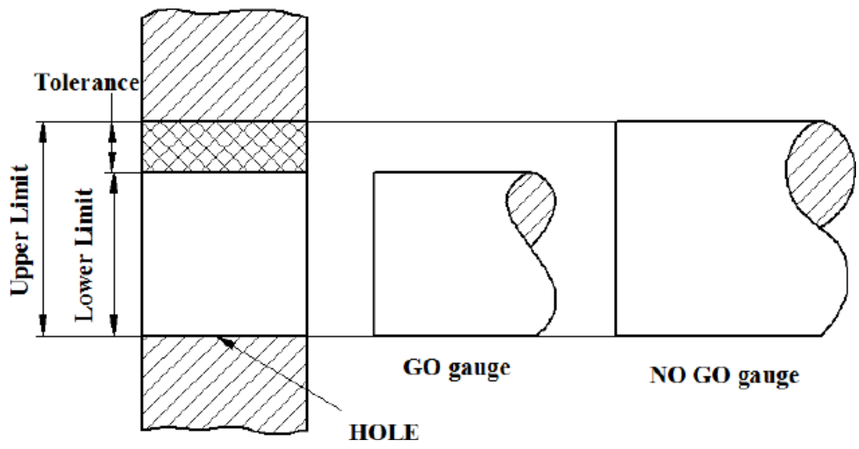
Limit gauging is adopted for checking parts produced by mass production. It has the advantage that they can be used by unskilled persons.

Instead of measuring actual dimensions, the conformance of product with tolerance specifications can be checked by a 'GO' and 'NO GO' gauges.

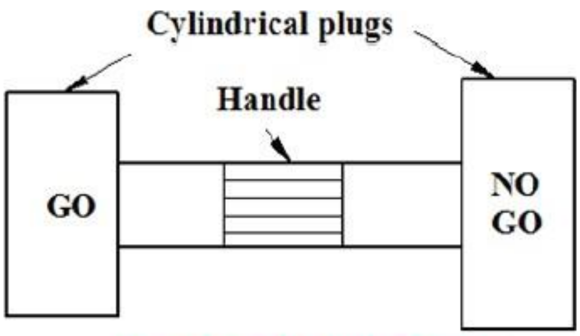
A 'GO' gauge represents the maximum material condition of the product (i.e. minimum hole size or maximum shaft size) and conversely a 'NO GO' represents the minimum material condition (i.e. maximum hole size or minimum shaft size).

Plug gauges:

Plug gauges are the limit gauges used for checking holes and consist of two cylindrical wear resistant plugs. The plug made to the lower limit of the hole is known as 'GO' end and this will enter any hole which is not smaller than the lower limit allowed. The plug made to the upper limit of the hole is known as 'NO GO' end and this will not enter any hole which is smaller than the upper limit allowed. The plugs are arranged on either ends of a common handle.



Plug gauges are normally double ended for sizes upto 63 mm and for sizes above 63 mm they are single ended type.

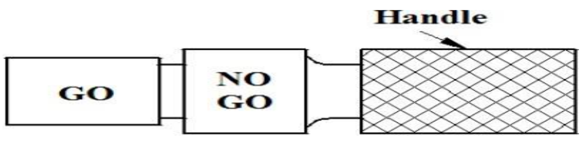


Double ended Plug Gauge

The handles of heavy plug gauges are made of light metal alloys while the handles of small plug gauges can be made of some nonmetallic materials.

Progressive plug gauges:

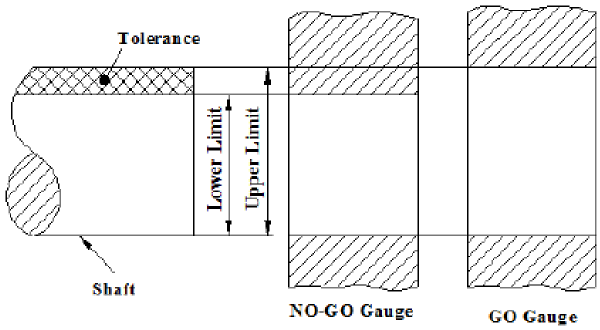
For smaller through holes, both GO & NO GO gauges are on the same side separatedby a small distance. After the full length of GO portion enters the hole, further entry isobstructed by the NO GO portion if the hole is within the tolerance limits.



Progressive Plug Gauge

Ring gauges:

Ring gauges are used for gauging shafts. They are used in a similar manner to that of GO & NO GO plug gauges. A ring gauge consists of a piece of metal in which a hole of required size is bored.



SNAP (or) GAP GAUGES:

A snap gauge usually consists of a plate or frame with a parallel faced gap of the required dimension. Snap gauges can be used for both cylindrical as well as non cylindrical work as compared to ring gauges which are conveniently used only for cylindrical work.

Double ended snap gauges can be used for sizes ranging from 3 to 100 mm.For sizes above 100 mm upto 250 mm a single ended progressive gauge may be used.

Desirable properties of Gauge Materials:

The essential considerations in the selection of material of gauges are;

1 Hardness to resist wear.

2 Stability to preserve size and shape

3 Corrosion resistance

4 Machinability for obtaining the required degree of accuracy.

5 Low coefficient of friction of expansion to avoid temperature effects.

Materials used for gauges:

High carbon steel: Heat treated Cast steel (0.8-1% carbon) is commonly used for most gauges.

Mild Steel: Case hardened on the working surface. It is stable and easily machinable.

Case hardened steel: Used for small & medium sized gauges.

Chromium plated & Hard alloys: Chromium plating imparts hardness, resistance to abrasion & corrosion. Hard alloys of tungsten carbide may also be used.

Cast Iron: Used for bodies of frames of large gauges whose working surfaces are hard inserts of tool steel or cemented carbides.

Glass: They are free from corrosive effects due to perspiration from hands. Also they are not affected by temperature changes.

Invar: It is a nickel-iron alloy (36% nickel) which has low coefficient of expansion but not suitable for usage over long periods.

(The name, Invar, comes from the word invariable, referring to its lack of expansion or contraction with temperature changes. It was invented in 1896 by Swiss scientist Charles Eduard
Guillaume. He received the Nobel Prize in Physics in 1920 for this discovery, which enabled improvements in scientific instruments).

Taylor's Principle of Gauge Design:

According to Taylor, 'Go' and 'No Go' gauges should be designed to check maximum and minimum material limits which are checked as below;

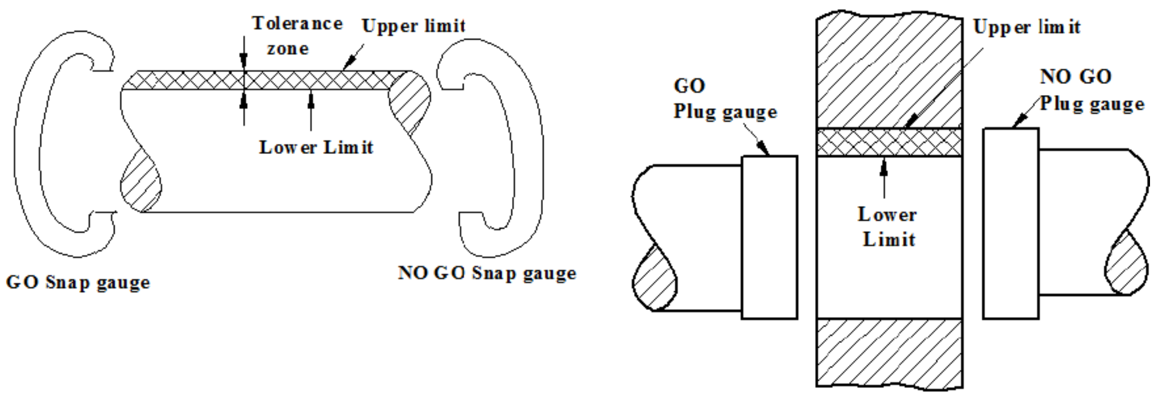
'GO' Limit. This designation is applied to that limit of the two limits of size which corresponds to the maximum material limit considerations, i.e. upper limit of a shaft and lower limit of a hole.

The GO gauges should be of full form, i.e. they should check shape as well as size.

'No Go' Limit:

This designation is applied to that limit of the two limits of size which corresponds to the minimum material condition. i.e. the lower limit of a shaft and the upper limit of a hole.

'No Go' gauge should check only one part or feature of the component at a time, so that specific discrepancies in shape or size can be detected. Thus a separate 'No Go' gauge is required for each different individual dimension.



Gauge Tolerance:

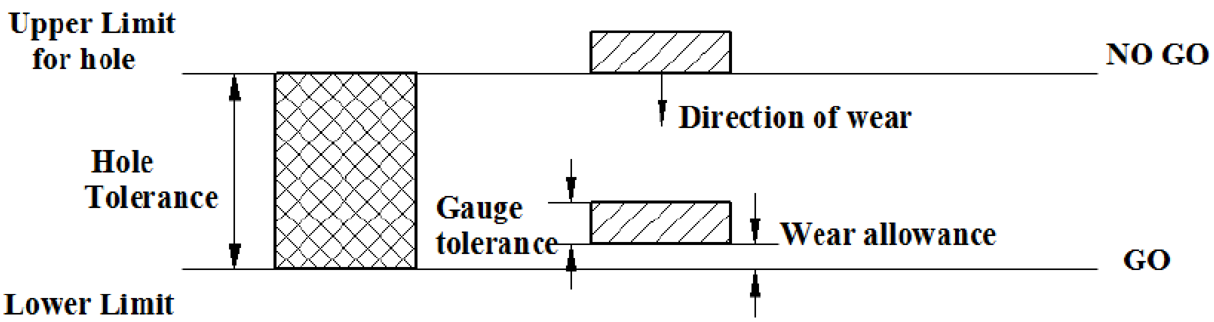
Gauges, like any other jobs require a manufacturing tolerance due to reasonableimperfections in the workmanship of the gauge maker. The gauge tolerance should bekept as minimum as possible though high costs are involved to do so. The tolerance onthe GO & NO GO gauges is usually 10% of the work tolerance.

Wear Allowance:

The GO gauges only are subjected to wear due to rubbing against the parts during inspection and hence a provision has to be made for the wear allowance. Wear allowances taken as 10% of gauge tolerance and is allowed between the tolerance zone of the gauge and the maximum material condition. *(i.e.* lower limit of a hole & upper limit of a shaft). If the work tolerance is less than 0.09 mm, wear allowance need not be given unless otherwise stated.

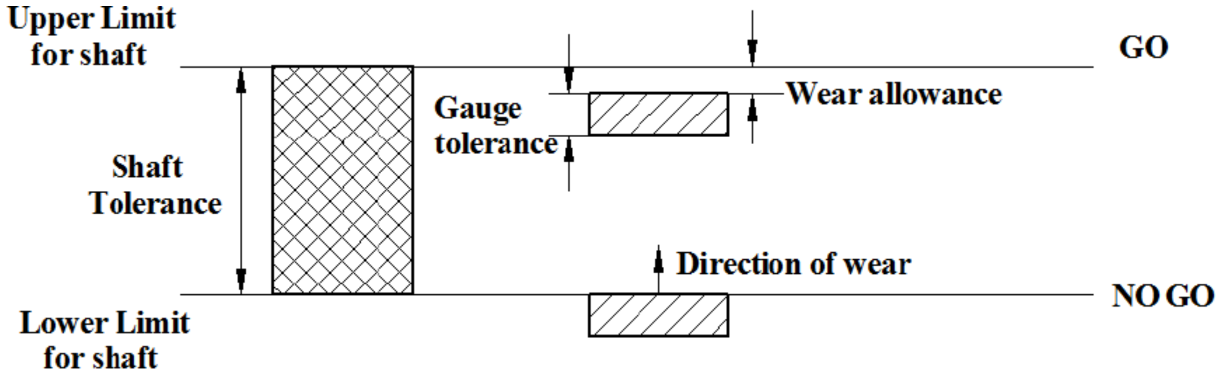
Present British System of Gauge & Wear Tolerance:

PLUG GAUGES: (For checking tolerances on holes)



GO & NO GO Plug Gauges (For checking hole tolerance)

RING/SNAP GAUGES: (For checking tolerances on shafts)



GO & NO GO Ring Gauges (For checking shaft tolerance)

Numerical Problem 1:

Calculate the dimensions of plug & ring gauges to control the production of 50 mm shaft & hole

pair of H_7d_8 as per IS specifications. The following assumptions may be made: 50 mm lies in diameter step of 30-50 mm. Upper deviation for 'd' shaft is $-16D^{0.44}$ and lower deviation for hole

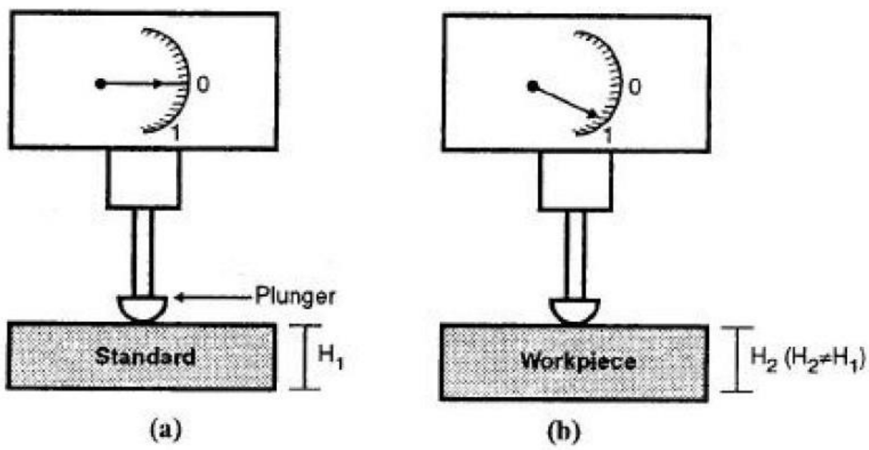
H is zero. Tolerance unit in 'i' in microns is $=0.45\sqrt[3]{D}+0.001D$ and IT6=10i and above IT6 grade, the tolerance is multiplied by 10 at each 5th step.

Numerical Problem 2

Determine the actual dimensions to be provided for a shaft and hole 90 mm size for H_8e_9type clearance fit. Size 90 mm falls in the diameter step of 80-100 mm. Value of standard tolerance unit $=0.45\sqrt[3]{D}+0.001D$. The values of tolerances for IT8 & IT9grades are 25i & 40i respectively. Value of fundamental deviation for 'e' type shaft is $-11D^{0.41}$. Also design the GO & NO GO gauges considering wear allowance as 10% of gauge tolerance.

2.6 COMPARATORS

Comparators can give precision measurements, with consistent accuracy by eliminating human error. They are employed to find out, by how much the dimensions of the given component differ from that of a known datum. If the indicated difference is small, a suitable magnification device is selected to obtain the desired accuracy of measurements. It is an indirect type of instrument and used for linear measurement. If the dimension is less or greater, than the standard, then the difference will be shown on the dial. It gives only the difference between actual and standard dimension of the workpiece. To check the height of the job H2 ,with the standard job of height H_1



Initially, the comparator is adjusted to zero on its dial with a standard job in positions shown in Figure(a). The reading H1is taken with the help of a plunger. Then the standard job is replaced by the work-piece to be checked and the reading H2 is taken. If H1and H2 are different, then the change i~ the dimension will be shown on the dial of the comparator. Thus difference is then magnified 1000 to 3000 X to get the clear variation in the standard and actual job.

In short, Comparator is a device which

(1) Picks up small variations in dimensions.

(2) Magnifies it.

(3) Displays it by using indicating devices, by which comparison can be made with somestandard value.

Characterstics or Basic requirements of comparators

1) The instrument must be of robust design and construction so as to withstand the effect of ordinary usage without impairing its measuring accuracy.
2) The including devices must be such that readings are obtained in least possible time. The system should be free from backlash, wear effects and the inertia should be minimum.
3) Provision for maximum compensation to temperature effects.
4) The scale must be linear and must have straight line characteristics.
5) The instrument must be versatile i.e., its design must be such that it can be used for a wide range of measurements.
6) The measuring pressure should be low and constant.
7) The indicator (pointer, liquid column etc) should be clear and free from oscillations.

2.6.1 Classification of comparators:

1. Mechanical Comparator: It works on gears pinions, linkages, levers, springs etc.

2. Pneumatic Comparator: Pneumatic comparator works by using high pressure air, valves,back pressure etc.

3. Optical Comparator: Optical comparator works by using lens, mirrors, light source etc.

4. Electrical Comparator: Works by using step up, step down transformers.

5. Electronic Comparator: It works by using amplifier, digital signal etc.

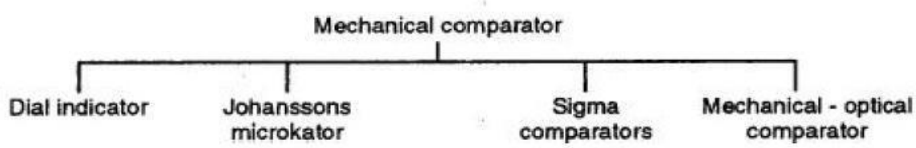
6. Combined Comparator: The combination of any two of the above types can give the best result.

Characteristics of Good Comparators:

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

2.6.2 Mechanical Comparator:

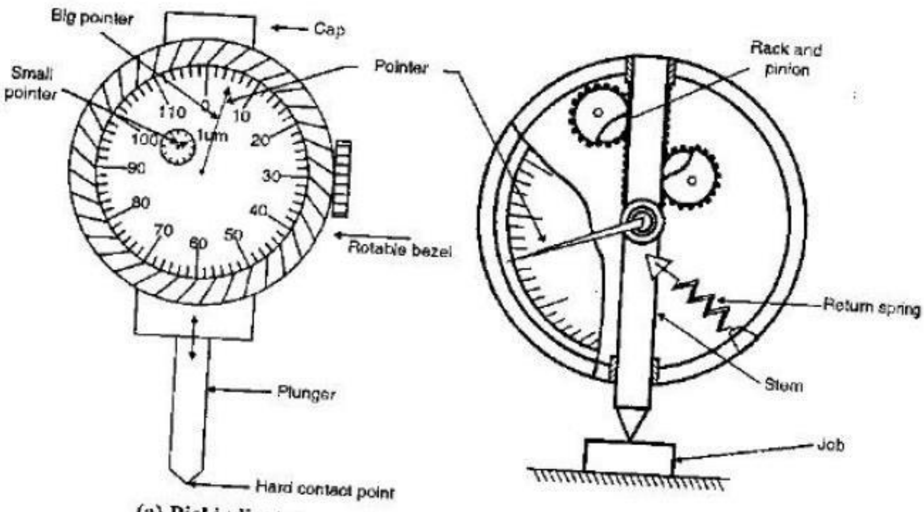
It is self controlled and no power or any other form of energy is required. It employs mechanical means for magnifying the small movement of the measuring stylus. The movement is due to the difference between the standard and the actual dimension being checked



The method for magnifying the small stylus movement in all the mechanical comparators is by means of levers, gear trains or combination of these. They are available of different make and each has it's own characteristic. The various types of mechanical comparators are dial indicator, rack and pinion, sigma comparator, Johansson mikrokator.

a. Dial Indicator:

It operates on the principle, that a very slight upward pressure on the spindle at the contact point is multiplied through a system of gears and levers. It is indicated on the face of the dial by a dial finger. Dial indicators basically consists of a body with a round graduated dial and a contact point connected with a spiral or gear train so that hand on the dial face indicates the amount of movement of the contact point. They are designed for use on a widerange of standard measuring devices such as dial box gauges, portal dial, hand gauges, dialdepth gauges, diameter gauges and dial indicator snap gauge.



(a) Dial indicator

(b) Mechanism of dial indicator

Corresponds to a spindle movement of 1 mm. The movement mechanism of the instrument is housed in a metal case for it's protection. The large dial scale is graduated into100 divisions. The indicator is set to zero by the use of slip gauges representing the basic size of part.

Requirements of Good Dial Indicator:

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

Applications:

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

6. To check trueness of milling machine arbors and to check the parallelism of shaper arm with table surface or vice.

b) Johansson Mikrokator :

This comparator was developed by C.F. Johansson.

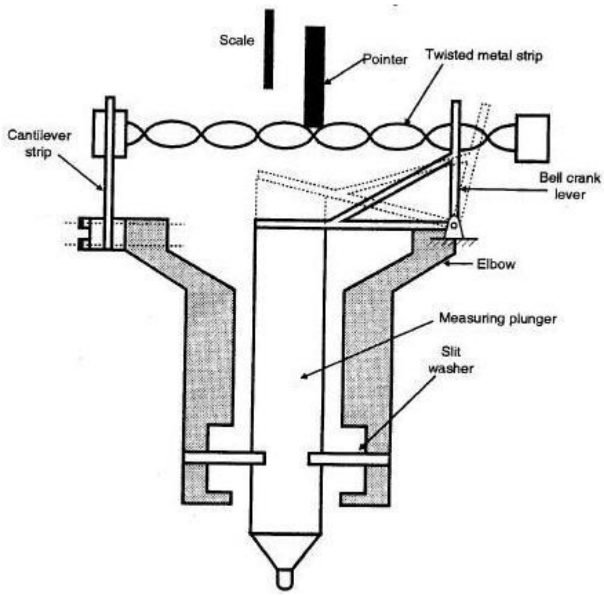
Principle:

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

Construction:

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

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



Advantages of Mechanical Comparator:

1. They do not require any external source of energy.

2. These are cheaper and portable.

3. These are of robust construction and compact design.

4. The simple linear scales are easy to read.

5. These are unaffected by variations due to external source of energy such air, electricityetc.

Disadvantages:

1. Range is limited as the pointer moves over a fixed scale.

2. Pointer scale system used can cause parallax error.

3. There are number of moving parts which create problems due to friction, and ultimatelythe accuracy is less.

4. The instrument may become sensitive to vibration due to high inertia.

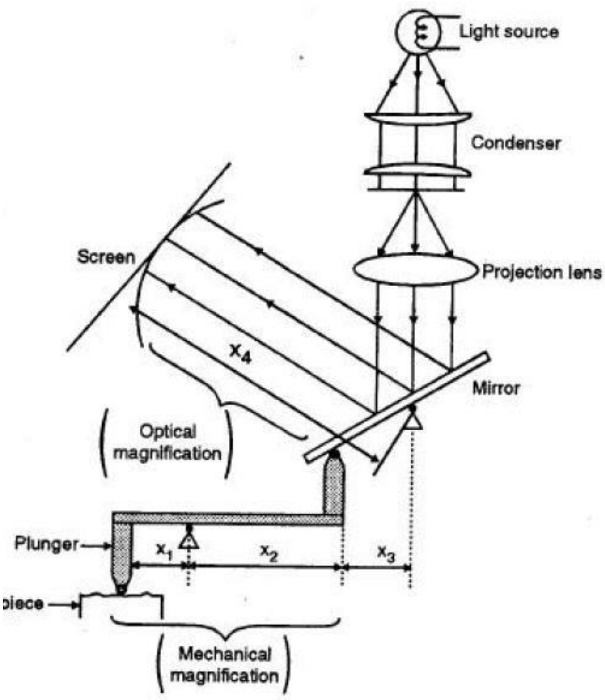
c) Mechanical - Optical Comparator:

Principle:

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

Construction:

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



The back reflection type mirror will give two reflected images as shown in Figure,hence the exact reflected image cannot be identified.

Advantages:

1. These Comparators are almost weightless and have less number of moving parts, due tothis there is less wear and hence lessfriction.70

2. Higher range even at high magnification is possible as the scale moves past the index.

3. The scale can be made to move past a datum line and without having any parallax errors.

4. They are used to magnify parts of very small size and of complex configuration such asintricate grooves, radii or steps.

Disadvantages:

1. The accuracy of measurement is limited to 0.001 mm

2. They have their own built in illuminating device which tends to heat the instrument.

3. Electrical supply is required.

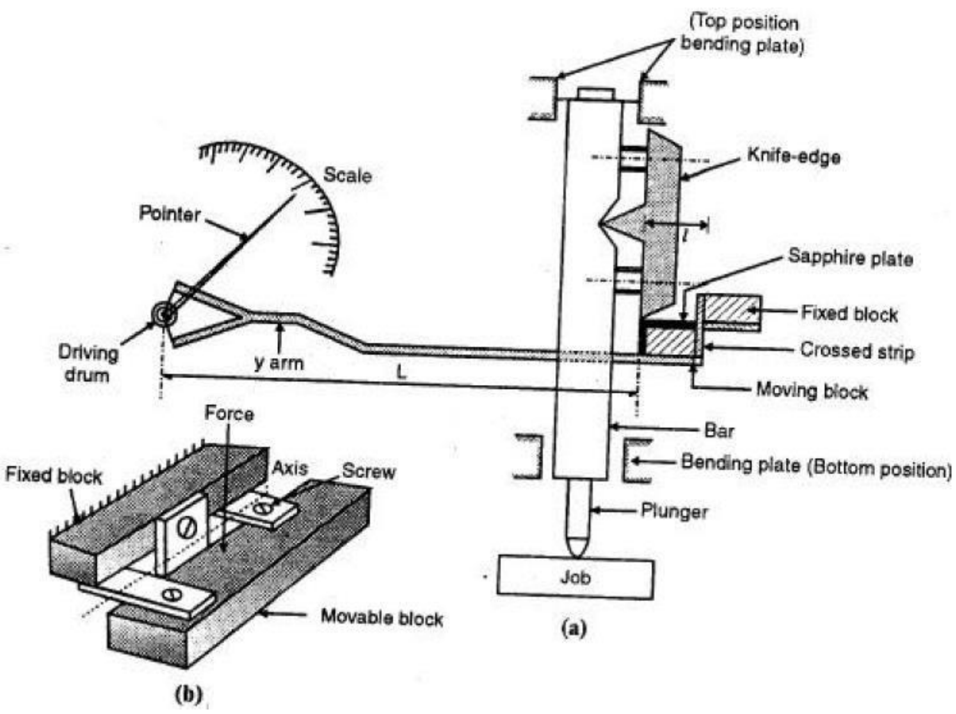
4. Eyepiece type instrument may cause strain on the operator.

5. Projection type instruments occupy large space and they are expensive.

6. When the scale is projected on a screen, then it is essential to take the instrument to a darkroom in order to take the readings easily.

d) Sigma Comparator:

The plunger is attached to a bar which is supported between the bending plates at thetop and bottom portion



The bar is restricted to move in the vertical direction. A knife edge is fixed to the bar.

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

If l = Distance from hinge pivot to the knife edge

L = Length of y-arm

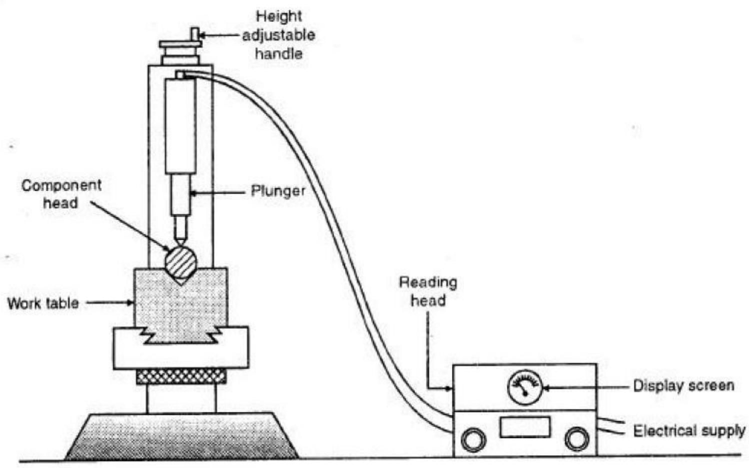
R = Driving drum radius

D Length of the pointer

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

2.6.3 Electrical Comparators

Electrical comparators give a wide range of advantages. As we know, components like levers, gears, racks and pinions, activate mechanical devices. The accuracy and life of the instruments are affected as they are subjected to wear and friction.



Electrical comparators have no moving parts. Thus a high degree of reliability is expected from these instruments. Generally there are two important applications of electrical comparators:

1. Used as measuring heads

2. Used for electrical gauging heads, to provide usual indication to check the dimensions within the limits laid down.

The first application is very important when there is a requirement for precise measurement for e.g. Checking or comparison of workshop slip gauges against inspection slip gauges. The second application is used to indicate with a green light if a dimension is within the limits. A red lamp indicates an undersize dimension; a yellow lamp indicates an oversize dimension. So the operator is not required to be aware of the actual tolerances on the dimension. After setting the instrument correctly, all that needs to be done is to place the component under the plunger of the gauging head. The signal lamps provide in standard positive indication of the acceptability of the dimension under test.

Advantages:

1. Measuring units can be remote from indicating units.
2. Variable sensitivity which can be adjusted as per requirement.
3. No moving parts, hence it can retain accuracy over long periods.
4. Higher magnification is possible as compared to mechanical comparator.

Disadvantages:

1. The accuracy of working of these comparators is likely to be affect due to temperature and humidity.
2. It is not a self contained unit; it needs stabilized power supply for its operation.
3. Heating of coils can cause zero drifts and it may alter calibration.
4. It is more expensive than mechanical comparator.

2.6.4 Pneumatic Comparators (Solex Gauge):

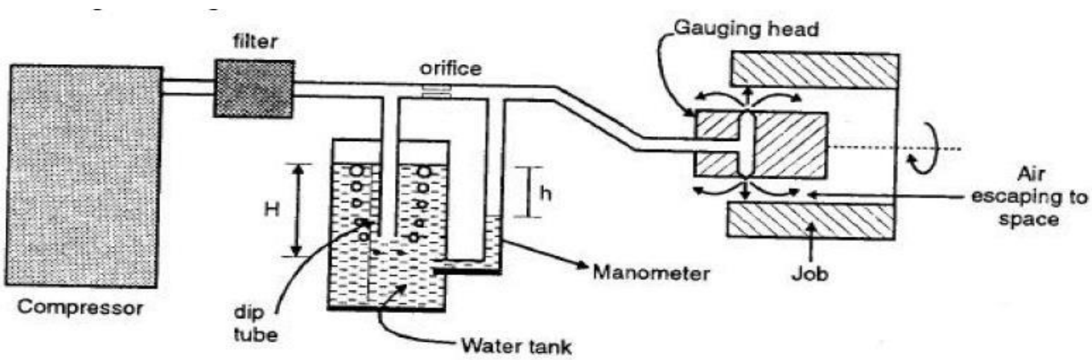
Principle:

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

Working:

The air is compressed in the compressor at high pressure whichis equal to Water head H. The excess air escapes in the form of bubbles. Then the metric amount of air is passed through the orifice at the constant pressure. Due to restricted area, atA1 position, the back pressure is generated by the head of water displaced in the manometer tube. To determine the roundness of the job, the job is rotated along the jet axis, if no variation in the pressure reading is obtained then we can say that the job is perfectly circular at position A1.

Then the same procedure is repeated at various positions A2, A3, A4, position and variation in the pressure reading is found out. Also the diameter is measured at position A1corresponding to the portion against two jets and diameter is also measured at various position along the length of the bore.



Any variation in the dimension changes the value of h, e.g. Change in dimension of0.002 mm changes the value of h from 3 to 20 mm. Moderate and constant supply pressure is required to have the high sensitivity of the instrument.

Advantages:

1. It is cheaper, simple to operate and the cost is low.
2. It is free from mechanical hysteresis and wear.
3. The magnification can be obtained as high as 10,000 X.
4. The gauging member is not in direct contact with the work.
5. Indicating and measuring is done at two different places.
6. Tapers and ovality can be easily detected.
7. The method is self cleaning due to continuous flow of air through the jets and thismakes the method ideal to be used on shop floor for online controls.

Disadvantages:

1. They are very sensitive to temperature and humidity changes.
2. The accuracy may be influenced by the surface roughness of the component beingchecked.
3. Different gauging heads are needed for different jobs.
4. Auxiliary equipments such as air filters, pressure gauges and regulators are needed.
5. Non-uniformity of scale is a peculiar aspect of air gauging as the variation of backpressure is linear, over only a small range of the orifice size variation.

OUTCOMES

Students will be able to

1. Understand the concept of limits, fits, gauges
2. Analysis types of fits and gauges.
3. Understand the principle of Johnson Mikrokator, sigma comparator, dial indicator, LVDT, back pressure gauges, Solex comparators and Zeiss Ultra Optimeter

SELF ASSESMENT QUESTIONS

1. What is a fit?
2. What is the difference between clearance and interference?
3. Mention the applications of clearance, interference and transitions fits.
4. Which of the following are clearance, transition and interference fits?
   i. Push fit,
   ii. Wringing fit,
   iii. Force fit, and
   iv. Slide fit.
5. Differentiate between „Hole basis system and „Shaft basis system.

FURTHER READING

1. Jain R. K., 1997, Engineering Metrology, Khanna Publishers.
2. Shawne A. K., 1998, Mechanical Measurement and Instrumentation, Dhanpat Rai and Co. (P) Ltd.
3. Hazra Chowdhury, 1995, Workshop Technology, Media Promoters and Publishers Pvt. Ltd