Chapter 1
System of Limits and Fits

1.1 Introduction:

The knowledge of metrology is of vital importance in the modern competitive industrial environment. This course is designed to familiarize Engineers and Scientists with Metrology, the science of measurement. A quantitative analysis of design based on sound metrology principles will help engineers and scientists to design better products and services. In order to evaluate multiple solutions to the design, physical measurements are made and the data analyzed. Predictions need to be made on how well the design will perform to its specifications before full scale production begins. Tests are performed using prototype models, computer simulation, designed experiments, destructive and non-destructive tests, scale models and stress tests among the many other methods of evaluation. In this course, you will learn to apply end-to-end metrology across all disciplines involved in producing a product. The role of metrology in the various phases of a products lifecycle will be covered.

1.2 Definition:

Metrology (from Ancient Greek metron (measure) and logos (study of)) is the science of measurement. Metrology includes all theoretical and practical aspects of measurement.

Metrology is concerned with the establishment, reproduction, conservation and transfer of units of measurement & their standards. For engineering purposes, metrology is restricted to measurements of length and angle & quantities which are expressed in linear or angular terms. Measurement is a process of comparing quantitatively an unknown magnitude with a predefined standard.

Measurement is collection of quantitative data. A measurement is made by comparing a quantity with a standard unit. Since this comparison cannot be perfect, measurements inherently include error.

1.3 Need for Inspection:

- Olden days production was in small scale, products used to be assembled by single person.
- Due to technological development mass production has started
- Hand fit method cannot serve the purpose
- Modern industrial mass production needs interchangeable production
- Production of each component becomes independent process
- It's essential any products chosen at random need to fit properly.

1.4 Precision and Accuracy:

Precision: The precision of an instrument indicates its ability to reproduce a certain reading with a given accuracy. In other words, it is the degree of agreement between repeated results. Precision data have small dispersion (spread or scatter) but may be far from the true value.

Accuracy: The degree of closeness to true value.

A measurement can be accurate but not precise, precise but not accurate, neither, or both. A measurement system is called *valid* if it is both accurate and precise.

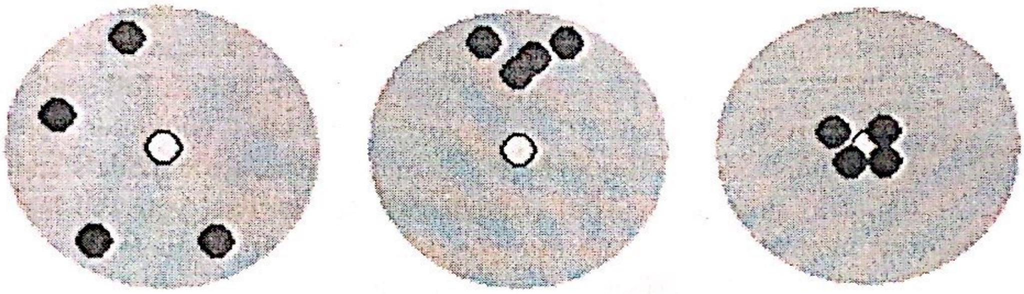


Figure indicates precision and accuracy

Table indicates the difference between accuracy and precision

Sl.No	Accuracy	Precision
1	It is the closeness with the true value of the quantity being measured	It is a measure of reproducibility of the measurements
2	The accuracy of measurement means conformity to truth	The term precise means clearly or sharply defined
3	Accuracy can be improved	Precision cannot be improved
4	Accuracy depends upon simple techniques of analysis	Precision depends upon many factors and requires many sophisticated techniques of analysis
5	Accuracy is necessary but not sufficient condition for precision	Precision is necessary but not a sufficient condition for accuracy

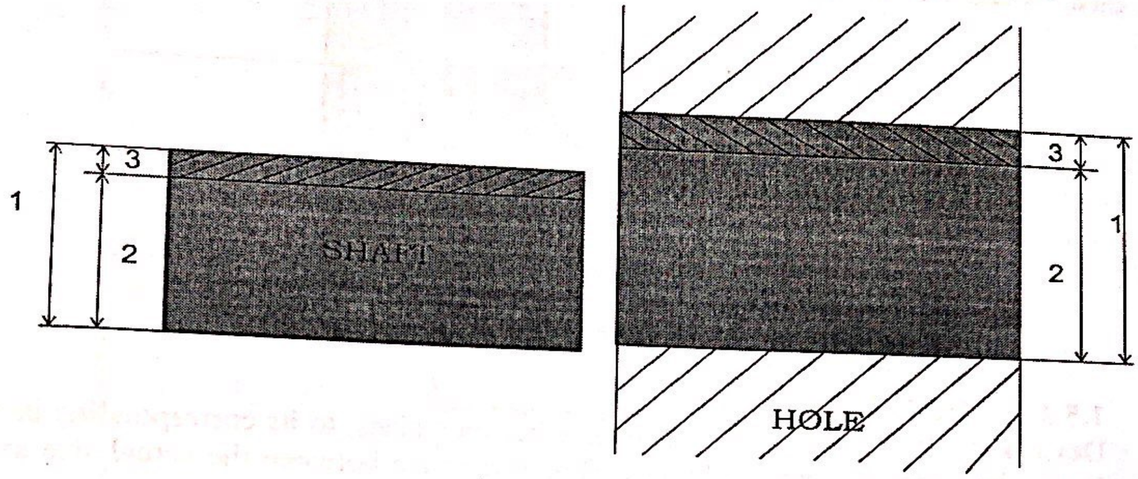
1.5 LIMIT SYSTEM:

1.5.1 Limit:

The maximum upper variation or lower variation given about to which a component can be made is called Limit.

Definition:

The two extreme permissible sizes between which the actual size of the object lies is called Limit. The maximum size is called upper limit the minimum size is called lower limit



1. UPPER LIMIT
2. LOWER LIMIT
3. TOLERANCE

1.5.2 Tolerance

Tolerance:

It is the difference between maximum limit of size and the minimum limit of size. It is always positive and is expressed only as a number without a sign. The permissible variation or deviation which can be given for the actual size of the object is called tolerance.

Types:

a) Unilateral Tolerance.

b) Bilateral tolerance.

a) Unilateral Tolerance: - A tolerance method using a deviation in only one direction, either plus or minus, from the specified dimension It may be completely above the actual size or below the actual size.

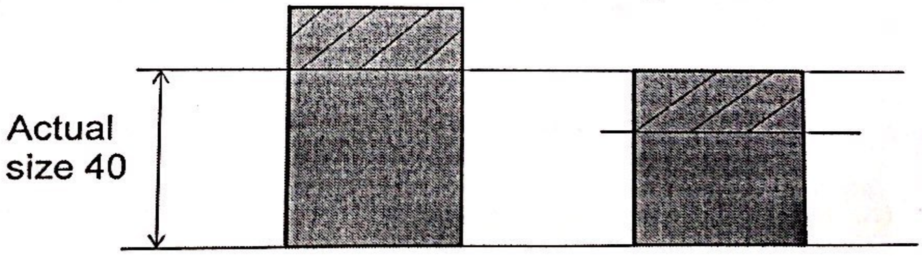


Figure indicates unilateral tolerance

b) Bilateral Tolerance: - A tolerance method using an equal plus and minus deviation from the specified dimension. Tolerance is given on both the sides of the actual size, and then it's called as bilateral tolerance

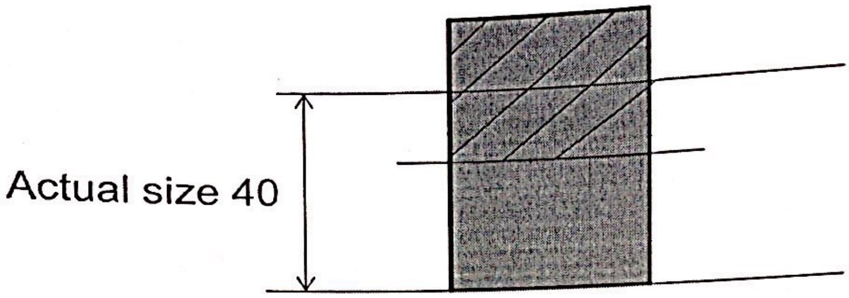


Figure indicates bilateral tolerance

1.5.3 Deviation

Deviation: - It is the algebraic difference between sizes, to its corresponding basic size. It may be positive, negative or zero. The difference between the actual size and basic size is called deviation

Types:

(a) Upper Deviation
(b) Lower Deviation

- Upper Deviation: - It is the algebraic difference between maximum limit of size and its corresponding basic size.
- Lower Deviation: - It is the algebraic difference between minimum limit of size and its corresponding basic size.
- Actual Deviation: - It is the algebraic difference between actual size and its corresponding basic size.

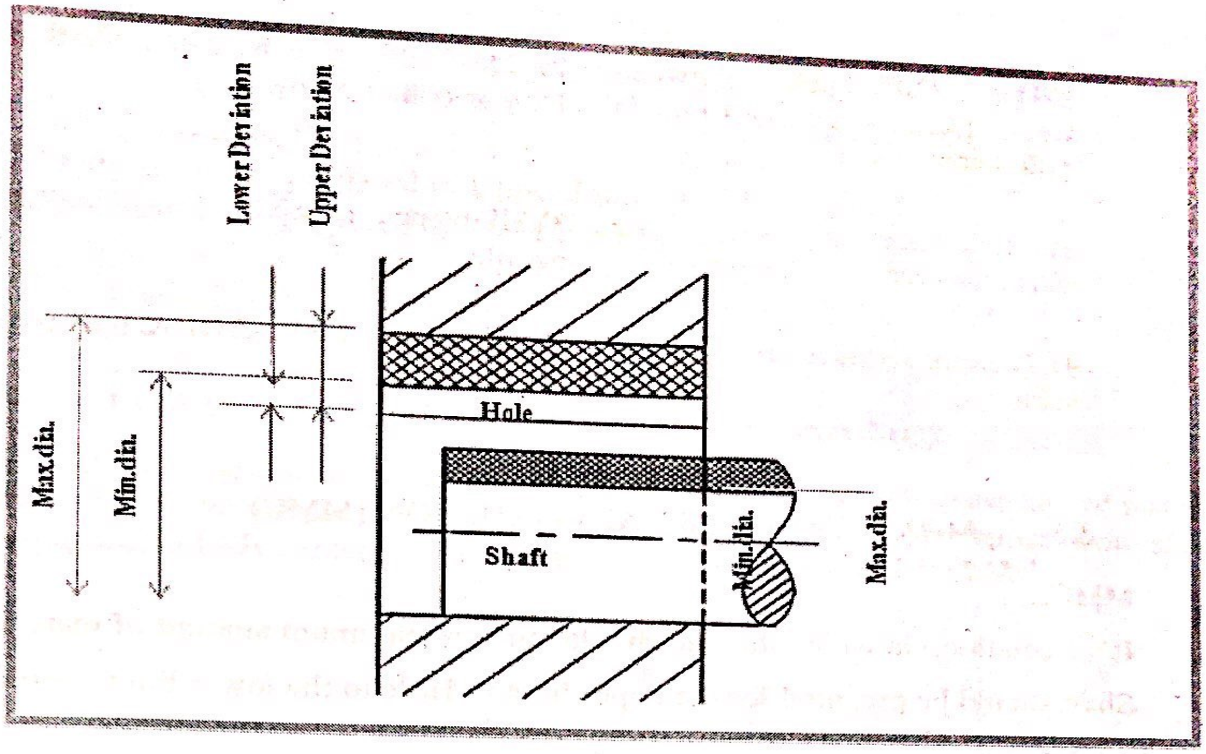


Figure indicates the upper and lower deviation

Shaft:	lower deviation will be more & upper deviation is less
Hole:	lower deviation is less & upper deviation is more.

1.5.4 Allowance & Tolerance

Tolerance is given for Manufacturers; Allowance is given for assembling people

Allowance:

The difference between the mating parts in order to get the required amount of fit is called Allowance

Types of Allowances:

1) Positive ⟹ MMC ⟹ Clearance Fit

2) Negative ⟹ LMC ⟹ Interference Fit

Table indicates difference between Allowance & Tolerance

TOLERANCE	ALLOWANCE
1)Permissible variation in Size/Dimension is called Tolerance	1) Difference Between the Dimensions of Mating Parts is called Allowance

2)The Difference between Upper Limit & Lower Limit is Tolerance	2) The Difference between Shaft & Hole is called Allowance
3) Tolerance are given for Manufacturers	3)Allowance is given for assembly people
4) Tolerance values are absolute values	4) Allowance are Positive & negative

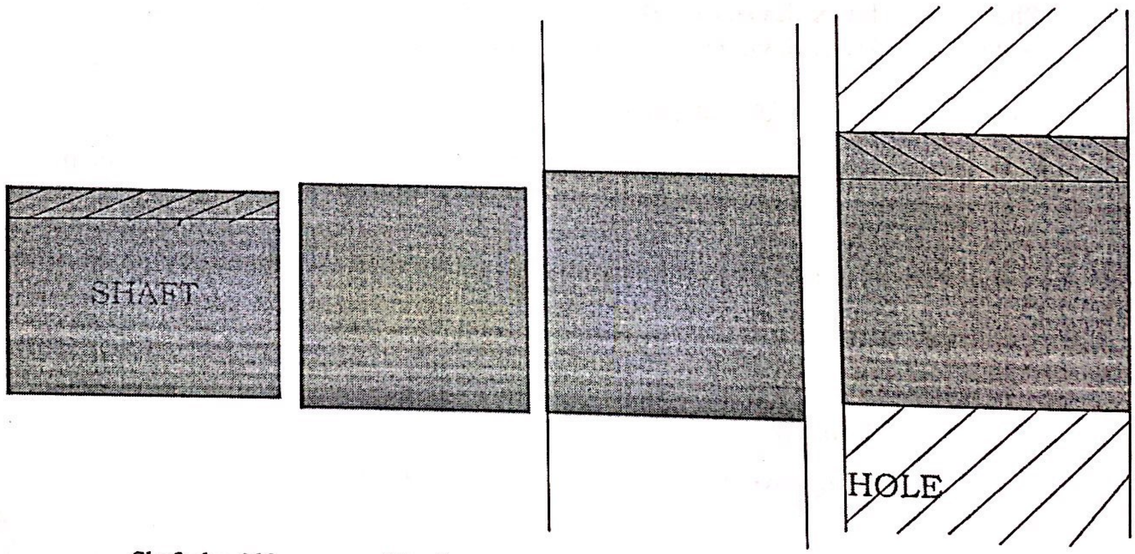
1.5.5 MAXIMUM MATERIAL CONDITION (MMC)

MMC:

It's a condition in which the size should contain maximum amount of material.

Shaft should be prepared for the upper limit & Hole to the lower limit should correspond to MMC.

Clearance fits are usually dimensioned for MMC



Shaft should be prepared for the upper limit (Large Diameter) & Hole to the lower limit(Small Dia) should correspond to MMC.
Clearance fits are usually dimensioned for MMC

Example:

$$\text{Shaft of Ø } 29.98^{+0.000}_{-0.015}$$

+0.025

+0.000

Hole of Ø 30.00

Shaft should be prepared to Upper Limit Ø 29.98

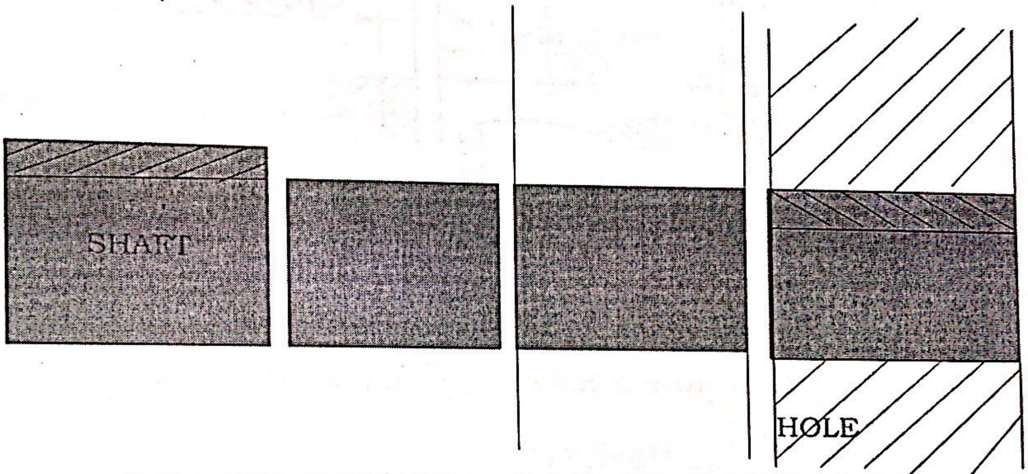
Hole should be prepared to lower limit Ø 30.00

Difference= +0.02

Fit obtained is Clearance

1.5.6 LOWER/LEAST MATERIAL CONDITION(LMC)

LMC: It's a condition in which the size should contain minimum amount of material. Shaft should be prepared for the lower limit & Hole to the upper limit should correspond to LMC. Interference fits are usually dimensioned for LMC



Shaft should be prepared for the Lower limit (Small Diameter) & Hole to the lower limit(Small Dia) should correspond to LMC.
Interference fits are usually dimensioned for LMC

Example:

+0.035

+0.020

Shaft of Ø 30

+0.021

+0.000

Hole of Ø 30

Shaft should be prepared to lower limit Ø 30.020

Hole should be prepared to upper limit Ø 30.021

Fit obtained is Interference

1.5.7 Terminology

Size: - It is a number expressed in a particular unit in the measurement of length.

Basic Size: - It is the size based on which the dimensional deviations are given.

Actual Size: - It is the size of the component by actual measurement after it is manufactured. It should lie between the two limits of size.

Zero line: - In graphical representation of the above terms, the zero line represents the basic size. This line is also called as the line of zero deviation.

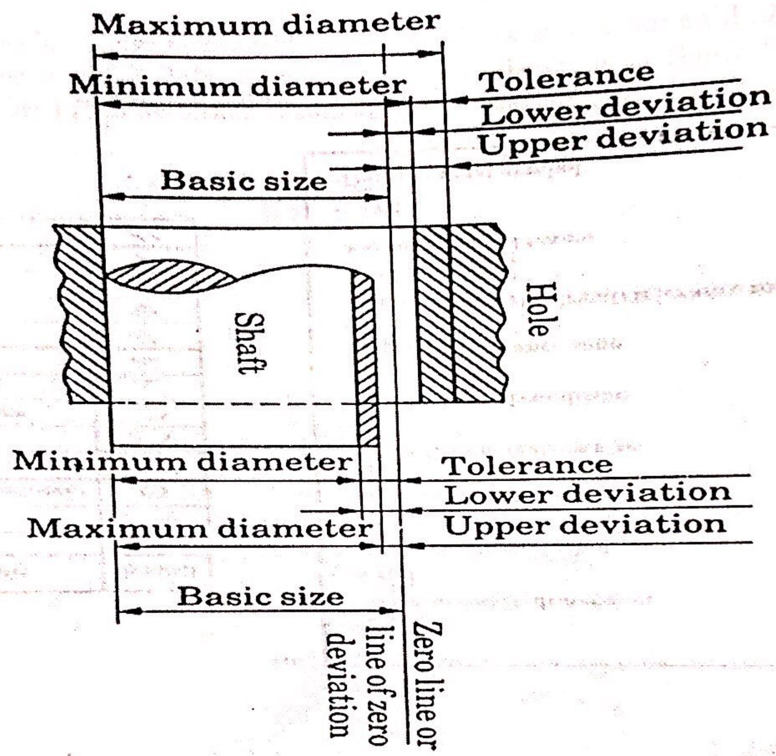


Figure indicates terminology of limit system

1.6 FITS:

It is the relationship that exists between two mating parts, a hole and shaft with respect to their dimensional difference before assembly.

Types of Fits:

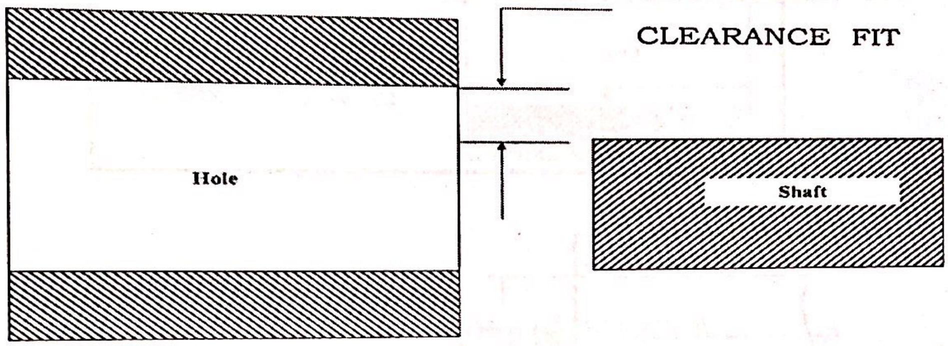
(1) Clearance

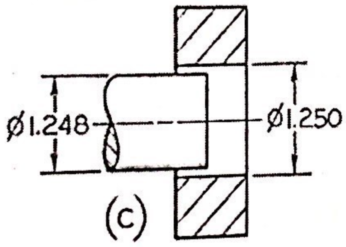
(2) Interference

(3) Transition

1.6.1 Clearance fit: - (Positive Allowance)

It is a fit which always provides clearance. Here the tolerance zone of the hole will be above the tolerance zone of the shaft.
e.g. 20 H7/g6.
Both MMC & LMC can be used here.
Maximum clearance is the difference between the maximum hole and minimum shaft. LMC
Minimum clearance is the difference between the minimum hole and maximum shaft. MMC





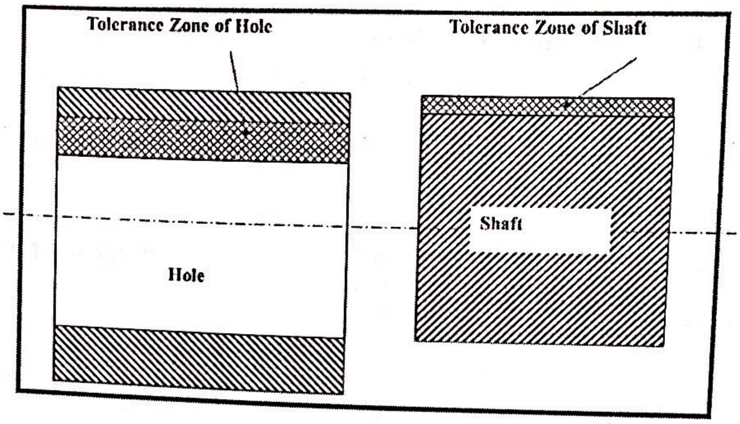
Minimum air space is 0.002". This is the allowance and is always positive in a clearance fit

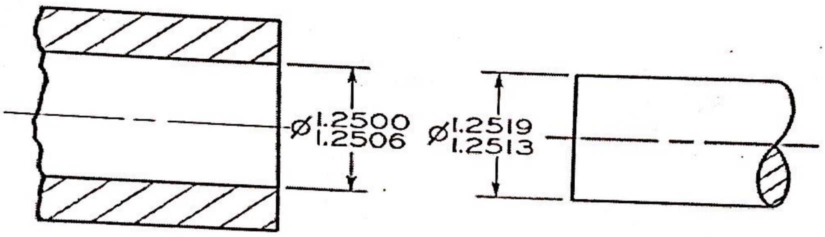
Figures show clearance fit

Types of fits in clearance:

- Precision sliding fit
- Close running fit
- Normal running fit
- Easy running fit
- Loose running fit.

1.6.2 Interference fit: - It is a fit which always provides interference. Here the tolerance zone of the hole will be below the tolerance zone of the shaft. e.g. 25 H7/p6. Maximum interference is the algebraic difference between the minimum hole and maximum shaft MMC. Minimum interference is the algebraic difference between the maximum hole and minimum shaft LMC





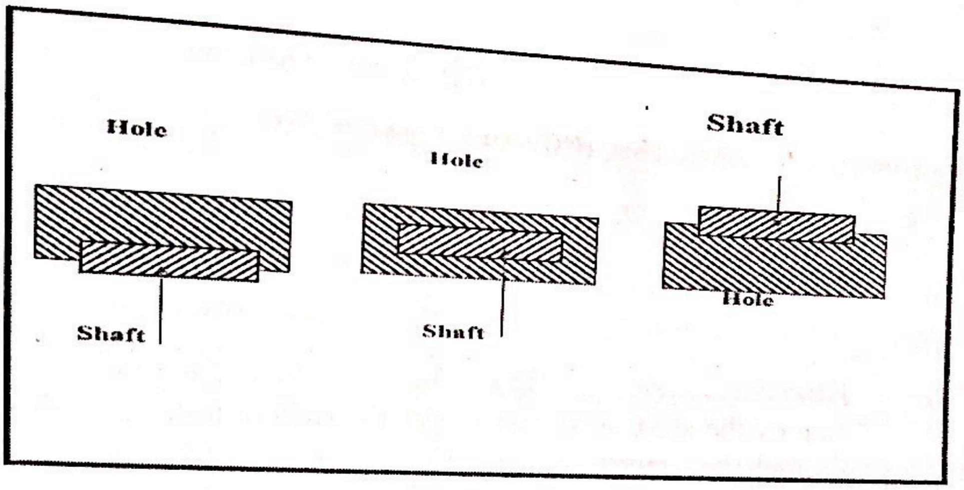
(a) INTERFERENCE FIT

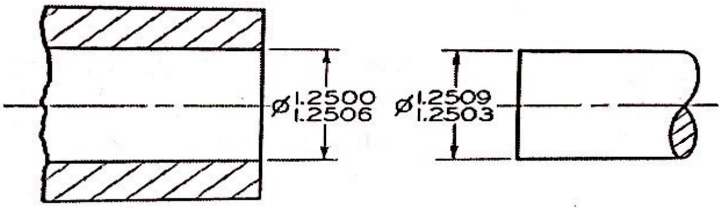
Types of fits in Interference:

- Shrink fit
- Heavy drive fit
- Press fit
- Medium press fit

1.6.3 Transition fit:-

It is a fit which may sometimes provides clearance and sometimes interference. When this class of fit is represented graphically, the tolerance zone of the hole and shaft will overlap each other. e.g. 75 H8/j7.





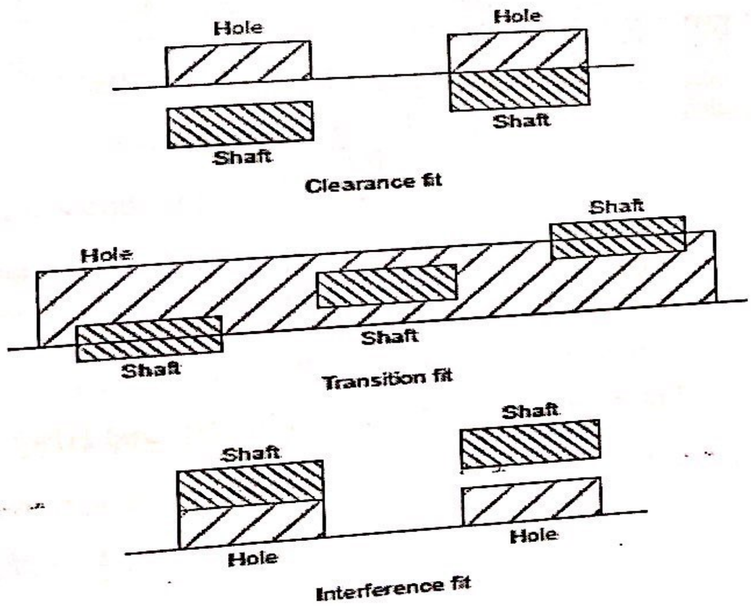
(b) TRANSITION FIT

Figure indicates transition fit

Types of transition fit

- Light Press Fit
- Force Fit
- Push Fit
- Easy Push Fit

1.6.4 Conventional representation of fit's.



1.7 Systems for obtaining different types of fits:

Systems are of two types:

(A) Hole basis system(HBS)

(B) Shaft basis system (SBS)

1.7.1 Hole basis system (HBS): Where the size of the hole is kept constant and the size of the shaft is varied to get the different class of fits, then it is known as the hole basis system.

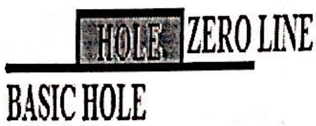


Figure indicates HBS

1.7.2 Shaft basis system (SBS): Where the size of the shaft is kept constant and the variations given to the hole to get the different class of fits, then it is known as the shaft basis system.

1.7.3 Fits in Shaft Basis and Hole Basis System

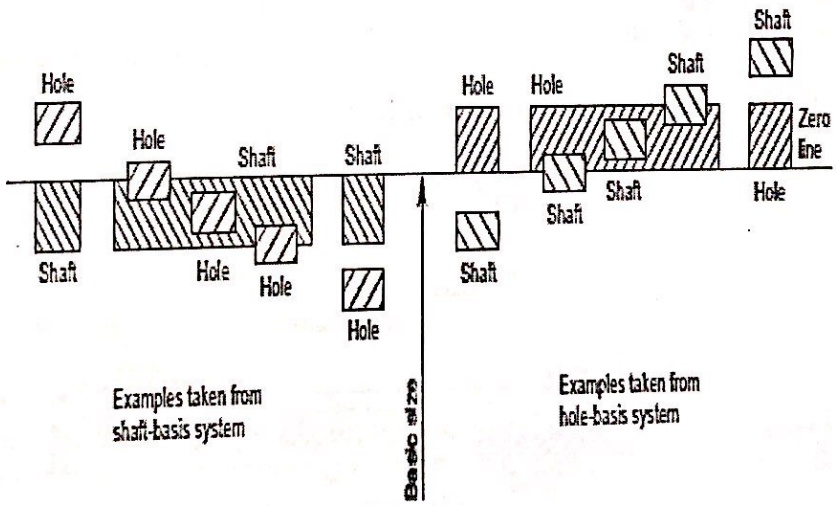


Figure indicates several fits in SBC and HBC

1.7.4 Difference between SBS & HBS

HOLE BASIS SYSTEM	SHAFT BASIS SYSTEM
1) The size of the hole is so prepared that the lower deviation value is assumed to be near zero line	1)Upper deviation of shaft is towards zero line & assumed to be basic size
2) This system is represented by letter (H)	2)This system is represented by letter (h)
3) The limits of the hole is kept constant & shaft is varied to desired fit	3) The limits of the shaft is kept constant & holes are varied to desired fit
4) Used in mass production	4) System not suitable for mass production,
5) Cost of production is less	5) Cost of production is high
6) Storage place for keeping the tool is less	6) Storage place for keeping the tool is more

1.8 Standard Limit System:

Three Types of Limit System Available are

(1) British System, (2) ISO 286-1988, (3) IS-919

1.8.1 Indian Standard System (Is)

In IS-919 there are:

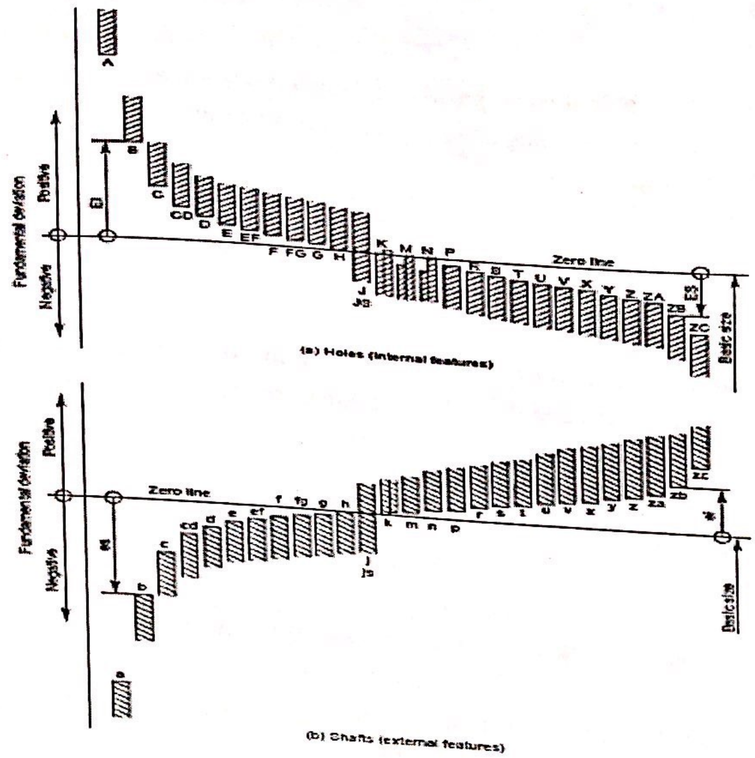
(a) 18 types of Fundamental Tolerances (Grades)

(b) 25 types of Fundamental Deviations

18 Grades: IT_{01}, IT_{00} IT_1, IT_2, IT_3…IT_{16}.

25 Deviations: Capital Letters- Indicates Holes: A, B, C, D, E, F , G, H, I, J_S, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, X, Y, Z, Z_A, Z_B, Z_C.

Small Letters- Indicates Holes: a, b, c, d, e, f, g, h, i, j_s, j, k, l, m, n, o, p, q, r, s, t, u, v, w, x, y, z, z_a, z_b, z_c.



Graphical Illustration of Tolerance Zones

Number symbol generally represents the Tolerance (IT Grade).

Eg:1 40H_7

40 indicates the Basic Size

H indicates Hole basis system

7 indicates IT Grade (IT_7)

Eg:2 43h_7

43 indicates the Basic Size

h indicates Shaft basis system

7 indicates IT Grade (IT_7).

1.8.2 Standard Tolerance

Standard tolerances are determined in terms of standard tolerance unit "i". ("i" in microns)

"i" is expressed as

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

Where D is geometrical mean of lower and upper diameter step where the actual size of shaft & hole lies

Various steps in IS-919 are as follows

1-3,3-6,6-10,10-14,14-18,18-24,24-30,30-40,40-50,50-65,65-80,80-100,100-120,120-140,140-160,160-180,180-250,250-315,315-400,400-500mm

Tolerances IT01-IT5 is calculated as below. Remaining like IT2-IT4 is scaled.

IT01=0.3+0.08D,

IT0=0.5+0.12D,

IT1=0.8+0.02D,

IT5=7i,

IT6=10i,

IT7=16i,

IT8=25i,

IT9=40i,

IT10=64i,

IT11=100i,

IT12=160i,

IT13=250i,

IT14=400i,

IT15=640i,

IT16=1000i

1.8.3 Fundamental Deviations for holes for sizes up to 500mm

Note: For shafts the same upper deviation formula used will become lower deviation with a change in sign, same way the lower deviation formula of hole become upper deviation with change in sign.

UPPER DEVIATION (es)	
Shaft	In Microns/ D in mm
a	=-(265+1.3D) for D≤120 =-3.5D forD≥120
b	=-(140+0.85D)forD≤160 =-1.8D for D≥160
c	$=-(52D^{0.2})$ for D≤40 =-(9.5+0.8D) for D ≥40
d	$=16D^{0.41}$
e	$=-11D^{0.41}$
f	$=-5.5D^{0.41}$
g	$=-5.5\ D^{0.34}$
h	=0

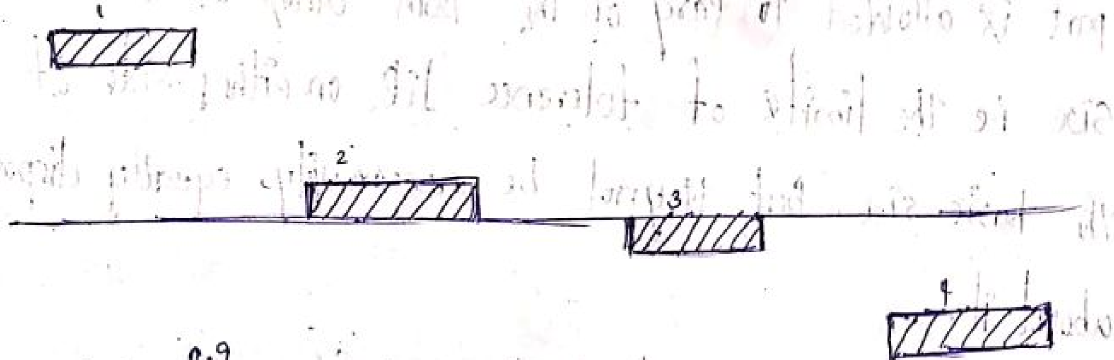
LOWER DEVIATION (ei)	
Shaft	In Microns/ D in mm
k4-k8	=+0.6³ √D
m	=(IT7-IT6)
n	=+5De0.24
p	=+IT7+0 to 5
r	=Geometric mean of values el for p and s
s	IT8+1 to 4 For D≤50 =+IT7 to + 0.4D For D>50
t	=IT7+0.63D
u	=+IT7+D
v	=+IT7+1.25D
x	=+177+1.6D
y	=+1T7+2D
z	=+1T7+2.5D
za	=+1T8+3+3.15D
zb	=+1T9+4D
zc	=+1T10+5D

System of Writing tolerances :—

1. uni lateral system
2. Bilateral system

1. unilateral system —

In this system the dimensions of the part is allowed to vary only on one side of the basic size i.e tolerance lies wholly on one side of the basic size either above or below it.



1 — $20.0^{0.2}_{+0.1}$

2 — $20.0^{+0.02}_{-0.00}$

3 — $20.0^{+0.00}_{-0.02}$

4 — $20.0^{-0.01}_{-0.02}$

unilateral system is preferred in interchangeable Manufacturer especially when precision fits are required. because

1. It is easy and simply to determine deviation

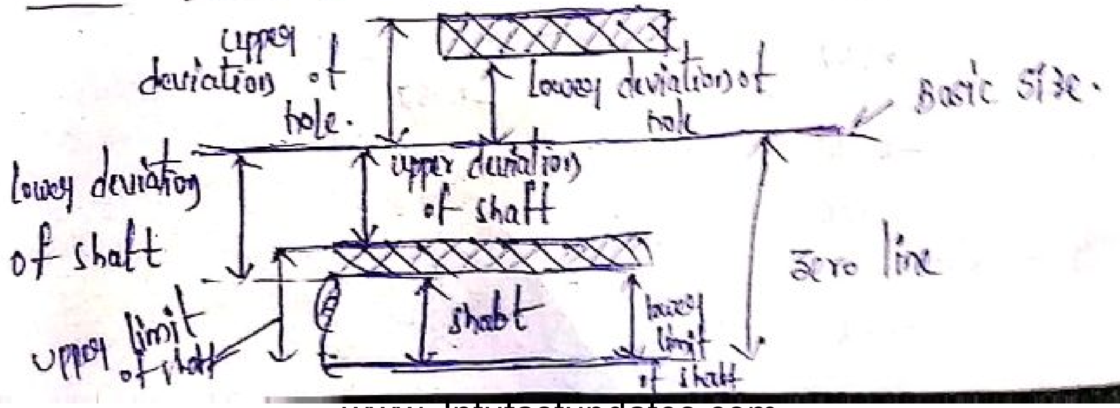
2. Another advantage of this system is that Go gauge ends can be standatized as the holes of different tolerance grades as the same lower limit and all the shafts have same upper limit

3. This form of tolerance gradely assists the operator when Machining of Making parts

2. Bilateral System –

In this system the dimension of the part is allowed to vary on the both sides of the basic size i.e the limits of tolerance lie on either side of the basic size. but May not be necessarily equally disposed about it.

Conventional diagram of limits and fits :–



Terminology for limits & fits :-

i) shaft – The term shaft refers ~~to~~ not only to diameter the circular shaft but also to any external dimensions of a component.

ii) hole – the term hole refers not only to diameter of a circular hole but also any ~~exter~~ internal dimensions of a component

iii) Basic (or) nominal size – It is a standard size of a part with reference to which the limits of variations of a size are determined.

iv) Actual size – Actual size is the dimension as measured on the Manufactured product.

v) Zero line – It is the straight line drawn horizontally to represent the basic size

vi) Deviation – It is the algebraic difference between the size and corresponding basic size

vii) upper deviation – It is the algebraic difference of the upper limit of the size and the corresponding basic size

viii) Lower deviation – It is the algebraic difference of the b/w The lower limit of the size and corresponding basic size.

the upper deviations for a shaft is denoted by 'es'

" " " " a hole " " 'ES'

lower deviation it is designated by 'ei' for shaft

" " " " 'EI' for hole;

the Tolerance is designated as 'IT' (international Tolerance)

Fundamental deviation —

the fundamental deviation is that one of the two deviations which is nearest to zero line either for a hole or a shaft the fundamental deviations are designated by capital letters i.e A, B, C - - - Z, ZA, ZB, ZC and excluding a few alphabets I, L, O, Q, W, for a shaft it is designated by small letters i.e. a, b, c, - - - - z, za, zb, zc

Basic shaft :- The basic shaft is the shaft whose upper deviations is zero. It is denoted by 'h'

Basic hole :- It is defined as the hole as the lower deviation is zero. i.e lower limit of the hole is same as basic size. It is denoted by 'H'

Tolerance zone :- It is the zone bounded by the two limits of a part

Tolerance grade :- It is an indication of the degree of accuracy of a Manufacturer. and it is designated (or) represented as 'IT' followed by number.

→ It is varies from IT01, IT1, --- ----IT16

→ The larger the number larger will be Tolerance. and the accuracy will be less Then cost less

Types of fits :-

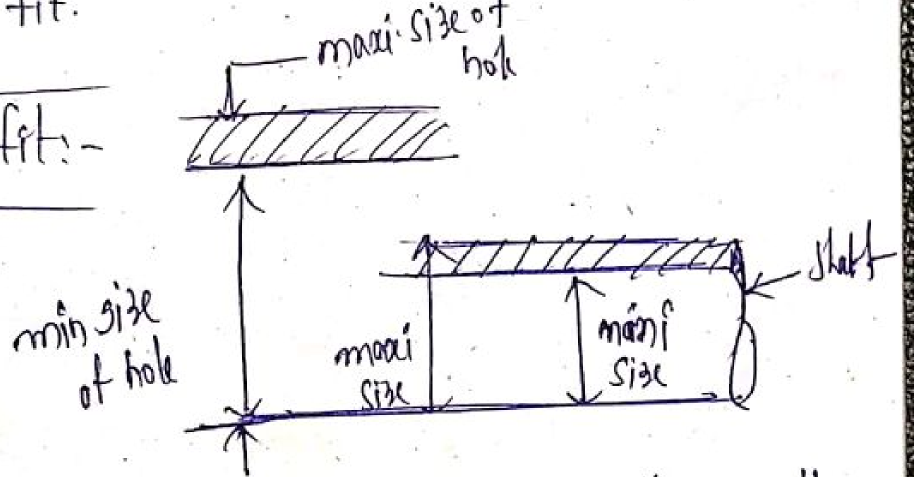
these fits are classified into three types

i) clearence fit

ii) Interference. fit

iii) Transition fit.

(i) clearence fit :-



In the clearence fit the shaft is always smaller than the hole i-e the largest permissible shaft diameter is smaller Than the diameter of the smallest hole.

So that the shaft can rotate (or) slide with different degrees of freedom. it is further classified as

(a) slide fit

(b) easy slide fit

(c) running fit

(d) slack running fit

(e) loose running fit.

Maximum clearance — the diff b/w the Maximum size of hole to Minimum size of the shaft

Minimum clearance — the diff b/w the Minimum size of the hole to Maximum size of the shaft

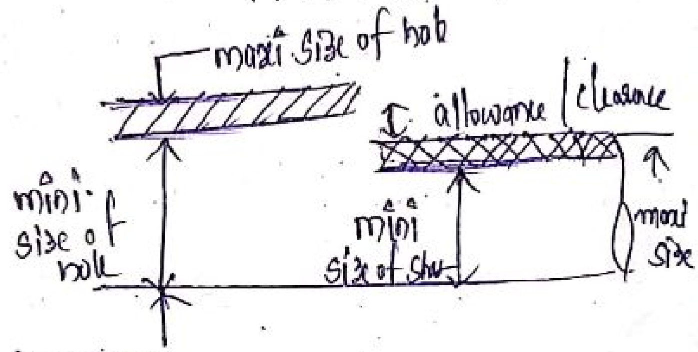
ii) Interference fit :—

① the limits shown on a drawing for the mating hole and shaft are for the hole $50.000^{+0.046}_{-0.000}$ mm, for shaft $50.000^{-0.010}_{-0.029}$ mm state the Type of fit and find the allowance. What is the gratest possible amount of clearence or interference.

Sol →

Given hole $50.000^{+0.046}_{+0.000}$ mm , shaft $50.000^{-0.010}_{-0.029}$ mm

50.000 , 50.046   49.99 , 49.971



Maxi metal limit of hole = 50.000 mm

Max metal limit of shaft = 49.99 mm

The type of fit is clearence fit

Mini clearence = mini. size of hole − Maxi. size of shaft

= 50.000 − 49.99

= 0.01 mm

Maxi. clearence = Maxi size of hole − Mini size of shaft

= 50.046 − 49.971 = 0.075 mm

Allowance = maxi metal limit of hole − maxi metal limit of shaft

= 50.0 − 49.99 = 0.01 mm

② the limits for a hole and a shaft combination are for hole $80.000^{+0.035}_{-0.000}$ mm for shaft $80.000^{+0.093}_{+0.071}$ mm state the type of fit and find the allowance what is the greatest possible amount of clearence (or) interferance.

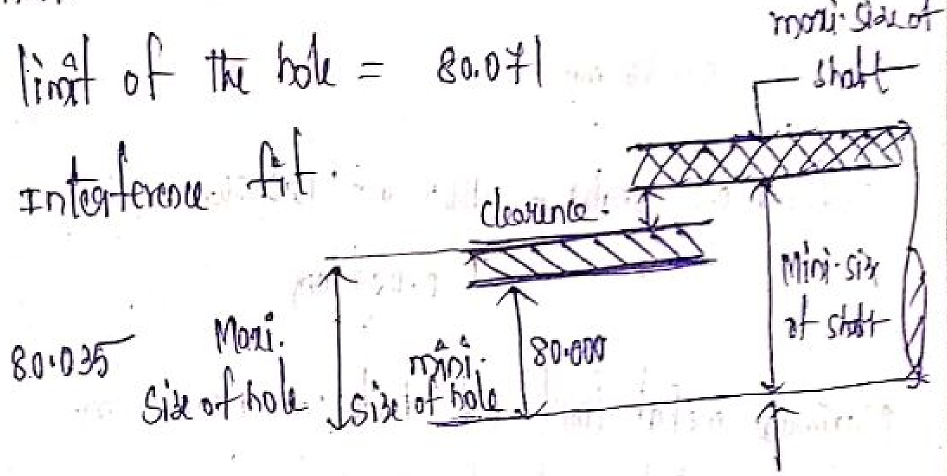
Sol → Given hole − $80.000^{+0.035}_{-0.000}$ shaft − $80.000^{+0.093}_{+0.071}$

80.035 , 80.000 80.093 , 80.071

Mini metal limit of the hole = 80.035

Maxi metal limit of the hole = 80.071

It is a Interference fit.



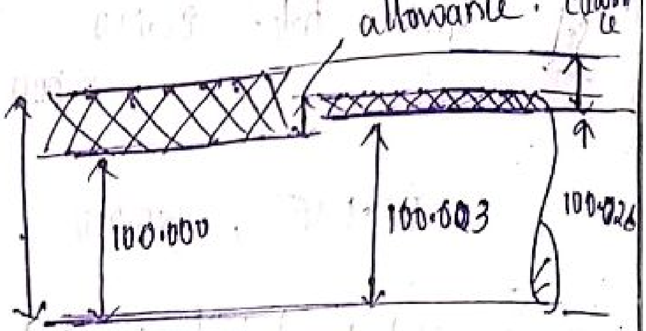
Allowance − Maxi metal limit of shaft − maxi. metal of hole

= 80.093 − 80.00

= 0.093

greatest interference = allowance

③ Maximum metal limit for the shaft is 100.026 mm Maximum metal limit for the hole is 100.000 mm, minimum metal limit for the hole is 100.036 mm, ~~determine~~ minimum metal limit for the shaft is 100.003 mm determine the allowance, Tolerance for shaft & hole Type of fit. and find the allowance, Tolerance for shaft & hole



Sol →

Tolerance of hole

$= 100.036 - 100.000$

$= 0.036$ mm

Tolerance of shaft $= 100.026 - 100.003$

$= 0.023$ mm

Maximum metal limit of hole = 100.000 mm

Maximum metal limit of shaft = 100.026 mm

↑ It is Interference fit when Maximum metal limits of both shaft & hole are considered.

Minimum metal limit of hole = 100.036

Maximum metal limit of shaft = 100.003

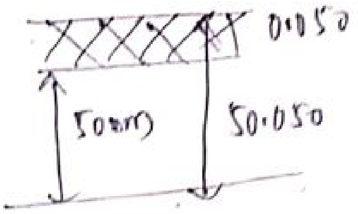
↑ It is clearance fit when Minimum metal limits of both shaft & hole are considered.

allowance - Maximum metal limit of shaft - maxi. metal limit of hole

= 100.026 - 100.00

= 0.026

(4) A 50mm diameter is made to rotate in the bush the tolerance for both shaft and bush are 0.050 mm determine the dimensions of shaft and bush, give an allowance of 0.075 mm with a hole basis system.



sol

For a hole basis system lower limit of hole is fixed = basic size.

= 50.000mm

upper limit of hole = lower limit + Tolerance

= 50.000 + 0.050

= 50.050 mm

Higher limit of shaft = lower limit of hole - allowance

= 50.000 - 0.075

= 49.925 mm

lower limit of shaft = Upper limit of shaft - tolerance

= 49.925 - 0.050

= 49.875 mm

→ The tolerance value is calculated using the relation

IT_5 to IT_{16}: → $i = [0.453 \sqrt[3]{D} + 0.001D]$ microns

Where, D – Diameter of the part in mm, and

0.001D is the linear factor

and 'D' is calculated by $D = \sqrt{D_{max} \times D_{min}}$

→ For IT01, $i = 0.3 + 0.008D$

→ For IT0, $i = 0.5 + 0.012D$

→ For IT1, $i = 0.8 + 0.020D$

Various diameter steps :-

1-3, 3-6, 6-10, 10-18, 18-30, 30-50, 50-80,

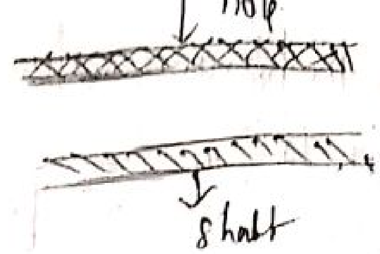
80-120, 120-180, 180-250, 250-315, 315-400, 400-500,

500-630, 630-800, 800-1000

① Design the general type of go and no-go gauges as per the british system for a 40mm shaft and hole pair designated as 40 H8e9. Given that $i = 0.453 \sqrt[3]{D} + 0.001D$, $IT_8 = 25 \times i$, upper deviation of shaft $-16D^{0.44}$ and also $IT9 = 40 \times i$. Sketch the hole and shaft with their tolerances.

Sol → Given 40 step diameter falls under 30-50mm

Diameter $D = \sqrt{D_{max} \times D_{min}}$



$= \sqrt{50 \times 30}$

$D = 38.72 mm$

Fundamental Tolerance $i = 0.453 \sqrt[3]{D} + 0.001 D$

$i = 1.571$ microns.

For hole quality $H_8 = 25 \times i$

$= 25 \times 1.571$

$= 39.28$ microns.

For The Hole the fundamental deviation is zero

the lower limit of the hole = 40mm

upper limit of the hole = 40 + Tolerance

$= 40 + 0.039$

$= 40.039$ mm

For shaft quality.

the fundamental Tolerance is $d_9 = 40 \times i$

$= 40 \times 1.571$

$= 62.84$ microns

For The Shaft the fundamental deviation is given by

$= -16 D^{0.44}$

$= -16 \times 38.72^{0.44}$

$= -79.96$ microns $\Rightarrow -0.079$ mm

The limit for the shaft are as follows

upper limit of shaft = 40 - fundamental deviation

= 40 - 0.079

= 39.921 mm

lower limit of the shaft = 40 - [0.079 + tolerance]

= 40 - [0.079 + 0.062]

= 39.859

Tolerance of shaft = upper limit of shaft - lower limit of shaft

= 39.921 - 39.859

= 0.062.

(2) Design and sketch the hole and shaft system of a $32H_7m_8$ and multiplication factors for the hole and shaft Tolerances are 16 and 25 and the upper deviation of the shaft is $-16D^{0.44}$

Sol → Given 32 mm diameter falls under 30-50 mm

Diameter $D = \sqrt{D_{max} \times D_{min}} = \sqrt{50 \times 30}$

$= 38.72 mm$

Fundamental Tolerance $i = 0.453 \sqrt[3]{D} + 0.001D$

$= 1.57$ microns.

For Hole quality $H_7 = 16 \times i$

$= 16 \times 1.57 \Rightarrow 25.12$ micron $\Rightarrow 0.025$ mm lower limit of hole = 32 mm

The fundamental deviation of hole is zero

upper limit of hole = 32 + 0.025

= 32.025 mm

For shaft quality $m8 = 25 \times i$

Fundamental Tolerance $= 25 \times 1.571 = 39.28$ microns

$= 0.039$ mm

For shaft the fundamental deviation is given by

$= -16 D^{0.44}$

$= -16 \times 38.72^{0.44}$

$= -79.94$ microns

$= -0.079$ mm

upper limit of shaft $= 32 - 0.079$

$= 31.921$ mm

lower limit of shaft $= 32 - [0.079 + 0.039]$

$= 31.882$

Tolerance of shaft = upper limit − lower limit

$= 31.921 - 31.882$

$= 0.039$ mm

Line standard :-

→ When the length being measured is expressed as the distance between the two lines This is known as line standard.

→ A scale is quick and easy to use over a wide range of dimension.

→ The line standards are not accurate as end standards and can't be used for close Tolerance Measurements.

→ A steel scale can be read to about ± 0.2 mm of truth value

→ The scale graduations are not subjected to ~~whore~~ wear although significance whore on leading, end leads to under sizing.

→ The Scales are subjected to parallax error of reading

They May be +ve or −ve reading.

→ Errors due to inaccuracy of graduations engraved on the scale are possible.

→ A scale doesn't provide A built in Measuring datum

End standards :-

→ When the length being Measured is expressed as the distance b/w the two Surfaces or ends. This known as End standards

→ They are time Consuming to use and prove only 1 dimension at a time

→ End standards are highly accurate and well suitable for close tolerance Measurement i.e 0.0005 mm Can be obtained.

→ They are subjected wear on their measuring surfaces also wringing of slip gauges leads to damage

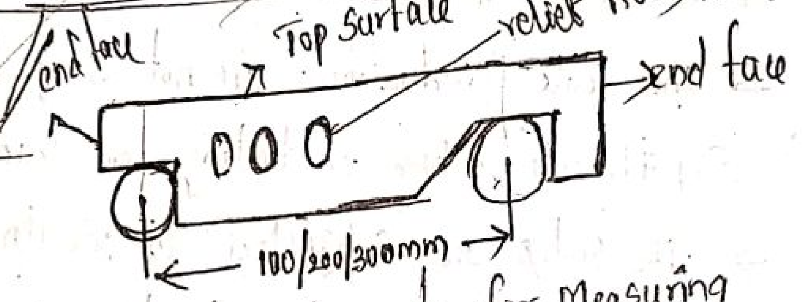
→ the parallax error is not associated with such type of measurement because the distance is measured b/w two flat surfaces.

→ They have a built in measuring datum as their measuring faces are flat and parallel.

~~Gauge blocks / slip gauges / Johnson's gauge / Jo gauge.~~

~~gage blocks~~

~~Sine bars~~



→ sin bar is the most accurate instrument for measuring angles. it consists of a accurate straight rectangular bar made up of high quality steel and having two accurately lapped cylinderical plugs rollers at the ends. the rollers are so fixed that when the sin bar is placed on the surface plate the surface of the bar is exactly parallel to surface plate. the various parts of the sin bar are hardened before grinding and lapping.

a sin bar is to be accurate then the following property must exist.

→ the distance b/w centers must be precisely known

→ The axis of rollers must be parallel to each other.

→ The upper surface of the sin bar must be flat and parallel.

→ The rollers must be of identical diameters and ground to within a close tolerance.

Sources of errors and sin bars

→ Constant angle error –
This is caused if the working surface and the cylinder axis are not parallel.

→ Progressive angle error –
This is due to the error in cylinder centre distance.

→ Gauge block tolerance accumulation is also source of progressive error.

Bevel protractor:–

A circle can be divided into 360 equal angles each angle is called a degree.

A circle is 360° for calculation a degree is divided into 60 parts called 'minutes' and a minute is divided into 60 sub parts called "seconds".

The Bevel protractor is used to establish and test angles to very close tolerances.

It reads upto 5 min. (or) $\frac{1}{20}^{\circ}$ and can be use completely through 360°. The bevel protractor consists of a beam graduated dial and blade which is corected to swivel plate by thumb nut and clamp

When the edges of the beam and blade are parallel a small line on the swivel plate coincides with the zero line on the graduated dial. and when any measurement of angle below the beam and the blade of 90° (or) under desired the reading may be obtained direct from the position of the line on the swivel plate with regard to the graduation number on the dial

Since the spaces both on the mainscale and the vernier scale are numbered both to the right and to the left from zero any angle can be measured the readings can be taken either to the right or to the left according to the direction in which the zero on the mainscale is moved.

The Bevel protractor vernier scale indicates every 5 minitues (or) $\frac{1}{20}^{\circ}$ each space on the vernier scale is 5' less than a spaces on the main scale.

24 spaces on the vernier scale equal in extreme length 23 double degrees

Thus the difference b/w the spaced occupied by 2° on a main scale and the space of the vernier scale is equal to one 24 th of 2° or one 12 th of 1° or 5 miniutes

Angle Gauge:-

An angle gauge is a hardened steel block approximately 75mm long, 16mm wide which has two lapped flat working faces lying at a very precise angle to each other. They are supplied in a sets of 13 and can be wrung together (Series) to forms desired angles.

The arrangement allows angles in 3 sec step to be obtained and thus no required angle expressed in 60' whole seconds and thus no required angle expressed in ... can be more than 1.5 sec in nominal error. An additional block of 9° is also available so that a 90° angle having an angle of 9° is also available can be built up.

Two diff grades are available A & B the only difference in a B type 0.05 when 9° is excluded and thus consists of only 12 gauges.

Sine Centers:-

Sine center basically a sine bar with blocks holding centers which can be adjusted and rigidly clamped in any position. The sine centers are used for inspection of conical objects b/w centers. They are used upto inclination of 60°. The rollers are clamped firmly to the body without any play.

Autocollimator :-

It is an optical instrument for noncontact Measurement of angles They are typically used to align components and Measure deflections in optical or Mechanical systems an autocollimator Works by projecting an image on to a target mirror and Measuring the deflections of the return image against a scale either visually or by means of electronic detector a ~~vision~~ visual autocollimator can measure angles as Small as 1 arc second i.e 4.85 micro radians while an electronic autocollimator can have upto 1000 time more resolution

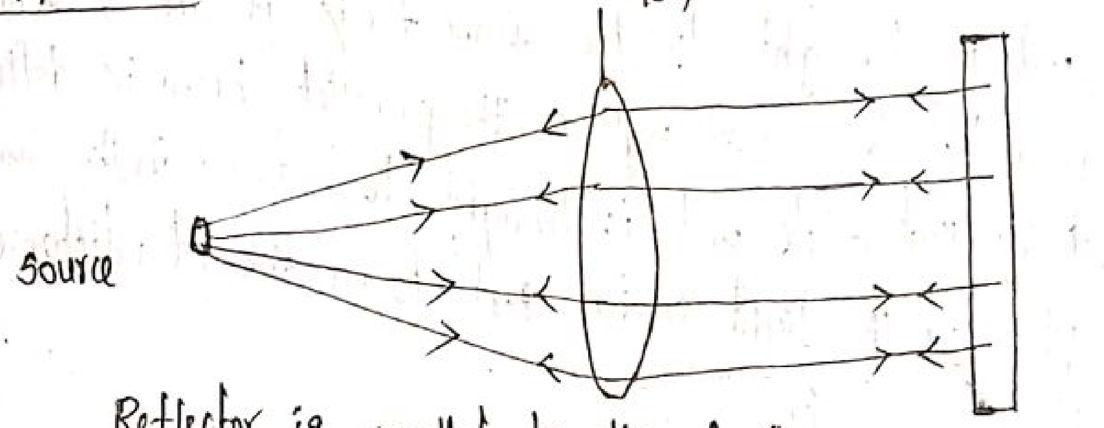
Principle:-

→ When a beam of rays coming out from a monochromatic source of light are Made parallel by placing a collimating lens and if These parallel rays are made to fall on reflector The rays reflect back and travels in the Same path and converges at the source Through The lens

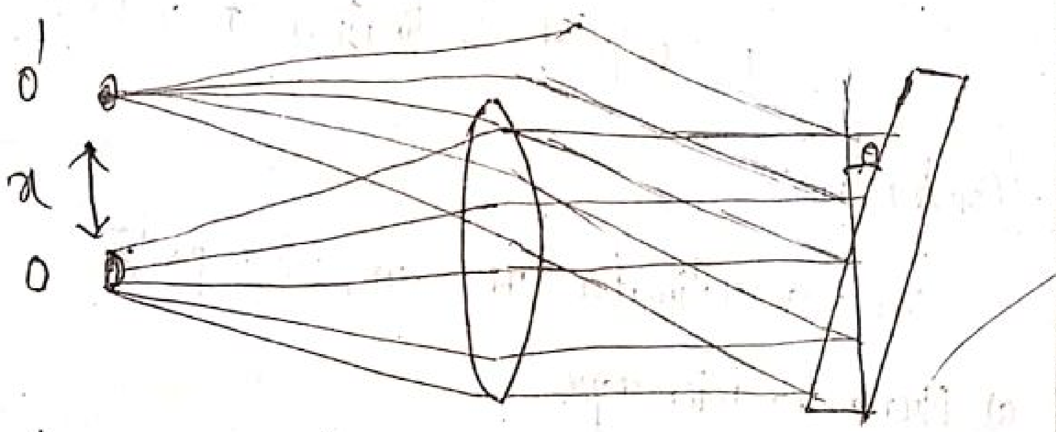
→ If the reflector is tilted by an angle 'θ' then the reflected rays make an angle '2θ' and converges at point 'O''

→ $O, O' = 2\theta f$ where f — focal length i.e the distance between The Source and Collimator.

Applications:-



Reflector is parallel to the lens.



Application

- Measurement of straightness and flatness
- precise angular indexing in conjuction with polygons
- Comparative measurement using master angles
- Essement of squareness and parallelism of components
- Measurement of small linear dimensions.

Working of collimator:—

If a light source is placed in the focus of a collimating lens it is projected as a parallel beam of light if this beam is made to straight a plane reflector is kept normal to the optical axis. it is reflected back along its own path and is brought to the same focus if the reflector is tilted to a small angle θ. The parallel beam is deflected twice that angle and is brought to a focus in the same plane as the light source but to one side at a distance 'x', $x = 2f\theta$.

Where f - focal length

θ - angle of inclination of reflecting mirror

Construction:-

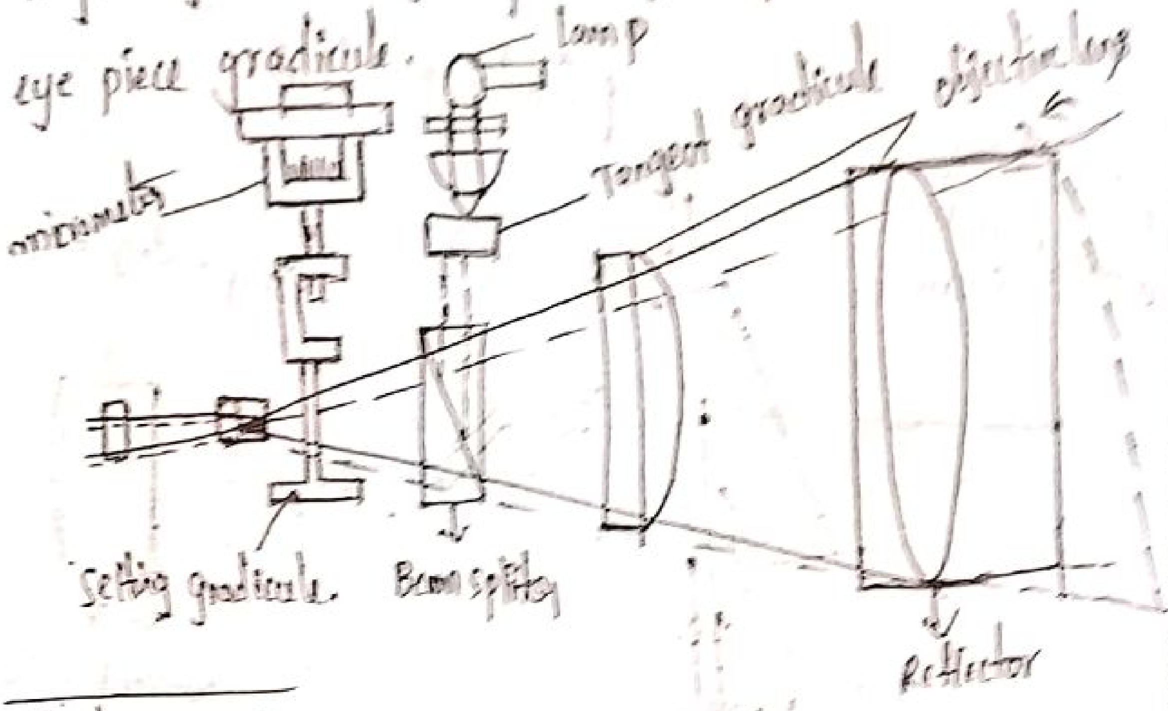
In a autocolimator there are three parts.

a) Micrometer microscope

b) lighting unit

c) collimating lens

a 45° transferent beam spliter ~~replace~~ reflects the light from the gradicule towards the object i.e collimating lens the image seen after reflection in the external reflector whose angular variation are being measured is ~~found~~ formed by the light from the objective lens this slight passes through the beam spliter and the image is pickedby the microscope for simentaneous measurements in two planes at right angles a micrometer is fitted to the tangent graticule optically at right angles to that on the eye piece graticule.



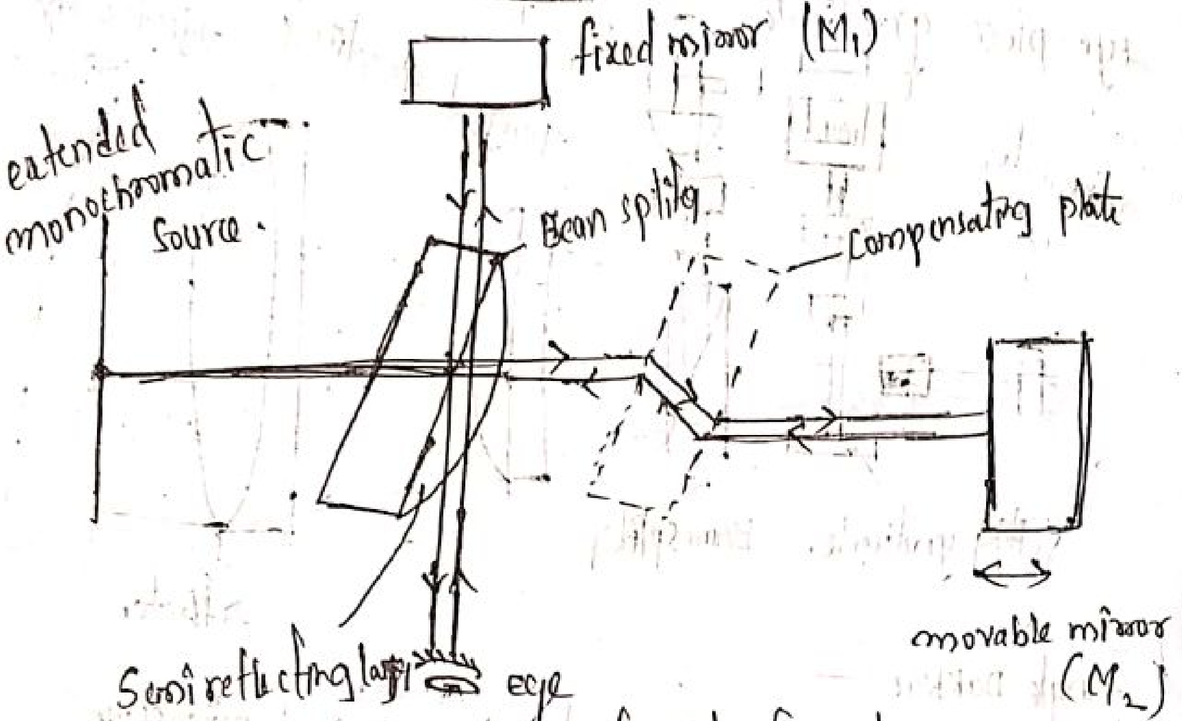
Angle Dekkor:-

→ This is a type of auto collimator it consists of microscope objective lens and two scales engraved on a glass screen which is placed in the focal plane of objective lens one of the scales called datum scale is horizontal and fixed

→ It is engraved across the centre of the screen and is always visible in the microscope eye piece

→ Another scale is an illuminated vertical scale fixed across the centre of the screen and the reflected image of the illuminated scale is received at right angles to this fixed scale and the two scales in the position intersects each other thus the reading on the illuminated scale. measures angular deviations from one axis at 90° to the optical axis

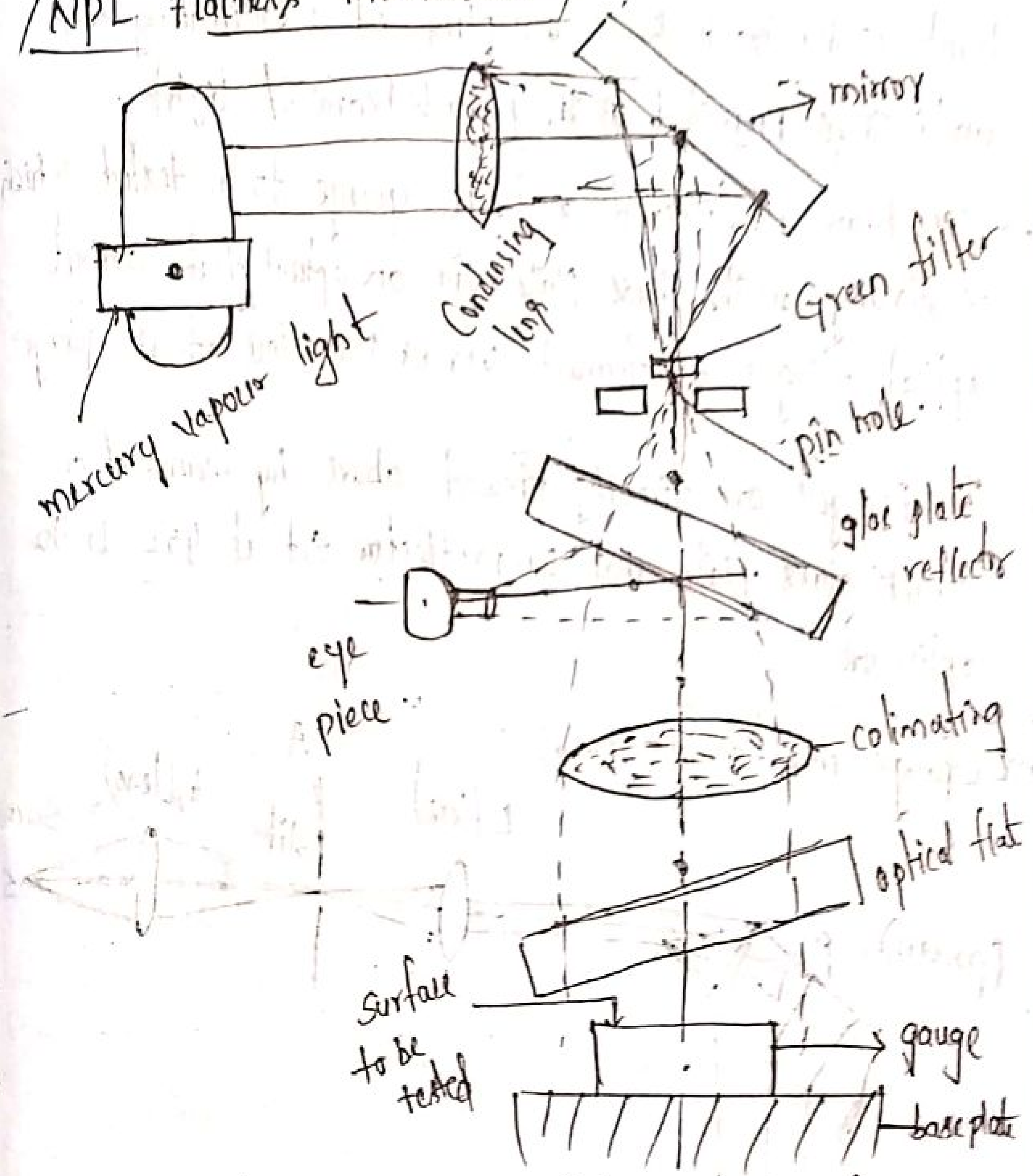
"Michelson's interferometer":-



→ This is the oldest type of interferometer
→ It utilizes monochromatic light from an extended Source
→ the Monochromatic light falls on a beam splitter consisting of semi reflecting layer
→ the light ray is devided into two parts i.e one is transmitted through compensating plate to the mirror M_1 and the other is reflected to the Beam splitter to mirror M_2
→ From both these mirrors the rays are reflected back and this reunite at the semireflecting surface and they are transmitted to the eye and the fringes can be observed.
→ mirror M_2 is fixed and M_1 is free (or) Movable i.e it is attached to the object whose dimension is to be

measured.

NPL flatness interferometer:-



→ It is used to Measure the flatness of a surface

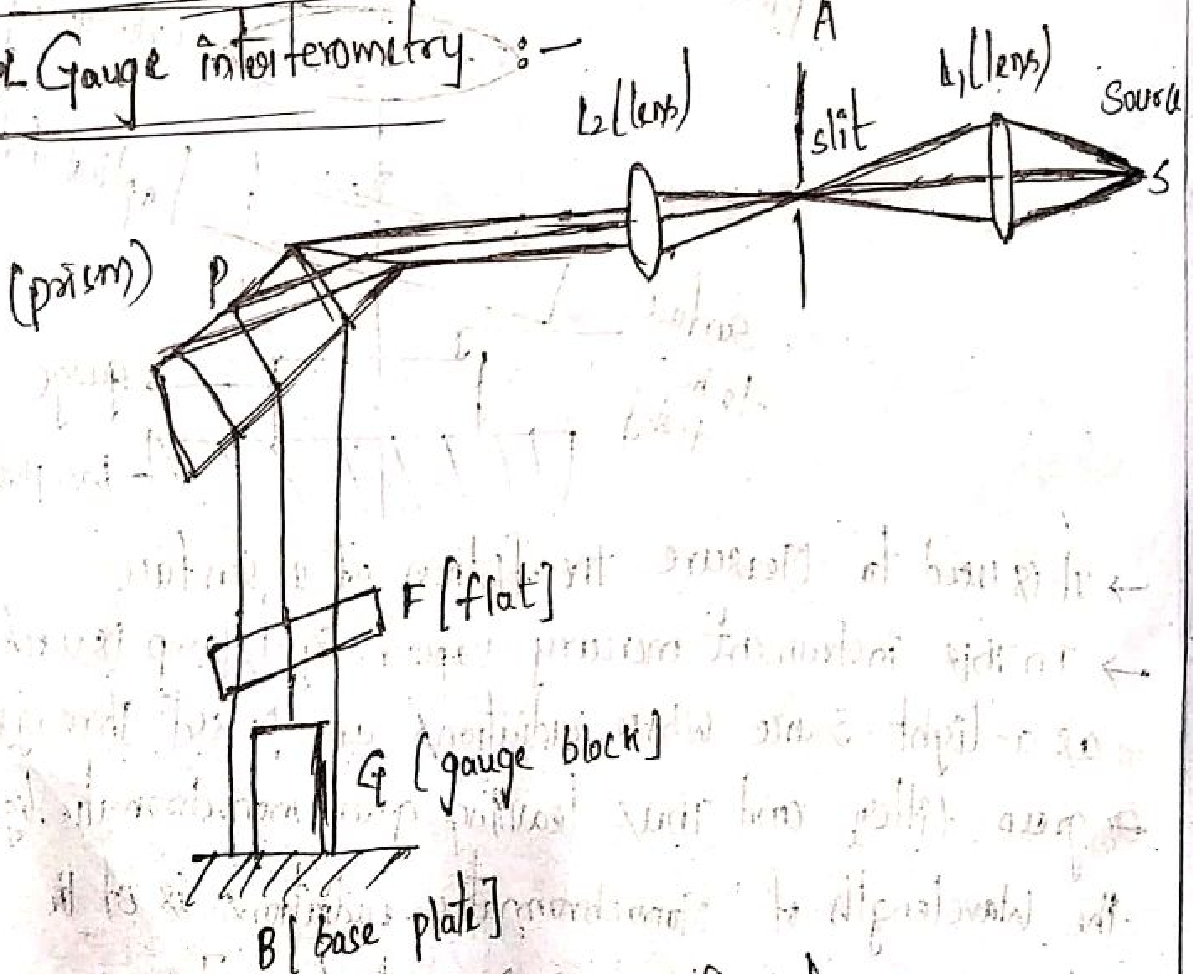
→ In this instrument mercury vapour light/lamp is used as a light source whose radiations are passed through a green filter and thus leaving green monochromatic light the wavelength of monochromatic radiations is of the order of 0.0005mm [i.e 0.5 micrometer/µm]

→ This radiation is brought to focus on pin hole inorder to obtain an intense point of source of Monochromatic light which is in the focal plane of a collimating lens and is thus projected as the parallel beam of light.

→ The beam is directed on to the gauge to be tested which is wrung on the base plate via an optical flat so that optical fringes are formed across the face of the gauge

→ the Fringes are directly viewed above by means of a thick glass plate that semi reflector set at 45°c to the optical axis.

NPL Gauge interferometry :-



It is also called Gauge interferometer

→ It is used to determine the actual dimension (or) absolute length of the gauges

→ The light from the sources falls on the slit 'A' through the lens 'L_1'

→ After collimation by lens 'L_2' it goes through constant deviation prism 'p' whose rotation determine wavelength pass passed through reference flat 'F' to upper surface of the gauge block 'G' and base plate 'B' to which it is wroung

→ light is reflected back in mirror 'p' and its pattern are observed through a telescope

→ This instrument should be used in standard conditions of temperature and pressure.

Interferometer :-

→ These are optical instruments used for measuring flatness and determining the length of slip gauges they are based upon the interference principle and employ wavelength of light as their measuring units

→ the interferometers make use of some type of beam devider. That splits an incoming ray into two parts

→ these two parts of the ray travel along different paths until they are recombine usually in the same beam devider.

→ In interferometers, the lay of optical flat can be controlled and the fringes can be oriented to the best advantage.

→ An arrangement to view the fringes directly from top and above the fringes is also incorporated.

Introduction

1. Find the values of allowances and tolerances for hole & shaft assembly for the following dimensions of mating parts

Hole : $25^{+0.05}_{+0.00}$ & shaft : $25^{-0.02}_{-0.05}$

sol

for hole :

Tolerance = upper limit – lower limit

= 25.05 – 25.00 = 0.05

for shaft :

Tolerance = upper limit – lower limit

= 24.98 – 24.95 = 0.03

Allowances = max metal limit

= low limit of hole – higher limit of shaft

= 25.00 – 24.98 = 0.02

clearance fit

2. A 50 mm dia of shaft is made to rotate in the bush. The tolerance for both shaft & bush are 0.05 mm. Determine the dimensions of the shaft in the bush to give a max clearance of 0.075 mm with the hole basis system

sol

low limit of hole = 50 mm

tolerance = 0.05 mm

high limit of hole = 50.05 mm

for shaft

Allowance = low limit of hole – high limit of shaft high limit of shaft = 50 − 0.075

= 49.925 mm

Tolerance = high limit of hole − low limit of shaft

low limit of shaft = 49.925 − 0.05

= 49.875 mm

3. For each of the following hole & shaft assembly find the shaft tolerance, hole tolerance and state whether the type of fit is clearance, transition & Interference.

(i) Hole : $50^{+0.25}_{+0.00}$; shaft : $50^{+0.05}_{+0.005}$

(ii) Hole : $30^{+0.05}_{+0.00}$; shaft : $25^{-0.02}_{+0.05}$

(iii) Hole : $25^{+0.04}_{+0.00}$; shaft : $25^{+0.06}_{+0.04}$

sol

for hole

(i) Tolerance = upper − lower

= 50.25 − 50.00 = 0.25

for shaft

Tolerance = upper − lower

= 50.05 − 50.005 = 0.045

Allowance = L.L.H − H.L.S

= 50.00 − 50.05 = −0.05 mm

Allowance = H.L.H − L.L.S

= 50.25 − 50.005 = 0.245 mm

transistion fit

i) for hole

Tolerance = upper - lower

= 30.05 - 30.00 = 0.05 mm

for shaft

Tolerance = upper - lower

= 25.05 - 24.98 = 0.07 mm

Allowance = L.L.H - H.L.S

= 30.00 - 25.05 = 4.95 mm

Allowance = H.L.H - L.H.S

= 30.05 - 24.98 = 5.07 mm

clearance fit

(iii) for hole

Tolerance = upper - lower

= 25.04 - 25.00 = 0.04 mm

for shaft

Tolerance = upper - lower

= 25.06 - 25.04 = 0.02 mm

Allowance = L.L.H - H.L.S

= 25.00 - 25.06 = -0.06 mm

Allowance = H.L.H - L.L.S

= 25.04 - 25.04 = 0

transition fit

4. The limit system the following limits are specified to give clearance fit b/w a shaft & hole

shaft : $50^{-0.006}_{-0.020}$; hole : $50^{+0.030}_{-0.000}$

find basic size, shaft & hole tolerance, max clearance, min clearance

sol

(i) Basic size = 50 mm

(ii) for shaft

Tolerance = upper − lower

= 49.994 − 49.98 = 0.014 mm

for hole

Tolerance = upper − lower

= 50.03 − 50.00 = 0.03 mm

(iii) max. clearance = L.L.S − H.L.H

= 49.98 − 50.03 = −0.05 mm

(iv) min clearance = H.L.S − L.L.H

= 49.994 − 50.00 = −0.006 mm

5. In a hole & shaft assembly of 30 mm of nomial size the tolerance for hole & shaft are specified below. Determine the maximum & minimum clearance obtained, allowances, hole & shaft tolerances, max metal limit shaft & hole, the allowance

Hole : $30^{+0.02}_{-0.000}$; shaft : $30^{-0.040}_{-0.070}$

max clearance = H.L.H − L.L.S

= 30.02 − 29.93 = 0.09 mm

min clearance = −H.L.S + L.L.H

= −29.96 + 30.00 = 0.04 mm

(ii) Allowance = L.L.H − H.L.S

= 30.00 − 29.96 = 0.04 mm

Allowance = H.L.H − L.L.S

= 30.02 − 29.93 = 0.09 mm

(iii) for hole

Tolerance = upper − lower

= 30.02 − 30.00 = 0.02 mm

for shaft

Tolerance = upper − lower

= 29.96 − 29.93 = 0.03 mm

clearance fit

6 A 50 mm dia shaft & bearing are to be assemblied with a clearance fit, the tolerance & Allowance are as follows

allowance = 0.035 mm

tolerance on hole = 0.025 mm

tolerance on shaft = 0.017 mm

find the limit of size for the hole & shaft. If the hole basis system is used ; shaft basis system is used

50

As we known in the hole basis system lower deviation zero "0". There fore low limit of hole is basic size 50.00

Tolerance of hole = U.L.H − L.L.H

0.025 = U.L.H − 50.00

U.L.H = 50.025 mm

Hole :-

L.L.H = 50.00 mm

U.L.H = 50.025 mm

shaft :

Allowance = L.L.H − U.L.S

0.035 = 50.00 − U.L.S

U.L.S = 49.965 mm

tolerance of shaft = U.L.S − L.L.S

0.017 = 49.965 − L.L.S

L.L.S = 49.948 mm

Hole = $50^{+0.025}_{+0.000}$; shaft = $50^{-0.035}_{-0.052}$

shaft basis system :-

As we known shaft basis system the upper deviation of shaft is zero "0". There fore upper limit of shaft is basic size is 50. mm

Tolerance of shaft = U.L.S − L.L.S

0.017 = 50.00 − L.L.S

L.L.S = 49.983 mm

L.L.S = 49.983 mm

U.L.S = 50.000 mm

for hole

Allowance = L.L.H − U.L.S

0.035 = L.L.H − 50.000

L.L.H = 50.035 mm

tolerance of hole = U.L.H − L.L.H

0.025 = U.L.H − 50.035

U.L.H = 50.060 mm

Hole : $50^{+0.035}_{+0.060}$; shaft : $50^{-0.017}_{+0.000}$

7. Determine limit dimensions for a clearance fit b/w mating parts of dia 40 mm providing a min clearance of 0.10 mm with the tolerance on a hole is 0.025 mm & shaft 0.05 mm using both systems

Sol Hole basis system

As we known hole basis system the lower limit of hole the basic size 50 mm is zero "0". There fore lower limit of hole is the

Tolerance of hole = U.L.H − L.L.H

0.025 = U.L.H − 50.00

U.L.H = 50.025 mm

for hole

U.L.H = 50.025 mm

L.L.H = 50.000 mm

for shaft

min clearance = L.L.H − U.L.S

0.10 = 50.00 − U.L.S

U.L.S = 49.90 mm

tolerance of shaft = U.L.S − L.L.S

0.05 = 49.90 − L.L.S

L.L.S = 49.85 mm

Hole : $50^{+0.025}_{+0.000}$; shaft : $50^{-0.10}_{-0.15}$

shaft basis system :

As we known that U.L.S = 50 mm

tolerance of shaft = U.L.S − L.L.S

0.05 = 50.00 − L.L.S

L.L.S = 49.95 mm

for shaft

L.L.S = 49.95 mm

U.L.S = 50.00 mm

for hole

min clearance = L.L.H − U.L.S

0.10 = L.L.H − 50.00

L.L.H = 50.10 mm

tolerance of hole = U.L.H − L.L.H

0.025 = U.L.H − 50.10

U.L.H = 50.125 mm

Hole : $50^{+0.10}_{+0.125}$; shaft : $50^{-0.05}_{+0.00}$

L.L.S = TT...

... parts are to have a nominal assembly size of 40mm 5
assembly is to have a max clearance of 0.15 mm and a min clearance of 0.05 mm. The hole tolerance is 1.5 times of shaft tolerance. Determine the limits of both hole & shaft by using hole based system & shaft based system

sol Basic size = 40 mm

max clearance = 0.15 mm

min clearance = 0.05 mm

hole tolerance = 1.5 times of shaft tolerance

max clearance − min clearance = hole tolerance + shaft tolerance

(0.15 − 0.05) = 1.5 shaft tolerance + shaft tolerance

shaft tolerance = 0.04 mm

hole tolerance = 1.5 (0.04) = 0.06 mm

(i) hole basis

L.L.H = 40 mm

hole tolerance = U.L.H − L.L.H

0.06 = U.L.H − 40

U.L.H = 40.06 mm

min clearance = L.L.H − U.L.S

0.05 = 40 − U.L.S

U.L.S = 39.95 mm

shaft tolerance = U.L.S − L.L.S

0.04 = 39.95 − L.L.S

L.L.S = 39.91 mm

Hole : $40^{+0.00}_{+0.06}$; shaft : $40^{-0.09}_{-0.05}$

(ii) shaft basis

U.L.S = 40

shaft tolerance = U.L.S − L.L.S

0.04 = 40 − L.L.S

L.L.S = 39.96 mm

max clearance = U.L.H − L.L.S

0.15 = U.L.H − 39.96

U.L.H = 40.11 mm

hole tolerance = U.L.H − L.L.H

0.06 = 40.11 − L.L.H

L.L.H = 40.05 mm.

Hole : $40^{+0.11}_{+0.05}$; shaft : $40^{-0.04}_{+0.00}$

9. Between two mating parts of 100 mm basic size the actual interference fit is to be 0.05 mm to 0.12 mm. The tolerance for the hole is same as the tolerance for the shaft. find the size of both the shaft & hole on hole basis system & shaft basis system

sol Basic size = 100 mm

max. interference = 0.12 mm

min. interference = 0.05 mm

hole tolerance = shaft tolerance

(i) hole basis system

L.L.H = 100 mm

max. interference = U.L.S − L.L.H

0.12 = U.L.S − 100

U.L.S = 100.12 mm

max interference − min interference = hole tolerance + hole tolerance

0.12 − 0.05 = 2 hole tolerance

hole tolerance = 0.035 mm

hole tolerance = U.L.H − L.L.H

0.035 = U.L.H − 100

U.L.H = 100.035 mm

shaft tolerance = U.L.S − L.L.S

0.035 = 100.12 − L.L.S

L.L.S = 100.085 mm

Hole : $100^{+0.035}_{+0.000}$; shaft : $100^{+0.12}_{+0.085}$

<u>shaft basis system</u> :

U.L.S = 100 mm

min interference = L.L.H − U.L.S

0.05 = L.L.H − 100

L.L.H = 100.05 mm

shaft tolerance = U.L.S − L.L.S

0.035 = 100 − L.L.S

L.L.S = 99.965 mm

hole tolerance = U.L.H − L.L.H

0.035 = U.L.H − 100.05

U.L.H = 100.085 mm

Hole : $100^{+0.05}_{+0.085}$; shaft : $100^{-0.035}_{+0.000}$

10. Determine the limits of size for a fit 20H7 f8 for the conditions

(i) $i = 0.045 (D)^{1/3} + 0.0010$

(ii) upper deviation of f- shaft $= -5.5 D^{0.41}$

(iii) 20 mm falls in the diameter step of 18 mm to 30 mm

(iv) IT7 = 16i

(v) IT8 = 25i

Sol (i) $D = \sqrt{16 \times 30} = 23.23$ mm

(ii) $i = 0.045 (23.23)^{1/3} + 0.001 (23.23)$

$= 0.15\ \mu$

$1\mu = 0.001$ mm

$i = 0.15 \times 0.001$

$= 1.5 \times 10^{-4}$ mm

(iii) IT7 = 16 i

$= 16 \times (1.5 \times 10^{-4}) = 2.4 \times 10^{-3}$ mm

(iv) IT8 = 25i

$= 25 \times (1.5 \times 10^{-4}) = 3.75 \times 10^{-3}$ mm

(v) upper fundamental deviation of shaft $= -5.5 (D)^{0.41}$

$= -5.5 (23.23)^{0.41} = -0.019$ mm

Limits

L.L.H = 20 mm

2.4×10^{-3} = U.L.H − L.L.H

2.4×10^{-3} = U.L.H − 20

U.L.H = 20.0024 mm

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7

$U.L.S = 20 - 0.019$

$= 19.981$ mm

$L.L.S = 20 - 0.019 - (3.75 \times 10^{-3})$

$= 19.977$ mm

11. Determine the limits of tolerance & allowances for a 45 mm shaft & hole pair designated H7d8 the basic sizes lies in the range of 30-50 mm. The multiplier for grades 7 & 8 (are) 16 & 25 respectively. The fundamental deviation for 'd' shaft is $(-16 D^{0.44})$

Sol

Basic size = 45 mm

step diameter = 30 - 50 mm

fundamental deviation $= -16 D^{0.44}$

$IT7 = 16i$

$IT8 = 25i$

$D = \sqrt{30 \times 50} = 38.72$ mm

$i = 0.045 (D)^{1/3} + 0.001 D$

$= 0.045 (38.72)^{1/3} + 0.001 (38.72)$

$= 0.19\ \mu$

$= 0.19 \times 0.001$

$= 1.90 \times 10^{-4}$ mm

$IT7 = 16i$

$= 16 \times (1.90 \times 10^{-4}) = 3.055 \times 10^{-3}$ mm

$IT8 = 25i$

$= 25 (1.90 \times 10^{-4}) = 4.77 \times 10^{-3}$ mm

fundamental deviation $= -16 D^{0.44}$

$= -16 (38.72)^{0.44}$

$= -79.94\ \mu$

$= -0.07994$ mm

Basic size L.L.H = 45 mm

tolerance on hole = U.L.H − L.L.H

3.055×10^{-3} = U.L.H − 45

U.L.H = 45.003 mm

U.L.S = Basic size − fundamental deviation

= 45 − 0.0799

= 44.9201 mm

L.L.S = Basic size − tolerance − fundamental deviation

$= 45 - 4.77 \times 10^{-3} - 0.0799$

= 44.915 mm

Taylor's principle - Design of GO and NO GO Gauges:

Taylor's principle of Gauge design:

This theory is the key to the design of limit gauges and defines the function and hence the form of most limit gauge. It states that,

1. The "GO" gauge should be designed to check the maximum material condition and should check as many dimension as possible.
2. The "NOT GO" or "No GO" gauge should be designed to check the minimum materials limit and should only check one dimension at a time.

Thus a separate "No GO" gauge is required for each individual dimension. consider a system of limit gauge for a rectangular hole as shown in figure.

The "GO" gauge is used to ensure that the maximum metal condition is not exceeded and that metal does not encroach in to the minimum allowable hole space. It shoulc

Rectangular hole oversize in one Direction

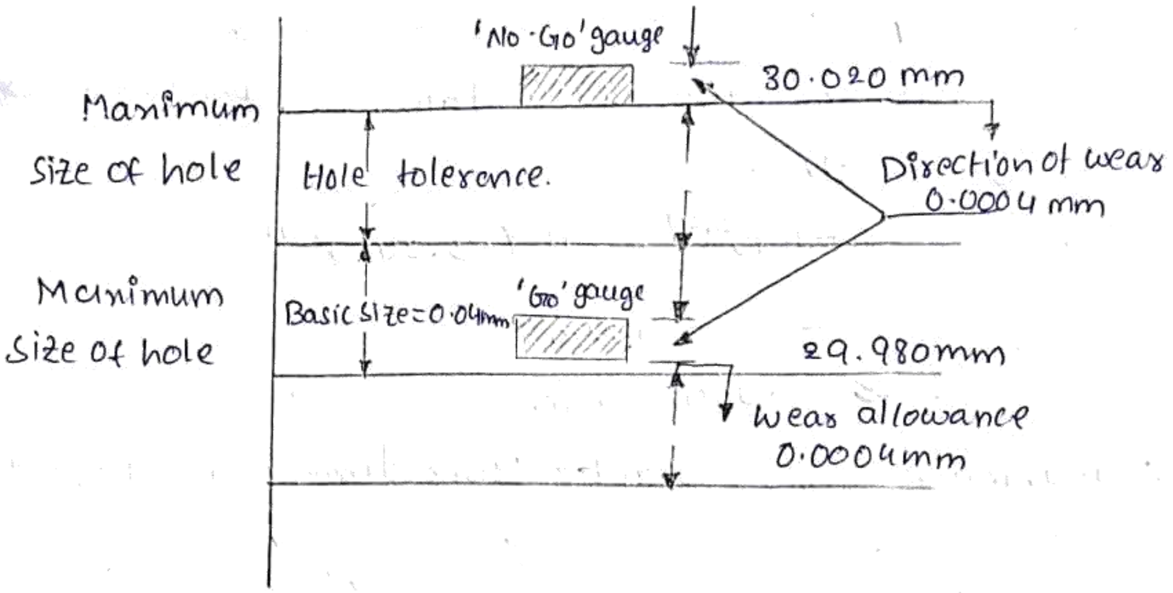
This system should be applied to all systems of limit gauges. The 'Go' gauge should be made equal in length to about three or four times of diameter, while the "No Go" gauge is always relatively short and approximately equal in length to the hole diameter, in case of circular hole.

In case of curved holes, if the length of the gauge is made shorter, then it will get pay through the obstruction in the hole and gives a wrong reading. But if the length of the gauge is made considerably long, it will not pass through the curved holes and error will be detected. A long gauges will thus check the surface not in one direction but in a number of sections simultaneously. The length of the "Go" gauge should not be less than 1.5 times the length of the hole to be checked.

Limitations of Taylor's principle:

1. Taylor's principle for 'Go' gauge is designed to have its length equal to the engagement length of fit. But in actual practice, it is not always possible. For instance, if Go gauge passes through a hole or shaft very easily so that it does not affect the required fit of assembly, then the length of 'Go' gauge (i.e., ring or cylindrical type gauge) might be less than engagement length of fit. Similarly for big holes, the full form gauge will be much heavy and unsuitable to use. Hence, if 'Go' gauge does not gives roundness error to a affect the engagement fit than other gauges like spherical gauge, segmental cylindrical bar etc, should be used.

(6) 'NO - GO' gauge = $30.020^{+0.0004}_{+0.000}$ mm



Q. Design a typical 'Go' and 'No Go' gauge for a shaft of 80 mm.

Answer:

Let us design the Go and NO Go gauge for 80 $H_8 e_9$ fit

Nominal diameter of shaft and hole is 80 mm

Since 80 mm diameter lies in the diameter steps of 50 and 80 mm.

$\therefore$ Value of D = $\sqrt{50 \times 80}$ = 63.246 mm

we know that, the fundamental tolerance factor,

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

$$\Rightarrow i = 0.45\sqrt[3]{63.246} + 0.001 \times 63.246$$

$$= 1.856\,\mu m$$

$$\cong 0.00186 \text{ mm}$$

Hole type is H_8, and for H-hole, fundamental deviation = 0, $\therefore$ minimum size of hole = 80.000 mm

For H_8 i.e., IT_8, the value of tolerance

$$= 25i$$

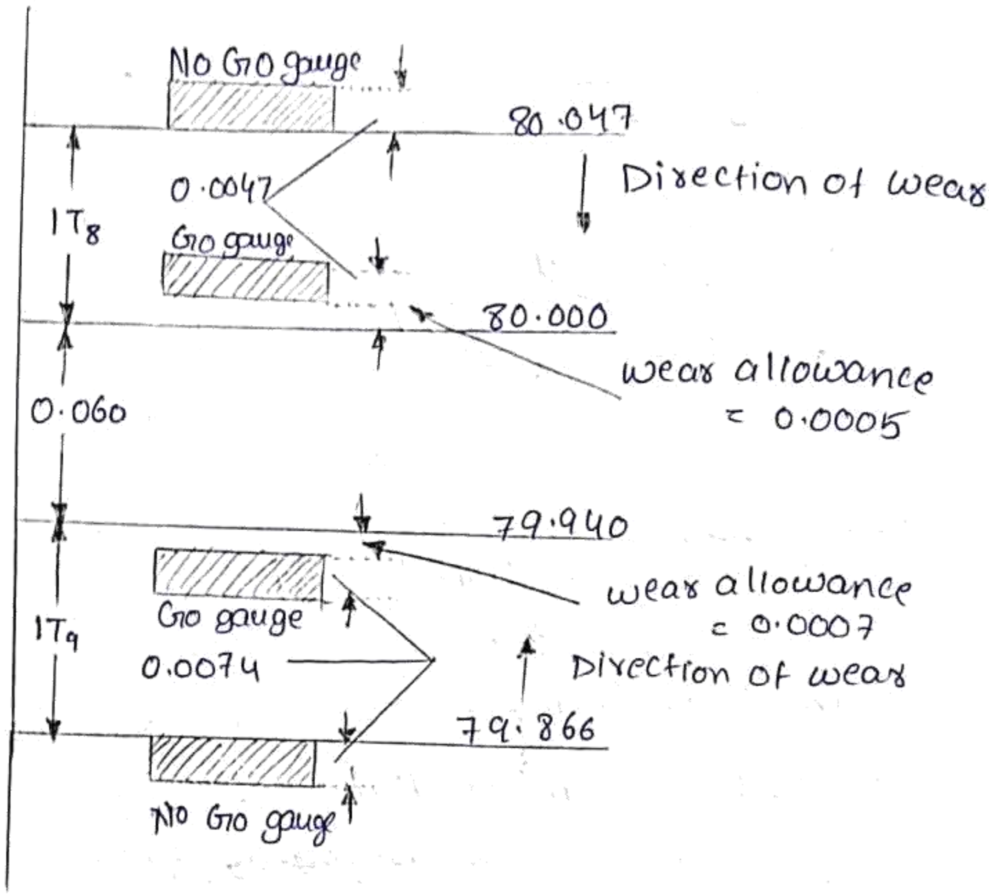
$$= 25 \times 0.00186$$

$$= 0.047 \text{ mm}$$

For shaft,

Go gauge $= 79.940^{-0.0007}_{-0.0007-0.0074} = 79.940^{-0.0007}_{-0.0081} = 80^{-0.0607}_{-0.0681}$ mm

No Go gauge $= 79.866^{-0.0000}_{-0.0074} = 80^{-0.1340}_{-0.1414}$ mm



Snap gauges:

These gauges are used for gauging the shafts and male components. The 'Go' snap gauge is of a size corresponding to the high (maximum) limit of the shaft, while the 'NOT Go' gauge corresponds to the low (minimum limit). It is a plain gauge, category of form of tested surface with single ended and double ended gauge. Its ranges from 3mm to 100mm with double end and 100 to 250 mm as single ended type. The gauging surfaces of the snap gauge is hardened and suitably grounded and lapped. Snap gauge have 'Go' and 'No-Go' checking facility. The various snap, gap and ring gauges are shown in figure.

checked is parallel to the axis, as it normally is the gauge must be positioned parallel to the shaft axis also. (55)

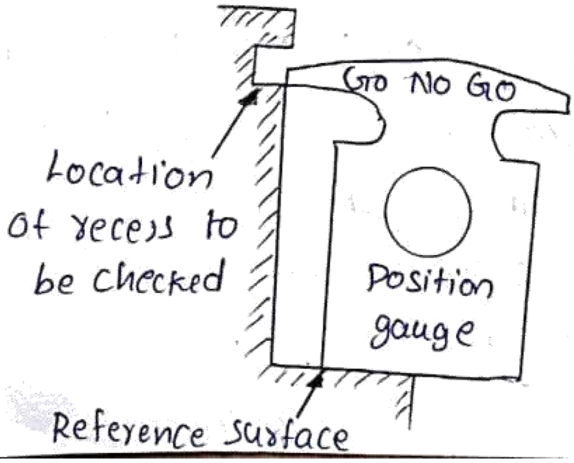
Profile gauges are used to check the form of the components. profiles are difficult to be checked by limit gauges and it is practice to use fixed gauges mated to profile for checking profiles. There are two method of tolerance the form of profile (consisting of straight lines and curves).

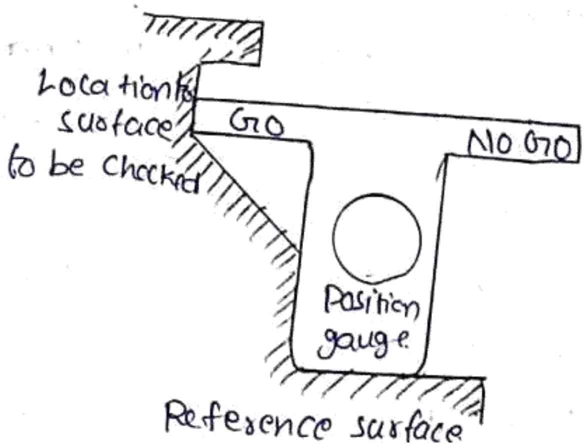
(i) It provide a tolerance zone within which the finished profile must lie. This method provides a uniform metal tolerance normal to the profile.

(ii) To use ordinates which are provided with individual tolerances. In this method the tolerance is normal to the surfaces will vary with the form of the profile.

Position Gauge:-

The position gauges are employed for checking the position of some features as the work in relation to other surface or reference point. They are available to avoid variety and their design is based on the principle of sighting the gauge and work or on the method of feel. Practically, different position gauges are required for different works.

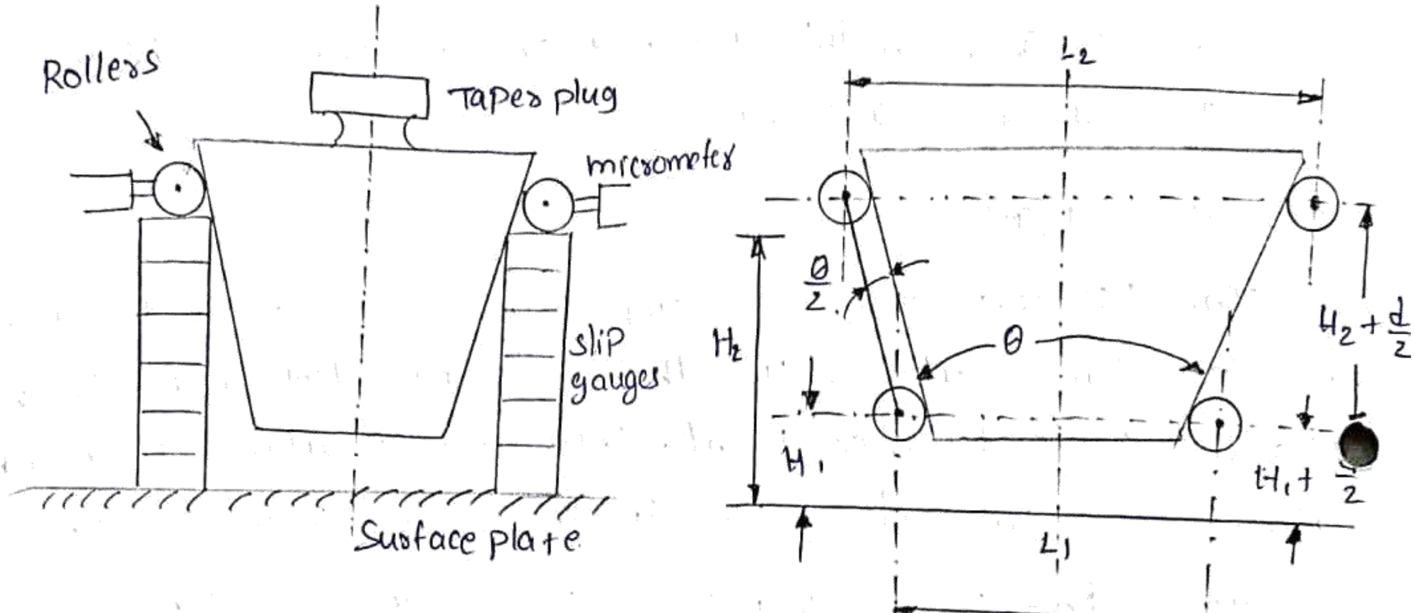




From the figure it may be noted that no light will pass between the reference surface and gauge surface in contact with "Go" side and light will pass "No Go" side. Figure shows checking to location of a recess in relation to a flat surface and figure shows the surface parallel to the reference surface to be located.

Checking the angle of taper using rollers, Micrometer and Slip gauges :

In this method, measurements are made over two equal rollers standing on slip gauges at each side of the taper plug gauge at two positions (one near the lower end and one near the upper end) are shown in figure (1).



(1): Measurement of Taper plug gauge.

At first the taper plug is placed on the surface plate. Two equal rollers are placed on the slip gauges on either sides of the taper plug at a height of H_2 and two equal rollers are placed on lower sides of the plug at a height of H_1. Now, the distance between the ends of the rollers are measured by a micrometer. Let 'L_1' be the distance between the two upper position rollers and 'L_2' be the distance between the two lower position rollers. Also "d" be the diameter of the roller then,

$$\tan\left(\frac{\theta}{2}\right)\left[\frac{\left[\frac{L_2-d}{2}\right]-\left[\frac{L_1-d}{2}\right]}{\left[H_2+\frac{d}{2}\right]-\left[H_1+\frac{d}{2}\right]}\right]$$

$$\therefore \tan\left(\frac{\theta}{2}\right)=\left[\frac{\left(\frac{L_2-d}{2}\right)-\left(\frac{L_1-d}{2}\right)}{\left[\frac{2H_2+d}{2}\right]-\left[\frac{2H_1+d}{2}\right]}\right]$$

$$=\frac{\left[\frac{L_2-d-L_1+d}{2}\right]}{\left(\frac{2H_2+d-2H_1-d}{2}\right)}$$

$$\tan\left(\frac{\theta}{2}\right)=\frac{L_2-L_1}{2(H_2-H_1)}$$

where, $\frac{\theta}{2}$ - Half the taper angle of the plug.

Q Calculate the angle of taper and minimum diameter of an internal taper from the following readings,
Diameter of bigger ball - 10.25 mm
Diameter of smaller ball - 6.07 mm
Height of top of bigger ball from datum - 30.13 mm
Height of top of smaller ball from datum - 10.08 mm.

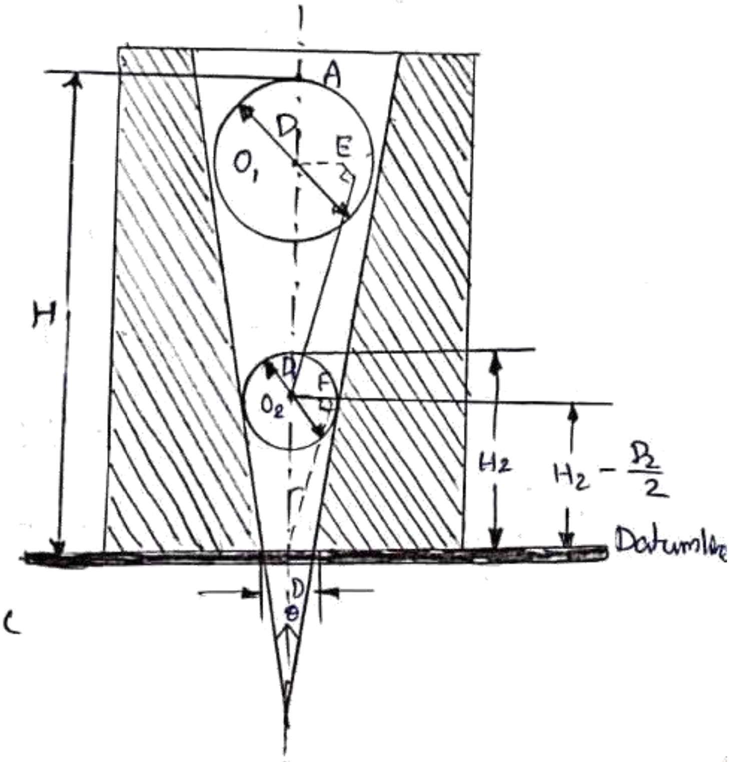
Answer: Given that

$D_1 = 10.25\text{mm}$

$D_2 = 6.07\text{mm}$

$H_1 = 30.13\text{ mm}$

$H_2 = 10.08\text{ mm}$



From triangle $O_1 O_2 D$, we have,

$$\sin\frac{\theta}{2}=\frac{O_1E}{O_1O_2}=\frac{O_1E}{AC-O_1A-O_2C}$$

$$\sin\frac{\theta}{2}=\frac{\frac{D_1}{2}-\frac{D_2}{2}}{H_1-\frac{D_1}{2}-\left(H_2-\frac{D_2}{2}\right)}$$

$$\sin\frac{\theta}{2} = \frac{D_1 - D_2}{2H_1 - D_1 - 2H_2 + D_2}$$

$$= \frac{10.25 - 6.07}{2(30.13) - 10.25 - 2(10.08) + 6.07}$$

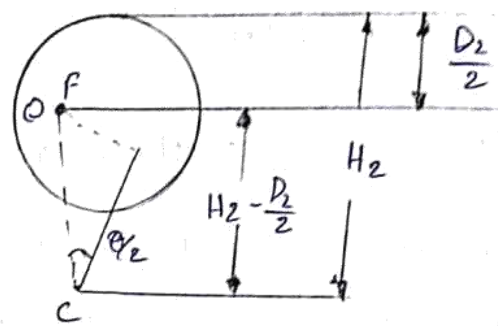
$$\sin\frac{\theta}{2} = \frac{4.18}{35.92} = 0.11637$$

$$\frac{\theta}{2} = \sin^{-1}(0.11637) = 6.68265^{\circ}$$

$\therefore$ Taper angle, $\theta = 13.3653^{\circ}$

For finding minimum diameter (D) of an internal taper.

Let us consider the triangle O_2CF i.e.,



$$\sin\frac{\theta}{2} = \frac{O_2F}{O_2C}$$

$$\sin\frac{\theta}{2} = \frac{\frac{D_2}{2} - \frac{D}{2}}{H_2 - \frac{D_2}{2}} = \frac{D_2 - D}{2H_2 - D_2}$$

$$0.11637 = \frac{6.07 - D}{2(10.08) - 6.07}$$

$$1.63965 = 6.07 - D$$

$$D = 6.07 - 1.63965 = 4.43 \text{ mm}$$

$\therefore$ minimum diameter of taper $= 4.43$ mm.

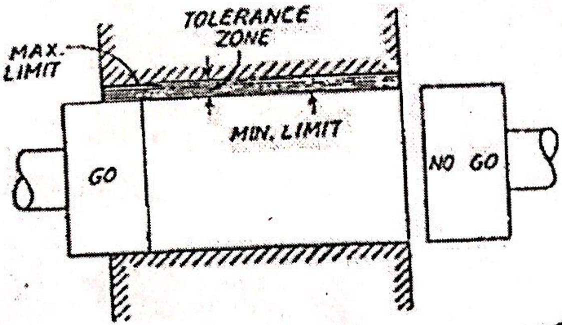
2.17 Gauges:

Before accepting any component that is manufactured, need to be inspected for high accuracy. In mass production several components will be manufactured checking each part requires high cost and time. Conformations for the parts can be done easily, by measuring the required tolerances of parts using gauges. Gauges are scale less rigid instruments, these gauges are made to specify the limits of the component. Unskilled persons can check the work piece. No need to do calculations for measurement. They give quick result.

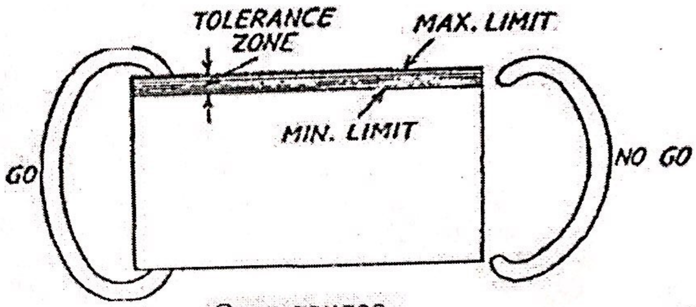
Gauges are of two types:

A **Go-No gauge** (or Go/no go) refers to an inspection tool used to check a workpiece against its allowed tolerances. Its name derives from its use: the gauge has two tests; the check involves 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 industry to ensure interchangeability of parts between processes, or even between different manufacturers.



Plug gauges

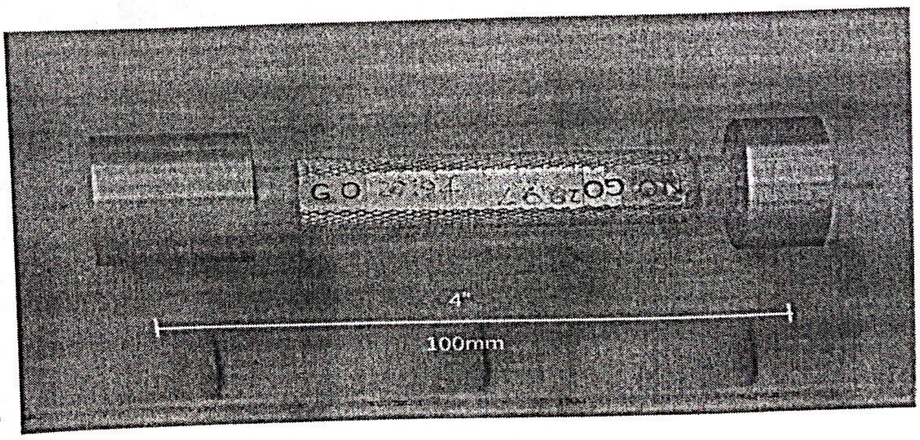


Snap gauges

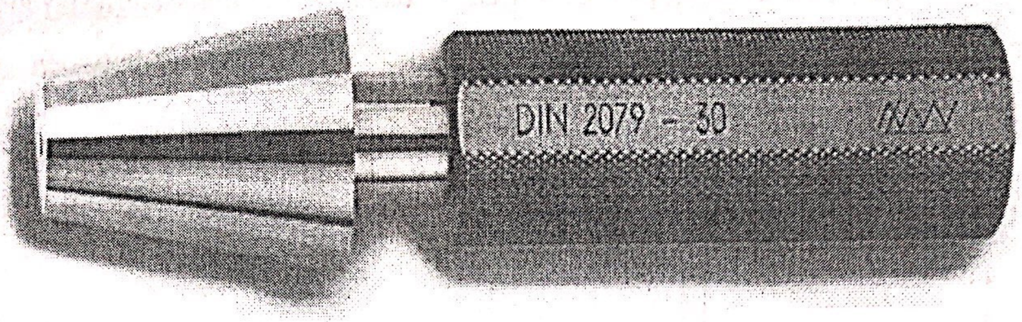
Types of gauges:

a.) PLUG GAUGE

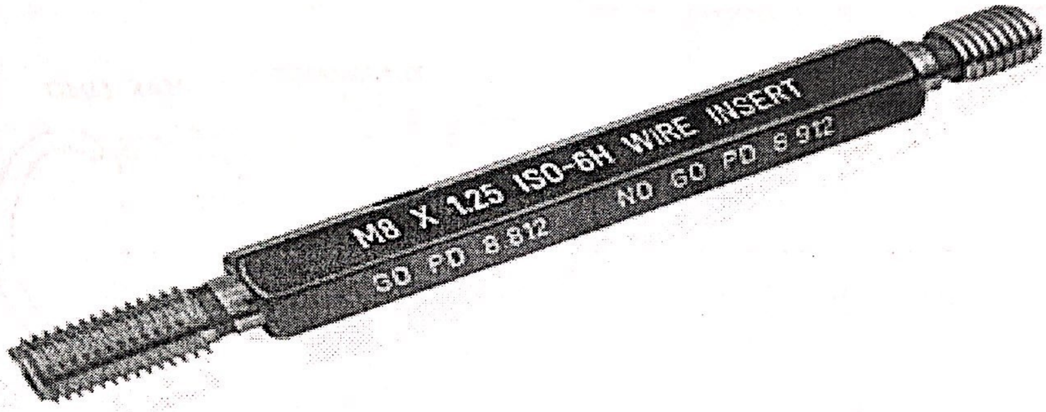
i. SOLID TYPE DOUBLE ENDED



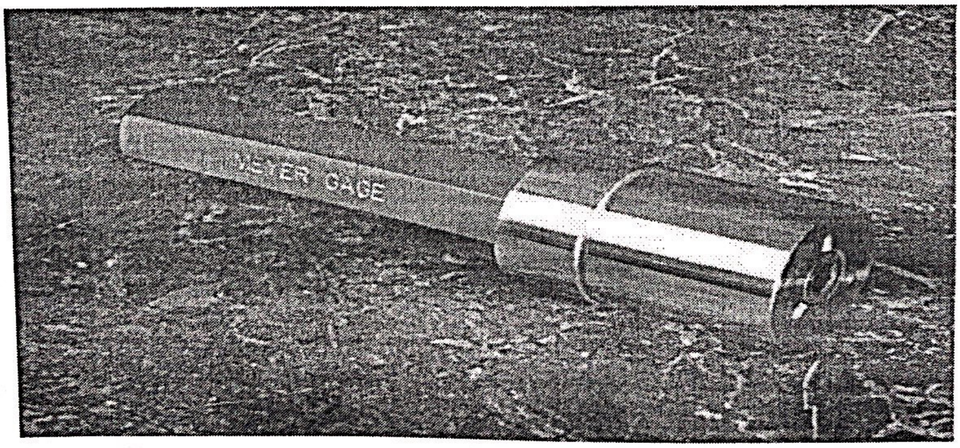
ii. TAPER INSERTED TYPE



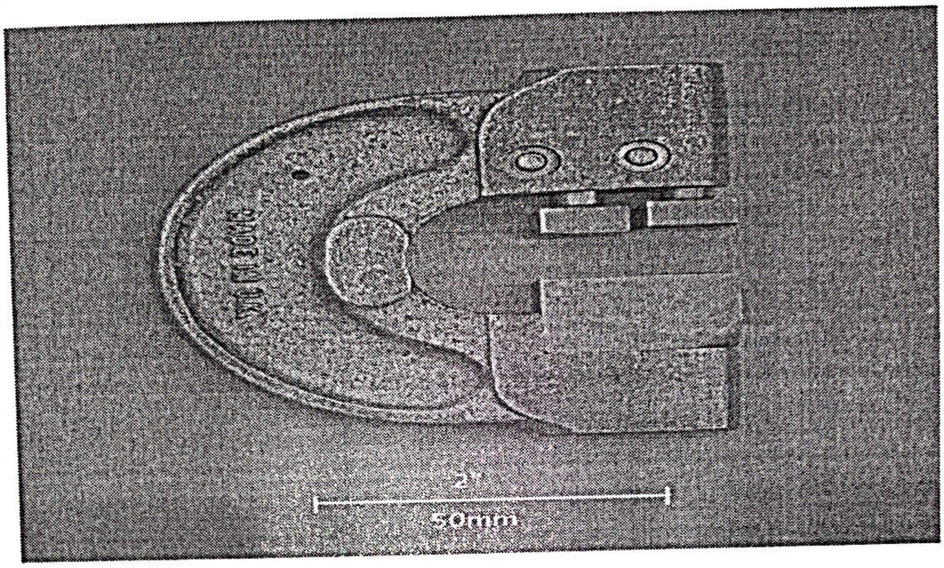
iii. FASTENED TYPE DOUBLE ENDED



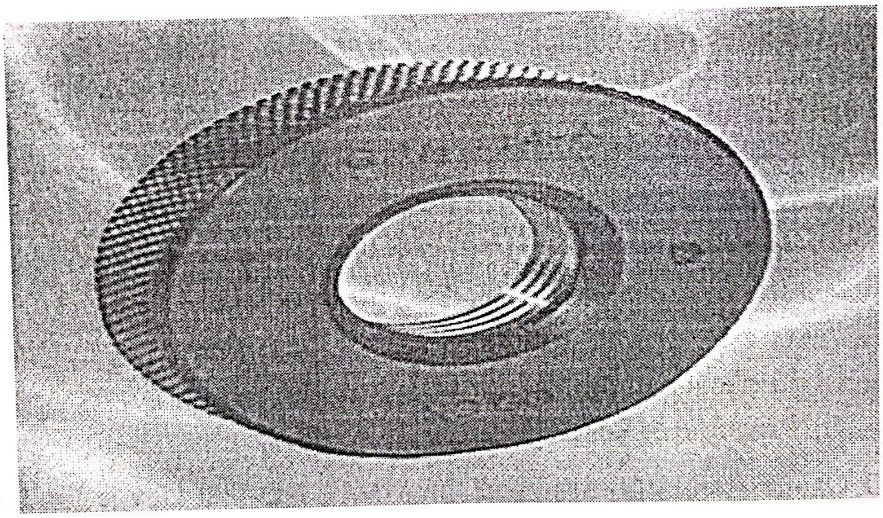
iv. PROGRESSIVE TYPE PLUG GAUGE



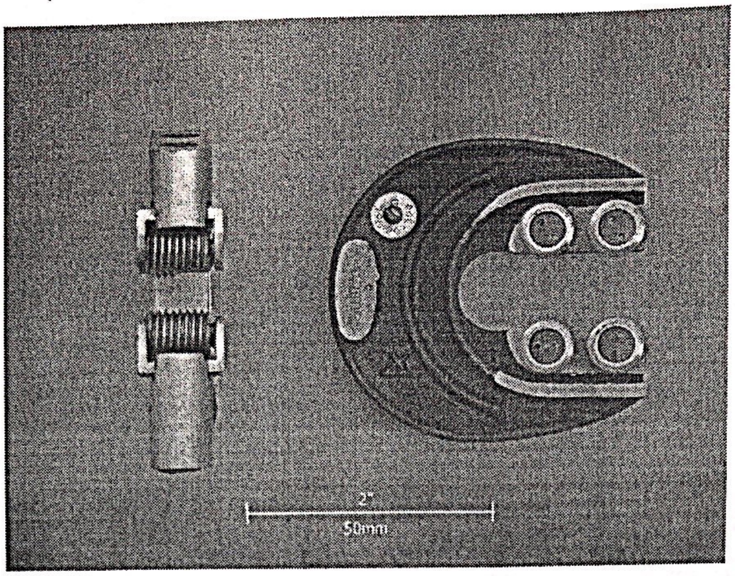
b.) SNAP GAUGE



c.) RING GAUGE



d.) THREAD SNAP GAUGE

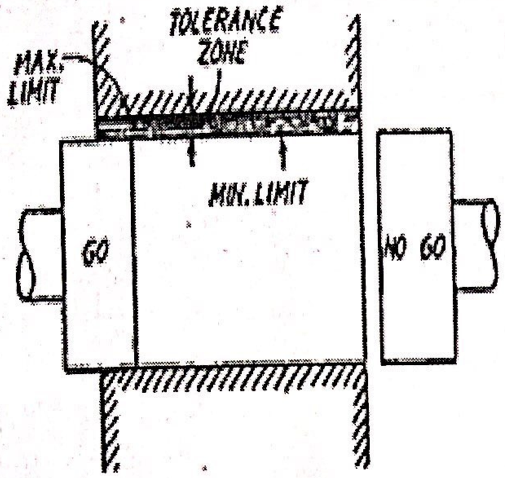


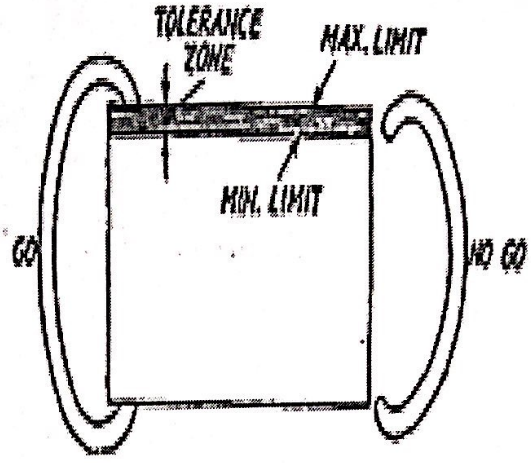
Material for gauge:

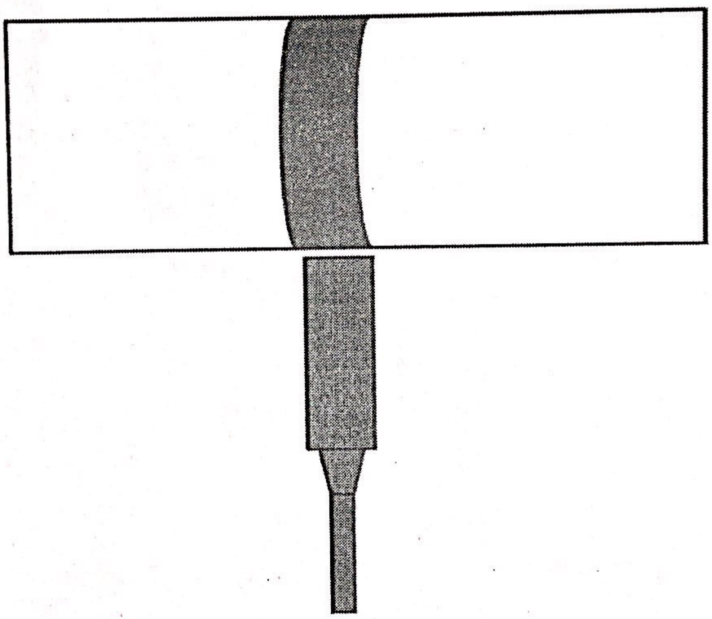
- Hardness to resist wear, Should be made with high carbon steel and heat treated to impart hardness
- Stability so that they won't change size and shape
- Corrosion resistant
- High degree of accuracy
- Low coefficient of thermal expansion
- Low thermal conductivity
- Coated products will be beneficiary

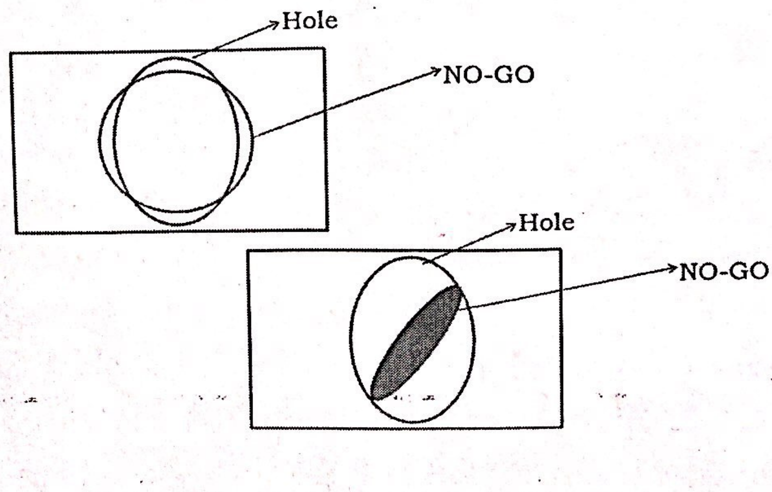
2.18 Taylors Principle of Gauge Design:

1. GO Gauge should be designed for MMC, NO-GO Gauge for LMC. If the plug gauge is check the hole, size of Go should be to lower limit and NO-GO to Upper limit. Similarly if snap gauge is used to check the shaft, size of GO should be to upper limit of shaft and NO-GO to lower limit.
2. Taylor's principle states that the "GO" gauge should check all the possible elements of dimensions at a time (Roundness, size, location, etc.) the no gauge should check only one element of the dimension at a time.
3. Holes that need to be inspected will in oval shape usually. So NO-GO will not enter and we wrongly prospect that NO-GO is not entering in hole so it's perfect.


TOLERANCE
ZONE
MAX.
LIMIT
MIN. LIMIT
GO
NO GO


TOLERANCE
ZONE
MAX. LIMIT
MIN. LIMIT
GO
NO GO




Hole
NO-GO
Hole
NO-GO