GOVT. TOOL ROOM AND TRAINING CENTRE
KARNATAKA

REFERENCE NOTES

ENGINEERING METROLOGY

SUBJECT CODE: DTDM IIIS 303

FOR
: DIPLOMA IN TOOL AND DIE MAKING
: DIPLOMA IN PRECISION MANUFACTURING

UNIT 1- STANDARDS OF MEASUREMENTS

Metrology

Metrology is a branch of engineering science which deals with measurement and inspection. It involves the measurement standards design and use of measuring or equipment and apparatus of machine under various engineering field.

Objectives of metrology

Metrology helps in carrying out various measurement and inspections objectives they are

1. To ensure that all measuring instruments properly maintained for use through periodical calibration.

2. To standardize the method of measurement and produce given component /machine/product.

3. To ascertain the capacity of the measuring instruments and ensure accurate measurement.

4. To assist in smooth and efficient use of instrument in inspection of components so as to minimize the cost/time of inspection reduce rejection.

5. To help in the design of gauges and fixtures required in product development.

6. To work as a part of inspection and quality control department in organization and contribute high productivity.

Standards

The term –standard means a physical object which serves to preserve the value of same unit.

It means it is unique and common to one and all. Universal standards mean the standards which is accepted and used all over the world. Universal standards are unique and same for the people all over the world.

Need for standards

Standards define the units and scales in use, and allow comparison of measurements made in different times and places. For example, buyers of fuel oil are charged by a unit of liquid volume.

In the U.S., this would be the gallon; but in most other parts of the world, it would be the liter. It is important for the buyer that the quantity ordered is actually received and the refiner expects to be paid for the quantity shipped. Both parties are interested in accurate measurements of the volume and, therefore, need to agree on the units, conditions, and method(s) of measurement to be used.

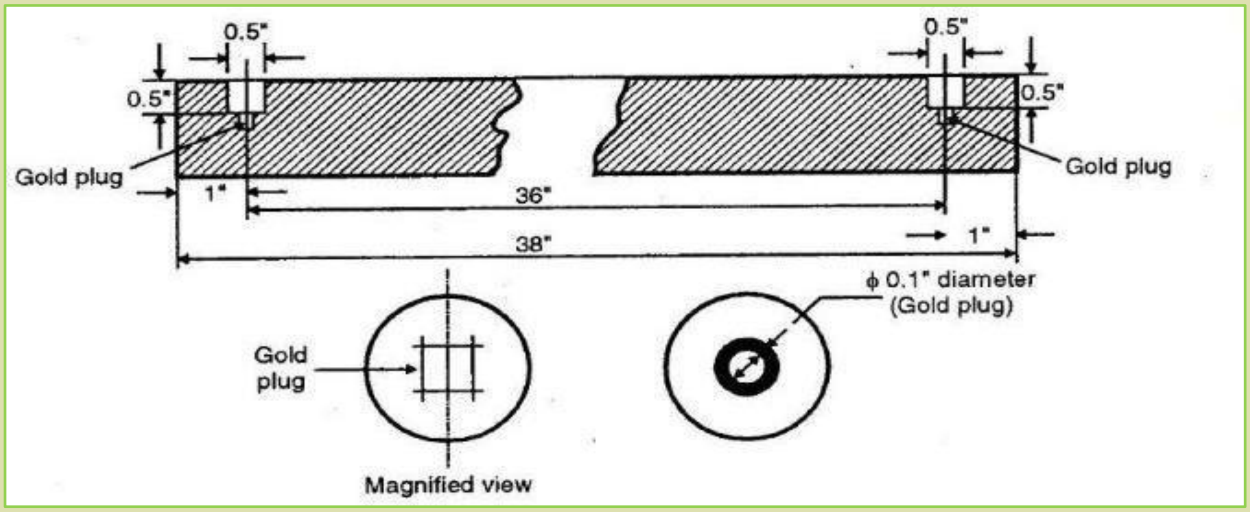
Persons needing to measure a mass cannot borrow the primary standard maintained in France or even the national standard from the National Institute of Standards and Technology (NIST) in the U.S. They must use lower-level standards that can be checked against those national or international standards.

Everyday measuring devices, such as scales and balances, can be checked (calibrated) against working level mass standards from time to time to verify their accuracy. These working-level standards are, in turn, calibrated against higher-level mass standards.

This chain of calibrations or checking is called –traceability. A proper chain of traceability must include a statement of uncertainty at every step.

Imperial standard yard

The imperial standard yard is made of 1 inch square cross section bronze bar. (82% copper, 13%tin, 5%zink) 38 inch long. The bar has two 1/2 inch diameter*1/2 inch deep holes. Each holes fitted with 1/10th inch diameter gold plug. The top surface of these plugs lie on the neutral axis of the bronze bar.



The purpose of keeping the gold plug lies at neutral axis has the following advantages:-

- Due to bending of beam the neutral axis remains unaffected
- The plug remains protected from accidental damage.

The top surface of the gold plugs is highly polished &contains 3 lines engraved transerverly & 2 lines longitudinally.

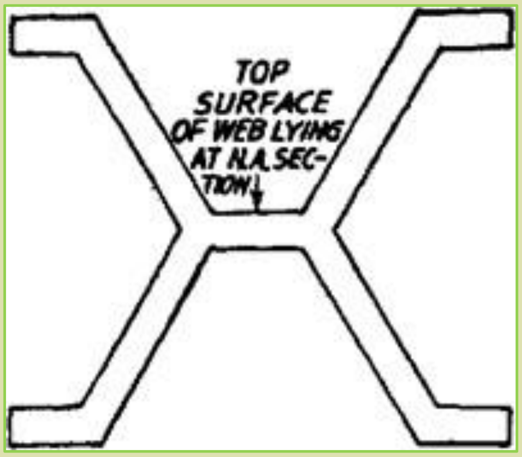
The yard is defined as the distance b/w 2 central transverse lines on the plugs when,

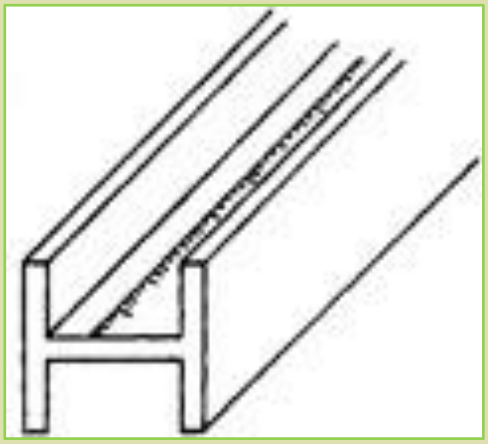
1. The temperature of the bar is constant at 62 degree f &

2. The bar is supported on rollers in a specified manner to prevent flexure.

This standard was legalized in 1853 & remained legal standard until 1960
1yard = 0.9144 meter = 38inch.

International standard meters





It is the primary reference standard. It is defined as distance at 0degree c b/w the center portion of 2lines graduated on the polished surface of bar of pure platinum iridium alloy (90%platinum, 10%irridium)of 1020mm total length with a cross section of 16mm square. Graduation is integrated on upper surface web which coincides with neutral axis of section. This section was specially designed to engrave graduation throughout its length &the shape to give high rigidity &stability of dimension. We know that under beam deflection neutral axis is unaffected &making remain stable.

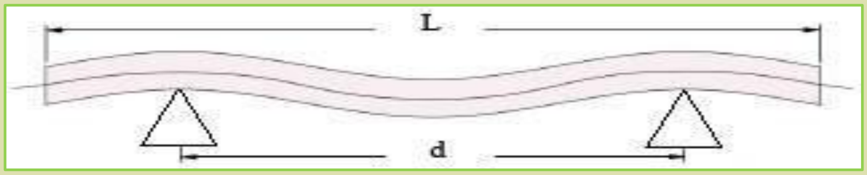
Original prototype meter is preserved at international bureau of weight & measurement near Paris in France.

Airy points

When straight bars above 125-200mm length are supported by horizontally for measuring by to supports at its end they will slag in the middle. If the supports are provide towards the center then the ends will bend.

This error can be minimized by providing the two supports at such a distance that the slope at the ends is 0& the end faces of the bar are mutually parallel.

Sir G B Airy showed that this condition was obtained.



When the distance b/w the supports is $\frac{l}{\sqrt{n^2-1}}$

Where,

n=number of supports

l=length of the bar

For a simply supported beam, the expressional becomes

$\frac{l}{\sqrt{(2)^2-1}} = \frac{l}{\sqrt{3}}$ =0.577L

These points of supports are airy points.

Types of standards

1. Line standard

2. **End standard**
3. **Wave length standard**

Line standard

As per the line standard the unit of length is considered as the distance b/w the center of engraved lines(standard rule) International prototype meters &imperial standard yard use line standard measurements & not convenient to use. It has limitation to accuracy with which lines can be produced on marked & involves microscope

End standard

Unit of length is taken as distance b/w end faces of instruments.

Ex: micrometer, slip gauge, etc.

For important works end standard are used distance b/w end measure the actual dimension ends are hardened highly polished &face are made of flat & parallel.

Difference between the line standard & end standard

Line standard	End standard
1.In this distance is measured b/w 2lines	1.In this distance measured b/w the 2 flat surfaces
2.Line standard give low accuracy(±0.2)	2.End standard give high accuracy(±0.001mm)
3.Line standard measurements are simple &quick	3. While in end standard is skillful time consuming
4.Simple to manufacture at low cost 5.The skilled &unskilled persons can be used	4.Manufacturing process is complex and cost is high 5.The skilled persons are used
6.They are subjected to parallel error Eg; yard, meter	6.They are not subjected to parallel error

	Eg; End bars, micrometer, vernier caliper

Wave length standard

In 1829 Jacques babient of France suggested this it is natural invariable unit of length used as primary standard. Pure monochromatic light source cd-114, kr-86&hg -198 are possible source of radiation of wavelength &most suitable for use as primary standard of length.
It is defined as length =1650763.73 vacuum wave length of orange radiation of krypton-86 under given reference is condition.

This is the present standard meter used throughout the world.

Advantages

1. It is not in physical &not need of preservation under controlled condition
2. It is only a radiation not effected by environmental condition like pressure, temperature &humidity.
3. Transfer from wavelength standard to other working standard is simple &easy
4. Easily accessible to all users
5. Highly constant &value does not change
6. Most suitable for accuracy comparative measurements & production of secondary/working gauges.

Subdivision of standard

1. **Primary standard**
2. **Secondary standard**
3. **Tertiary standard**
4. **Working standard**

1. Primary standard:

For precise definition of standard unit of length (meter) .It is essential to have one

& only one material standard. Primary standard are material standards.

These are basic standards which do not change their value & preserved carefully. These cannot be used for direct measurement based on these additional standard are used called secondary standard &compared after every 10-20 years.

Disadvantages:

1. Line standards are not convenient to use
2. Preserved at highly controlled condition .maintenance is expensive
3. Not used for direct measurement other than comparison with secondary.

2. Secondary standard:-

These are reproduced standard of fully based on primary standard. They are identical to the primary standard with respect to design material size. a number of units of secondary standard produce& preserve for the comparison of tertiary standard are compared with primary standard for standard error.

3. Tertiary standard:-

The primary &secondary standard is applicable only as ultimate control. The tertiary standards are the first standard to be used for reference purpose in laboratories &workshops. They are made of true copy of the secondary standard. They are used for comparison at intervals with working standard

4. Working standard:-

These are the standards used in day to day measurements in engineering fields. These are similar to other 3 standard but cheaper less controlled &variable for every once use.

Standard & standardizing organization

For higher economy, efficiency &productivity, interchangeability in industry & country standardization is necessary. It is done in various levels international, national associate company.

In India –bureau of Indian standard –(BIS) is responsible for evaluating standard on metrological instruments. B I S is national body for standard in India.

Function of B I S

1. Formulating, publication & promotion of Indian standard
2. Inspection of articles (or) process under certification scheme
3. Establishments , main tense& recognition of laborites
4. Formulate ,implement& co-ordinate activities in product & process
5. Bring out hand books, guides & other publications

Different standard organizations

1. International organization on weight & measure
2. General conference of weight & measure
3. International committees of weight & measure
4. International system of units (S I)

QUESTIONS

1. With a neat sketch, explain standard meter.
2. Explain sub-divisions of standards.
3. Define 1) metrology. 2) Wavelength standard.
4. With a neat sketch, explain a standard yard.
5. Explain how standards are sub divided.
6. Differentiate between line and end standards.
7. What are airy points? Explain with a neat sketch.
8. How are the standards sub-divided? Explain.
9. Define metrology. What are its objectives?
10. Explain the 2 types of standards with suitable examples.
11. Explain imperial standard yard with the help of neat sketch.

12. Explain secondary and working standards.
13. What is line and end standard? What are the advantages and disadvantages of both standards?
14. Define line standard, end standard & wavelength standard.
15. Explain line standard & end standard. Give examples of these two types of standards.
16. What do you understand by material standard? How the wavelength standard is superior to other standard?
17. What do you understand by line standard & end standard? Define yard & meter.
18. What do you understand by line standard & end standard? How are end standard derived from line standard? Give examples of these two types of standards.
19. Explain the difference between the two material standards? What are the disadvantages of material standards?
20. What do you understand by line and end measurements? Explain their relative characteristics.
21. Explain the following: 1) primary standard 2) Secondary standard
    a. 3) Tertiary standard 4) Working standard 5) Wavelength standard.

WRITE SHORT NOTES

a. Wavelength standard
b. Sub-division of standards
c. Line and end standard

Useful Links

- https://www.youtube.com/watch?v=zC2Wivnq344
- https://www.youtube.com/watch?v=7vT-988yH3M
- https://www.youtube.com/watch?v=mmW8W3-1zfk

UNIT 2 – LIMITS, FITS AND TOLERANCE

Introduction

We know that every day process is a combination of 4 elements (4ms) i, e man, machine, material and money a change in any one of this element will constitute a change in the process these variable result in the variation of size of components.

If the pros be under control i, e all the assignable causes of variation and controllable causes of variation have been removed controlled.

Concepts of tolerance

It is due to the inevitable human error and inevitable in accuracy of machines. Machines methods and in build machine error. It is not possible to make any part accurately.

Tolerance

Tolerance can be defined as the magnitude or permissible variation of size or dimension from the basic size or specified size it is obvious that it is impossible to provide a part to an exact size allowance known as tolerance the tolerance allowed also depends on the functional requirements of the parts

Needs of tolerance or why tolerance are specified

1. Variations in properties of all being machined introduce error.
2. The production all is them serve have some inherent in accuracy built into them limitation to produce perfect part.
3. It is an impossible for an operator to make perfect setting in the machine i, e in adjusting the tools and work piece on machine. Some errors are likely to creeping.
4. Tolerance is the compromise between accuracy required for proper functioning & the ability to produce this accuracy.

Relation between tolerance & cost

It is impossible to manufacture a part a specified definite size particularly in a mass production. Even if it is produced exactly to a measure it accurately enough to prove it more over considering the function requirement no purpose is served by producing any since some variations depending on function can be tolerance the cost of attempting to produce parts to a specified definite size.

Without any variation in mass or large quantity would be too high thus justifying the need for tolerance for tolerance.

Ex: manufacturing cost of the products with high or close tolerance is more compared to the products with lower or less tolerance.

Accuracy & precision

The term accuracy & precision are associated with the measuring process they are part & parcel of the measuring method or process.

Precision

Precision is defined as the reparability of a measuring process in most measurement it is the precision which is of great importance the chief cancer is with comparing the dimension of measuring relative to each other it being a assumed that the scale used for measurement relative to each other it being a assumed that the scales used for measurement a standard & accepted one.

Accuracy

Accuracy is defined as the agreement of the results of a measurement with the true value of the result of a measured quantity in mechanical inspection the accuracy of measurement is the most important aspect it is therefore better to understand & various factors which affect it & which are acted by it.

Types of tolerance

- Unilateral tolerance
- Bilateral tolerance

Unilateral tolerance

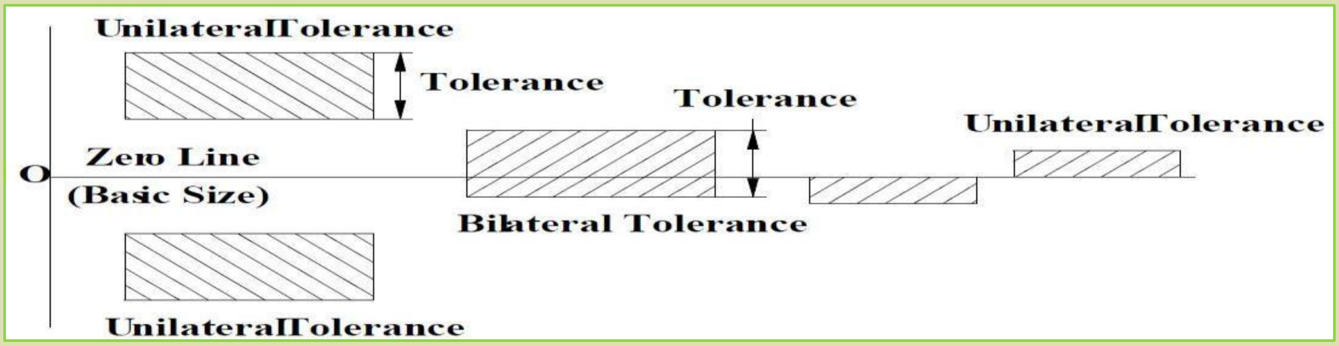
In unilateral tolerance the permissible tolerance is allowed to deviate from the basic size rather than undersized this form of tolerance is usually indicated when the machining of mating parts

Ex: $25^{+0.05}$, $30.0^{+0.03}$, $30^{-0.06}$

Bilateral tolerance

In bilateral tolerance the permissible variation tolerance is allowed to deviate on both variation tolerance is allowed to deviate on both (plus & minus) sides form the basic size bilateral tolerance system defines the theoretically designed size and the probable deviation permitted on either side on basic size.

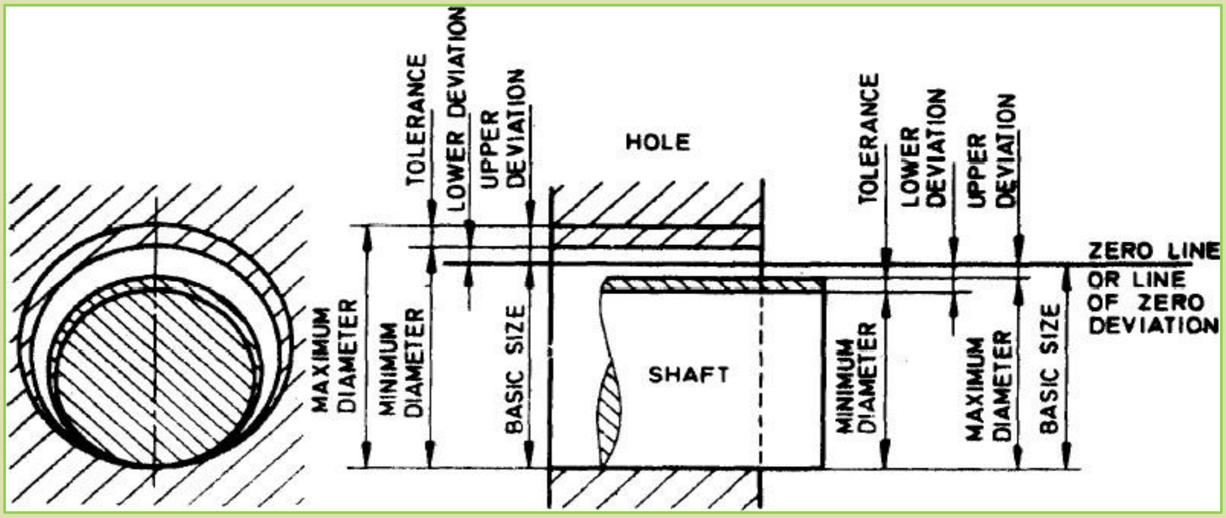
Ex: $25^{\pm 0.01}$, $10^{+0.1}_{-0.1}$



Rules for addition and subtraction of tolerance

1. Rearrange the tolerance
2. While addition of tolerance add linearly with signs
3. While suds traction. Subtract tolerance & diagonally with signs
4. Verification of un known tolerance
5. Rearrange the tolerance i, e maximum tolerance value will become lower limit

I S O representation of holes & shafts assumptions & terminology.



In the standard followed certain conventions are used. In order to explain the definitions simplified schematic diagram is conventionally used a shaft & hole system is drawn.

It is assumed that the shaft touches at the bottom of hole & then other dimensions are considered a line is assumed to be there in b/w the upper tolerance on shaft & lower tolerance on hole this is called –zero line‖ this line refers to basic size from the axis of the shaft or hole all tolerance &deviations are referred to from this datum line.

Terms & terminology

Nominal size;
The nominal size of a dimension or part is the size by which it is referred to as a matter of convenience.

Basic size;
The theoretical size of a part derived from the design formulation after rounding off the respected standard size is known as –basicsize‖ the tolerance are always specified to the basic size when used for fit between the shaft hole same basic size is specified on both shaft & hole.

Zero line;
This is the line which represents the basic size so that the deviation from the

basic size is zero.

Actual size;
It is the size of the part obtained by the measurement this is the measured size.

Limits;
These are two extreme permissible sizes for any dimension (high &low)

Minimum limit;
The minimum permissible size for given basic size is called minimum limit.

Maximum limit;
The maximum permissible size for the given basic size is called maximum limit.

Tolerance;
The difference between the maximum & minimum limits of size.

Deviation;
The difference between limit sizes are maximum to minimum size & the basic size is called as deviation.

Allowance;
The difference between the maximum shaft & minimum hole is known as allowance. In a clear fit, the minimum clearance &is a positive allowance. In an interference fit it is the maximum interference & is a negative allowance.

Upper deviation;
It is the algebraic difference b/w the maximum limit of size & the corresponding basic size.

Lower deviation;
It is the algebraic difference b/w the minimum limit of size & the corresponding basic size.

Classes & grades of tolerance;

In India we are following Indian standard for system of holes & shaft. The system comprises suitable combination of 18 grades of fundamental tolerances or in other words grades of accuracy of manufacture. These grades of tolerance are designated as; IT01,IT2,IT3,IT4,IT5,IT6,IT7,IT8,IT9,IT10,IT11,IT12,IT13IT14,IT15,IT16,IT7,IT18.

The tolerance grades decides the accuracy of manufacture the 7 finest grades (IT01 to IT05)over sizes up to 500 mm & the eleven co-arrest grades up to 3150mm.

The tolerance in each grade depends on the size of the shaft or hole.28 types of standard deviation indicated by letter symbols for both holes & shafts (capital letters A to ZC for holes & small letters a to zc for shafts) in diameter steps up to 500mm. the various 28 designation are representation by. A, B, C, CD, D, E, EF, F, FG, G, H, J, J_S, K, M,N,P,R,S,T,U,V,X,Y,Z,ZA,ZB,ZC.

For shaft these are represented as a,b,c,d,e,f,g,h,i,j,j_s,k,m,n,p,r,s,t,u,v,x,y,z ,za,zb,zc.

The various diameter steps specified by I S I are 1-3,3-6,10-18,18-30,30-50,50-80,80-120,120-180,108-250,250-315,315-400,&400-500mm –D‖ being taken as the average size (geometric mean) for a particular range to avoid a continues variation of tolerance with size.

Grades of Tolerance

Grades	Values	Step - D iameter
IT5	7i	1-3mm
IT6	10i	3-6mm
IT7	16i	10-18mm
IT8	25i	18-30mm
IT9	40i	30-50mm
IT10	64i	50-80mm
IT11	100i	80-120mm
IT12	160i	120-180mm
IT13	250i	180-250mm
IT14	400i	250-315mm
IT15	640i	315-400mm
IT16	1000i	400-500mm

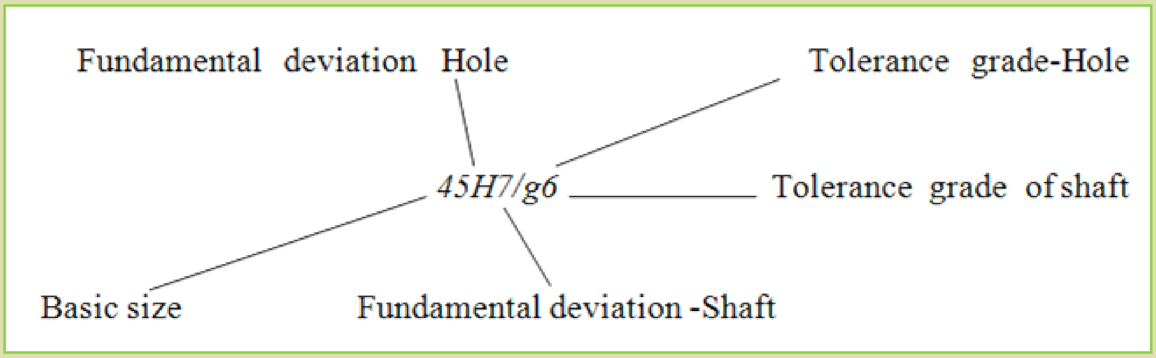
Symbol for tolerances, deviations and fits

The tolerance is designated by a number symbol called grade. The position of tolerance zone is indicated by a letter symbol. [Capital letter for hole and small for shaft.]

The tolerance size is just defined by basic value followed by a letter and numeral.

Eg: 50H7, 35g6.

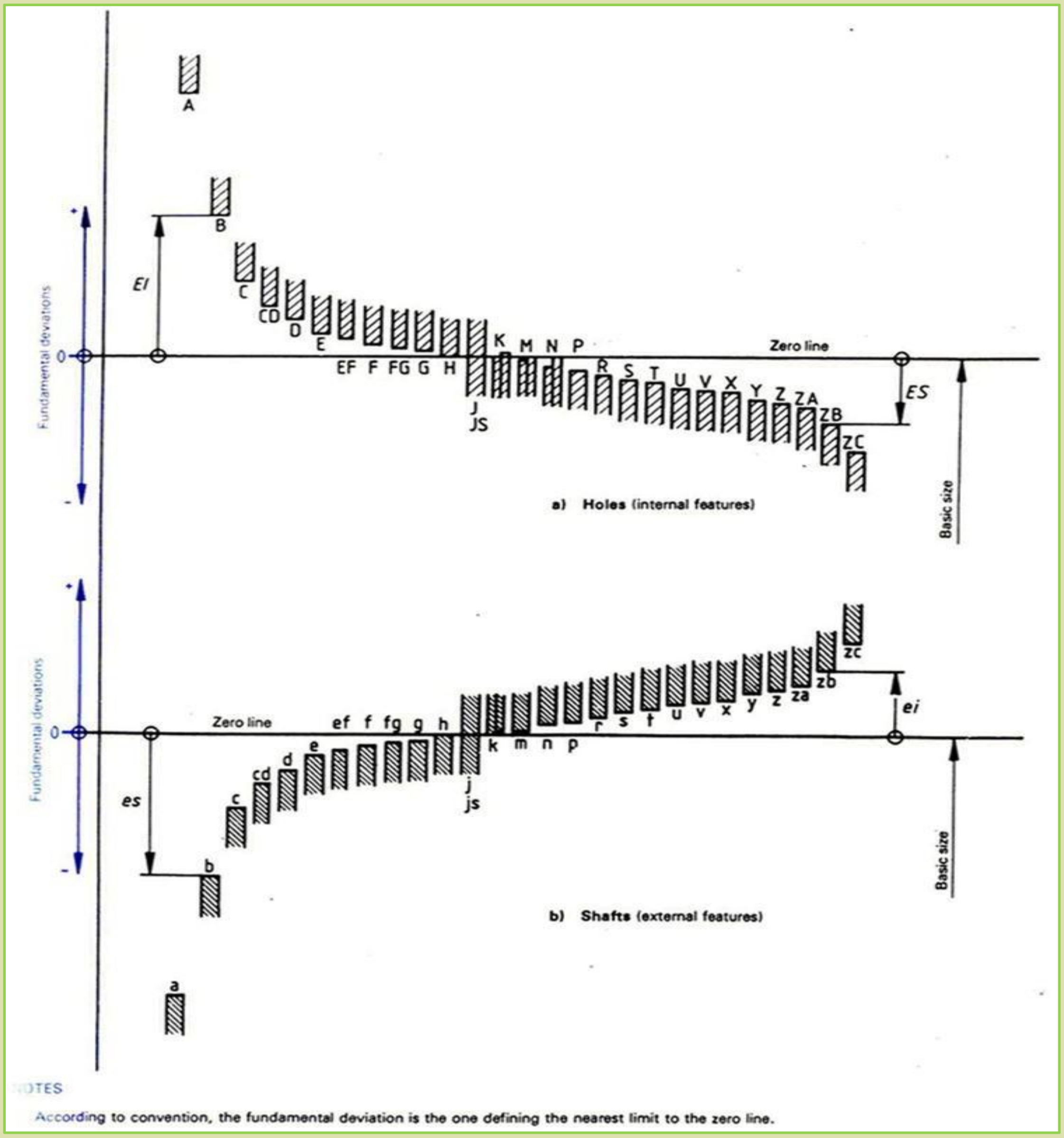
A fit is indicated by the basic size common to both components followed by symbols corresponding to each component, the hole being written first.



The following symbols are used to denote upper and lower deviations.
Upper deviation of hole - ES
Lower deviation of hole - EI
Upper deviation of shaft- es
Lower deviation of shaft- ei

$$ES = EI+IT$$

$$es = ei+IT$$



Selective assembly;

If the system of Interchangeability is not adopted, then each component should be selected such that it matches/fits exactly with it mating component. And this process is known as Selective assembly. Selective assembly is not desirable. Because it consumes more time becomes very costly. However some special cases of accuracy & requiring close tolerance on mating parts. The selective assembly concept is applied. In such cases, the fits achieved will meet the functional requirements, which may not be possible with the use of fully interchangeable parts.

Interchangeability;

A system of this type in which one component will assemble/fit correctly with other mating component, both being selected randomly is known as Interchangeability system.

In mass production as indicated we should be able to select one part at random &assemble it successfully with another mating part again selected at random such part those get assembled without any difficulty by random selection are termed as interchangeable part.

Today‘s production technique is mass production for economic outputs. This approach led to breaking up of a complete process into several smaller activities which in terms are specialized as a result none of the manufacturing activity is self-reliant with respect to components various mating components would undergo production on several machines. Hence it is absolutely essential to have a précised control over the dimensions of portions which have to match with other parts. –any one component selected at random should assemble correctly with other parts. The too selected at random

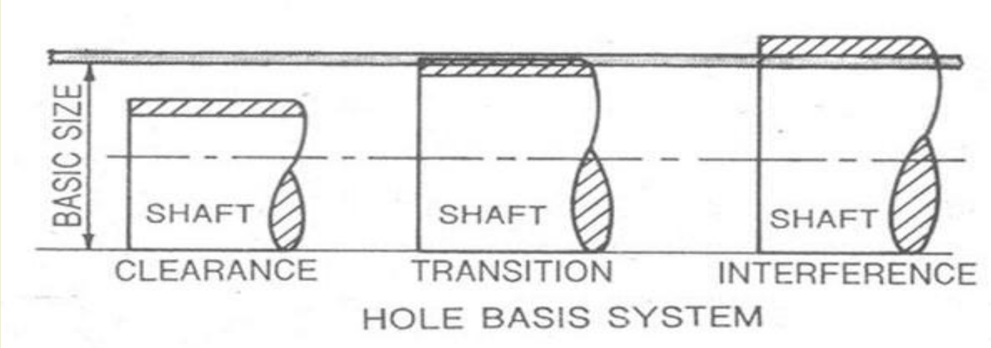
Advantages or characteristics;

1. An operator can easily specialize since the he is concerned with only a limited portion of work.
2. Interchangeability ensures increased output with reduced production cost.
3. Assembly time is reduced considerably.
4. De-centralized production depending on the resources available can be achieved.

There are 2 system of fit for obtaining clearance, interference or transition fit;

1. **Hole basis system.**
2. **Shaft basis system.**

1. Hole basis system;

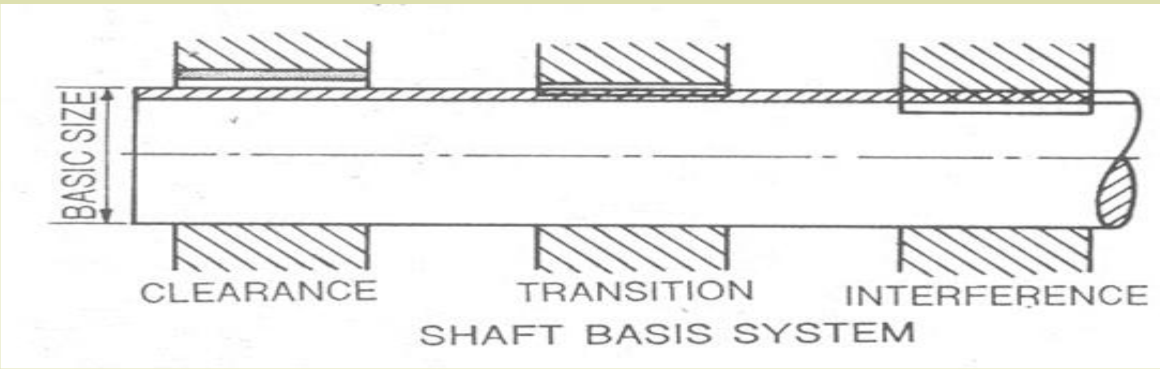


In this basis system the hole size with tolerance is kept constant &the shaft size are varied to give the various types of fits. In this system lower deviation of the hole is zero, i.e., the low limit of hole is the same as basic size. The high limit of hole & the two limit of the size for the shaft are then varied to give the desired type of fit.

The hole basis system is most commonly used because it is more convenient to make correct holes of fixed sizes. Using the standard drills, reamers etc. and there sizes are not adjustable on the other hand & sizes of shaft produced by turning, grinding etc. can be very easily varied.

Ex; Assembly of the guide pillars with guide bushes in press tools.

2. Shaft basis system;



In the Shaft basis system the shaft is size with tolerance is kept constant & the sizes of the holes are varied to give various types of fits. In this system the upper deviation of shaft is zero ie, the high limit of shaft is the same as basis system of sizes &the various fits are obtained by the low limit of shaft & both the limits of hole .

This system is used when the ground bars or drawn bars are readily available these bars do not require further machining & fits are obtained by varying the sizes of holes.

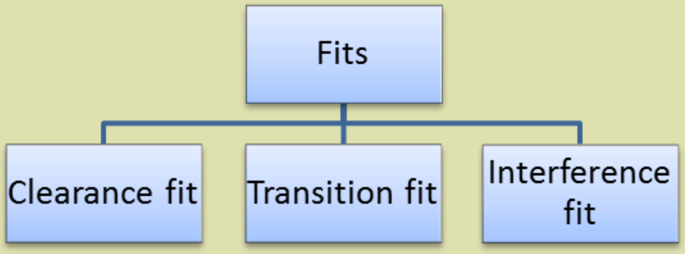
Ex: -

1. Suiting of dowel pins with machined holes.
2. Suiting of standard ejector & push back pins with respective hole in molds.

Difference between hole & shaft basis system

Hole basis system	Shaft basis system
1. Size of hole whose lower deviation is zero (H-hole) is assumed the basic size.	1. Size of shaft whose upper deviation is zero (h-shaft) is assumed as basic size.
2. Limits on the hole are kept constant & those of shafts are varied to obtain desired type of fit.	2. Limits on the shafts are kept constant & those on the hole are varied to have necessary fit.
3. Hole basis system is preferred mass production because it is convenient & less costly to make hole of correct size due to availability of standard drills & reamers.	3. This system is not suitable for in mass production because it is in convenient. Time consuming & a costly to make a short of correct size.
4. It is much easier to vary the shaft sizes according to the required fit.	4. It is rather difficult to vary the hole sizes according to the fit required.
5. It requires less amount of capital & storage space for tools needed to produce shafts of different sizes.	5. It needs large amount of capital & storage space for large number of tools required to produce holes of different sizes

Types of fits (classification)



1. Clearance fit;

In this type of fit the largest permissible shaft diameter is smaller than the diameter of the smallest hole so that the shaft can rotate or slide through with different degrees of freedom according to the purpose of mating part, clearance fit exists when the shaft & the hole are at their maximum metal conditions the minimum size of the hole is greater than the maximum size of the shaft then the fit is called clearance fit.

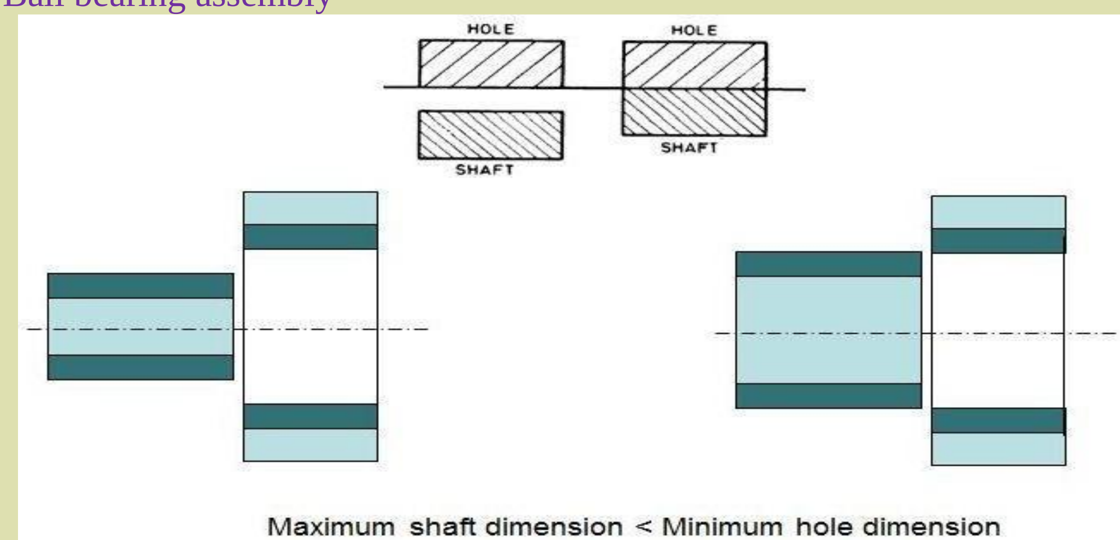
Maximum clearance;

It is the difference between the minimum sizes of the shaft to the maximum size of the hole.

Minimum clearance;

It is the difference between the maximum size of the shaft to the minimum size of the hole.

Ex: Ball bearing assembly



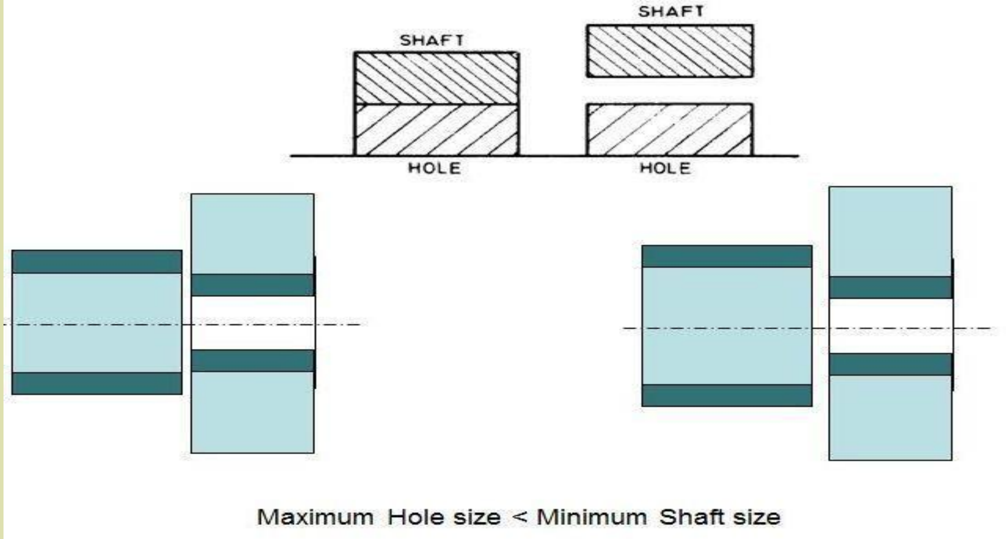
2. Interference fit;

In this type of fit the minimum permissible diameter of the shaft is large than the maximum allowance diameter of the hole. Thus the shaft & the hole members are intended to be attached permanently used as a solid component.

Elastic strains developed on the mating surfaces during the process of assembly prevent relative movement of the mating parts.

In this fit –minimum size of the shaft is greater than the maximum size of the hole‖

Ex: Drill bush in jig plate, Bearings in the gears, Pillars between bottom plates.

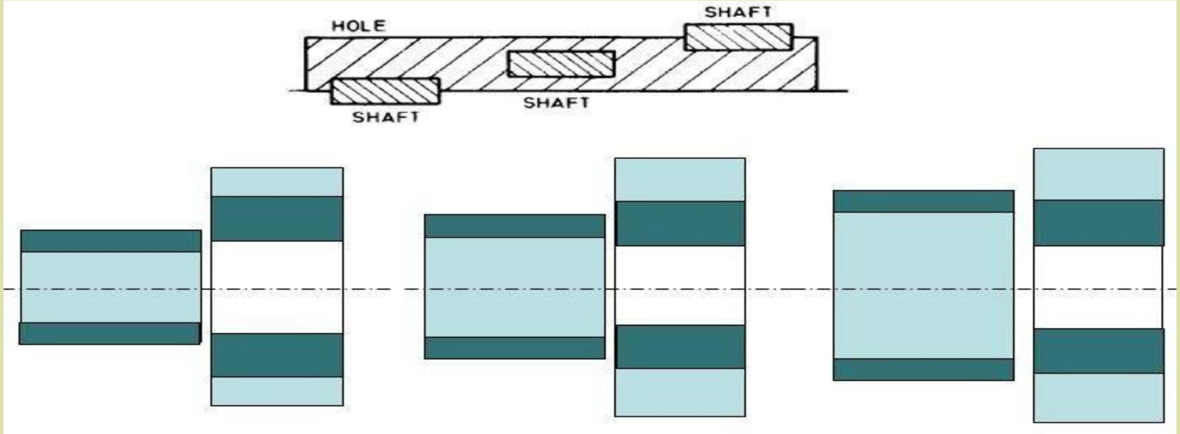


3. Transition fit;

In this type of fit the diameter of the largest allowable holes is greater than that of smallest shaft. But the smallest hole is smaller than the largest shaft, so that small positive or negative clearance between shaft & hole members are employable location fits.

Ex: spigot in mating holes, coupling rings & recesses

In this type of fit the tolerance zones of the hole & shafts over lop completely or in part.



Difference between tolerance & allowance

Tolerance	Allowance
1. It is the permissible variation in dimension of a part.	1. It is prescribed as difference b/w the dimension of two mating parts.
2. It is the difference b/w higher & lower limits of a dimension of a parts.	2. It is prescribed as difference b/w the lower limit of hole & higher limit of shaft
3. The tolerance is provided on a dimension of a part as it is not possible to make a part to exact dimension	3. Allowance is to be provided on the dimension of mating parts to obtain desired type of fit specified
4. It has absolute value without sign.	4. Allowance may be positive (clearance) or negative (interference)

GAUGES

INTRODUCTION;

Manufactured part is checked to determine whether they are according to the specifications are not and also to control their dimensions. There are several methods available for the control of dimension of the manufactured part.

The dimensions of the component can be checked with various precision measuring instruments which measure the actual dimension of the part.

In mass production where large number of components is produced to measure the dimension of each part will be time consuming and costly process .therefore in mass production instead of measuring the actual dimension of the component the conformance of the part with tolerance specification can be checked by gauges.

GAUGES

Gauges are scale less inspection tolls of rigid design which are used to check the dimension of manufactured parts. Gauges do not indicate the actual value of the inspected dimension on the work they can only be used for determining as to whether the inspected dimension on the work. They can only be used for determining as to whether the inspected parts are made within the inspected parts are made within the specified limits.

Advantages of gauges:

1. They can be easily employed
2. They can be easily used by the unskilled person
3. For checking the component with a gauge it is not necessary to make any calculation or to determine the actual dimension of the part
4. They give quick results and time taken for the inspection is considerably reduced
5. They are well suited for mass production of similar components
6. They are well suited for mass production of similar components
7. These can be designed to check combinations of several dimensions comprising lengths diameters and angles.
8. They also check the form and relative positions of the sue faces of parts

These provide uniform reference standards

Disadvantages of gauges:

1. They are not general purpose instruments but are designed for some particular components which is to be produced in large quantities [i.e. mass production]
2. They do not determine actual sizes of a part as measuring instruments
3. They only check whether the part is produced within the specified limits of tolerance
4. They are expensive compared to conventional measuring instruments

Difference between measuring instruments and gauges

Measuring instruments	Gauges
1. These are measuring tolls carrying calibrated scales.	1.These are inspection tools without scales
2. These are used to measuring actual dimensions of parts.	2. These are used to determine whether the dimensions of part are within the specified limit or not.
3. These are time consuming.	3. These are easy and take less time.
4.It is not suitable for mass production	4.These are suitable for mass production
5.For using Measuring instruments required	5. For using gauges skill is not skill is required.
6.Component cost is more	6.Component cost is less
7.These are expensive	7.These are not expensive
8. It is used for all type of work	8. It is used for only specific works.

Materials used for gauges:-

The material used for manufacturing the gauges must fulfill the following requirements either by virtue of its own properties or by a heat treatment process.

1. Hardness to resist wear.
2. Stability to ensure that its size and shape will not change over a period of time.
3. Corrosion resistance.
4. Low co-efficient of linear expansion to avoid effect of temperature.
5. The parts of the gauges which are to be held in hand should have low thermal conductivity.
6. Machinability to enable it to be machined easily into the required shape and to the thermal degree of accuracy.

Classification of gauges:

1] According to their type:

a. Standard and limit gauges
b. Limit gauges.

2] According to their purpose

a. Work shop gauges
b. Inspection gauges
c. Reference or master gauges

3] According to the form of the tested surface

a. Plug gauges for checking holes
b. Snap and ring gauges for checking shafts.

4] According to the design

a. Single limit and double limit gauges
b. single ended and double ended gauges
c. Fixed and adjustable gauges

Specification of gauges:

i. Nominal size
ii. Class of tolerance
iii. The word ―GO‖ on the ―go‖ side
iv. The word ―NO GO‖ on the ―no go‖ side
v. The actual values of tolerance
vi. Manufacturer‘s name or trade mark.

Standard gauges:

If a gauge is made as an exact copy of the mating part of the component to checked it is called as ―standard gauge‖.

E.g.: If a bushing is to be made which is then mats the bushing is checked by a gauge which is a copy of the mating part in form of its surface size. A standard gauge cannot be used to check an interference fit. It has limited applications.

Limit gauges:

Limit gauges are widely used in industries as there are two permissible limits of the dimension of a part high and low .two gauges are needed to check each dimension of the part one corresponding to the low limit of shaft and other to the high limit of size of that dimension these are known as ―GO ―and ―NO GO‖ gauges.

The difference between the sizes of these two gauges is equal to the tolerance on the work piece. GO gauges check the maximum metal limit and NO-GO gauges checks the minimum metal limit.

In the case of a hole maximum metal limit is when the holes is as small as possible i.e. the low limit of size in case of hole their fore GO gauges corresponds to the low limit of size while NO-GO gauges corresponds to high limit of size.

For a shaft the maximum metal limit is when the shaft is on the high limit of size thus in case of shaft GO gauge corresponds to the high limit of size and NO-GO gauges corresponds to the low limit size.

A part is considered to be good if the GO gauge passes through or over the work and NO-GO gauge fails to pass under the action of its own weight. This indicates that the actual dimensions of the part is within the specified tolerance that holes is under size or shaft is over size if both the gauges pass it means that the hole is over size or the shaft is under size.

Types of gauges:

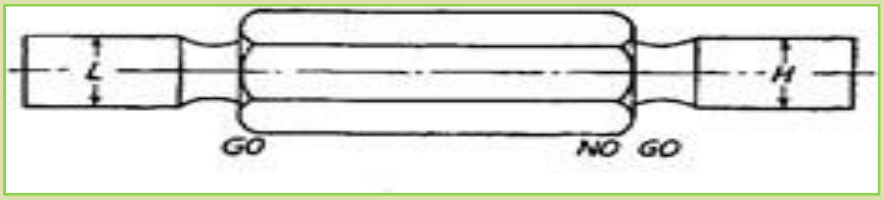
1. Plug gauges,
2. Ring gauges,
3. Snap gauges,

Plug gauge:

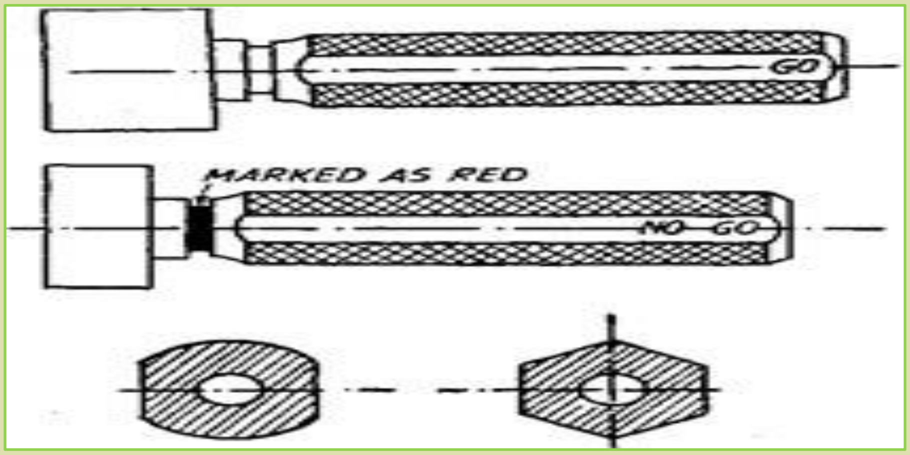
This type of gauges is used for to checking internal diameter of the bore. Generally the gauging member of the plain plug gauges is made of suitable wear resisting steel. The handles can be made of any suitable steel and these are suitably stabilized and ground and lapped.

Types of plug gauges are:

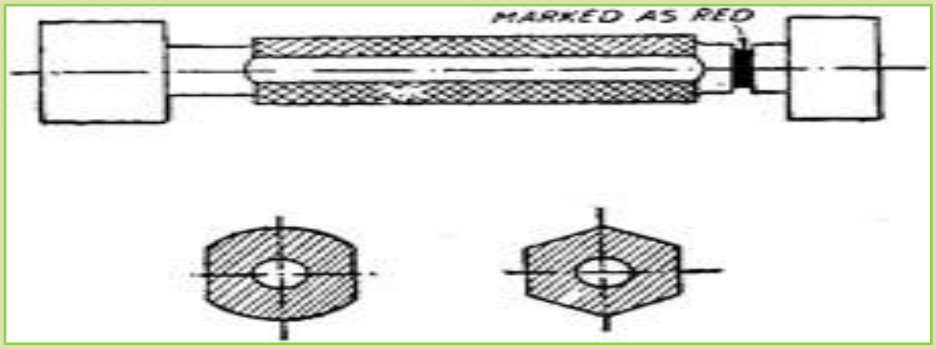
1. **Solid type:** Solid type plug gauges are used for sizes up to 10mm.



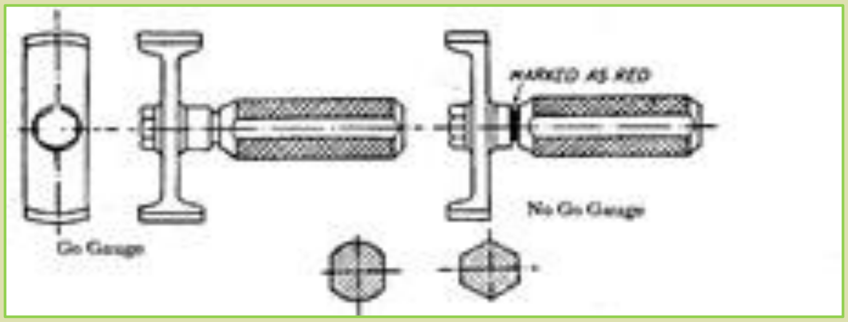
2. **Renewable type [taper inserted type]:** These are used for sizes over 10m and up to 30mm.



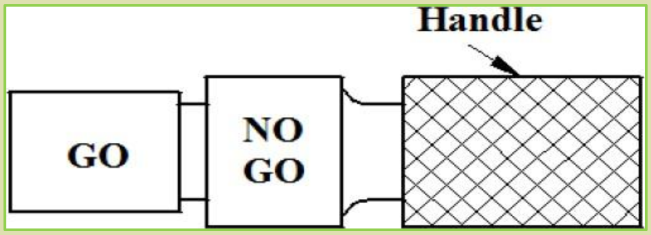
3. **Fastened type plug gauge:** Double ended type gauge are used for sizes over 30mm and up to 63 mm single ended type plug gauges are used for sizes over 63mm and up to 100mm.



4. **Flat type plug gauges:** These gauges come in single ended only there will be individual GO gauge and NO-GO gauge for each basic size. These types of gauges are used for sizes over 100mm and up to 250mm.



5. **Progressive form of plug gauge:** These are used for smaller through holes another useful renewable end plug gauge is the progressive type of gauge in which both the GO‘ and _NOT GO‘ gauging members are provided on same side separated by a small distance first GO portion is further obstructed by NOT GO portion if hole is of tolerable size.



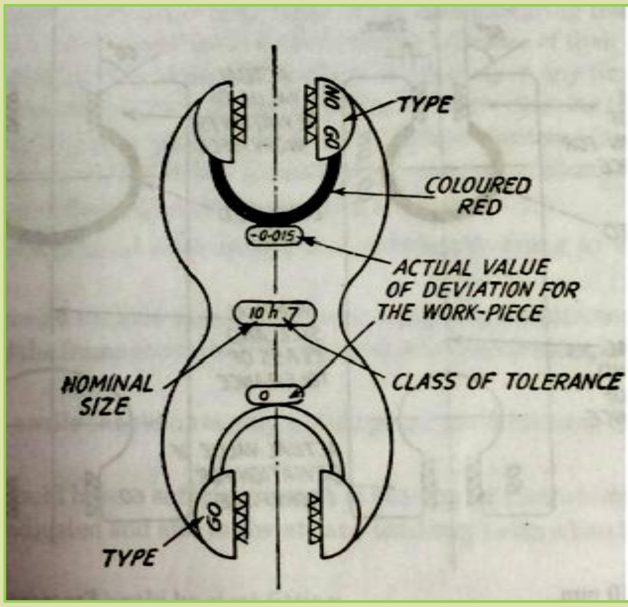
6. Snap gauge or ring gauges:

Snap gauge gap gauges or ring gauges are used for checking the shafts snap gauges can be used for both cylindrical as well as non-cylindrical work. Ring gauges are conventionally used only for cylindrical work.

To GO snap gauge is the size corresponding to the high limit of the shaft while the–NO GO‖ gauges correspond to the low limit.

Double ended snap gauges can be conveniently used for checking size from 3 to 100mm and single ended progressive type snap gauges are suitable for checking size from 100 to250mm.

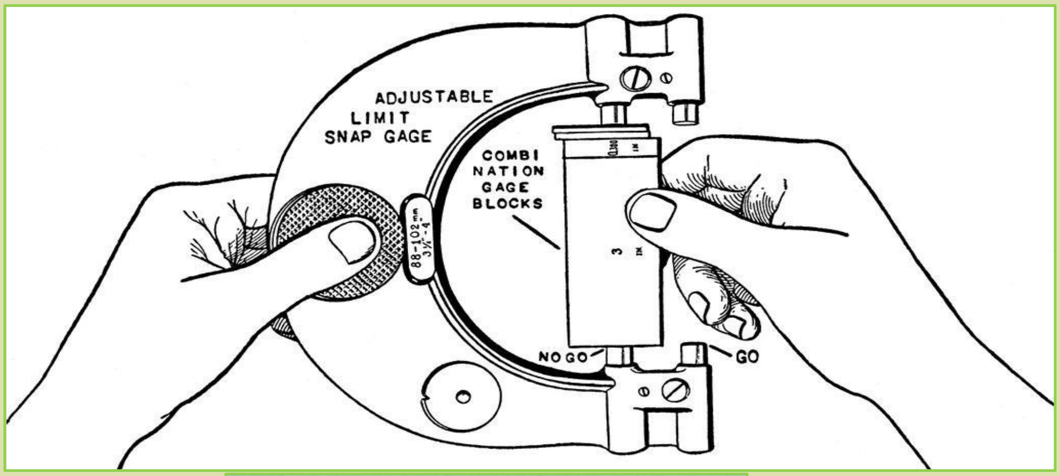
The gauging surface of the snap gauges are hardened up to 750 hv and are suitably stabilized ground lapped ring gauges are available in two designs GO and NO GO these are designated by GO and NO GO as may be applicable the nominal size the tolerance of the work piece to be gauged and number of standard allowed

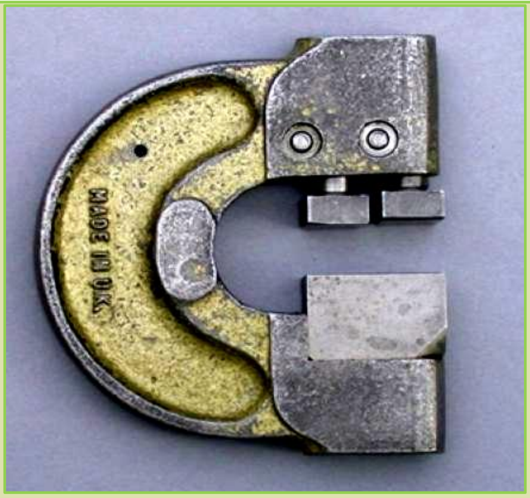


Adjustable type gap or snap gauges:

In case of snap gauges no change can be made in the size range where as in adjustable gauges the gauging anvils are adjustable end wise in the horse –shoe frame thus a small change within about 0.002mm can be made in the size range.

E.g.: suppose a gauge is used to check a 50mm for shaft it for same tolerance grade of f8 or f6 the same gauge can be used after adjustment





Also the anvils of such gauges can be reset with the help of slip gauge by means of independent and finely threaded screws provided at the back end. After resulting they can be finally locked in position by means of clamping screw fixed gauges are less expensive initially but they do not permit adjustments for wear adjustable gauges are expensive but they permit adjustment to compensate for wear and can also be used over a small range of different setting.

Rib type snap gauges:

Double ended type snap gauges can be conveniently used for checking sizes in the range of 3mm to 100mm and single ended progressive type snap gauges are suitable for size range of 100 to 250mm. The gauging surfaces of the snap gauges are hardened up to 720 HV and suitably stabilized ground and lapped the other surface are finished smooth.

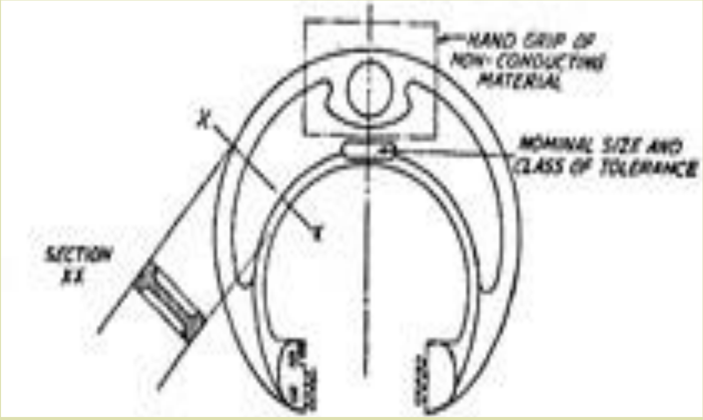
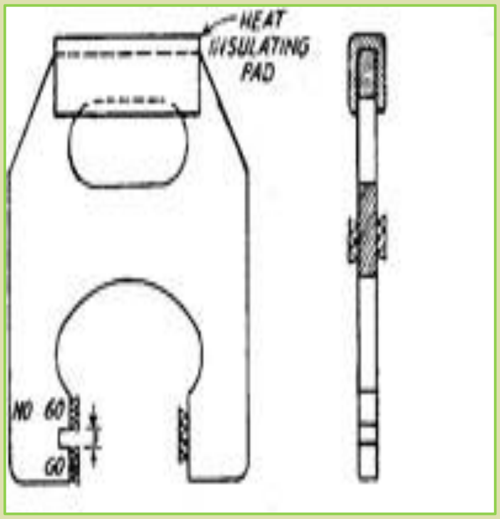


Plate snap gauges:

Double ended type plate snap gauges are used for sizes in the range of 2 to 100mm and single –ended progressive type in the size range of 100-250mm. These are made of wear resistant steel of suitable quality the gauging surface are properly hardened stabilized ground and lapped other surface are smooth finished. The gauges are reasonably flat and all sharp corners and edges are removed.


KCP
KCP


HEAT
INSULATING
PAD
NO GO
GO

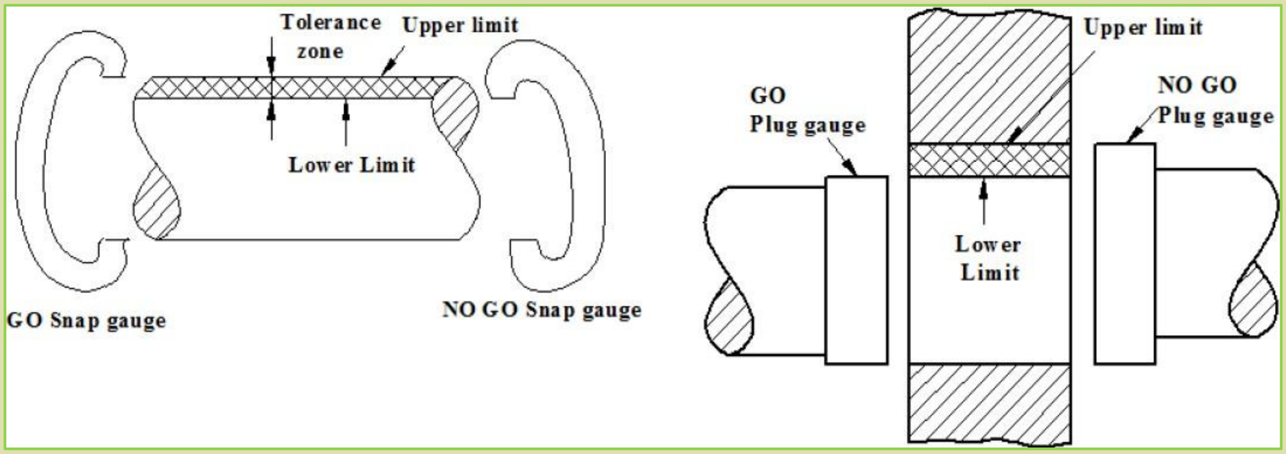
Taylor’s principle of gauge design:

It states that Go gauges should be designed to check maximum material limit, while the No Go gauges should be designed to check the minimum material limit.

Now, the plug gauges are used to check the hole. Therefore the size of the low limit of hole, while that of No-Go plug gauge corresponds to the high limit of hole.

Similarly the Go snap gauge on the other end corresponds to the high limit of shaft while No-Go snap gauge corresponds to the low limit of shaft.

The difference in size between the Go & No Go plug gauges as well as the difference in size between Go & No Go snap gauges is approximately equal to the tolerance of the tested hole or shaft in case of standard gauges.



PROBLEMS

1) Determine tolerance on the hole and shaft for a precision running fit designated by 50H7g6 i=$0.45\sqrt[3]{D+0.001D}$ $diameter\ 50mm\ lies\ between\ 30-50mm\ standard\ ø$ set fundamental

for deviation for hole is zero fundamental deviation for _g‘ shaft -2.5D$^{0.34}$

& IT7=16i IT6= 10i

SOLUTION;

Given data:

D=50H7g6

i= Ø50mm lies between 30-50mm

set fundamental deviation for

_g‘ shaft = -2.5D$^{0.34}$

IT7 =16i IT6= 10i

D = Geometrical mean diameter D

= $\sqrt{30*50}=38.72$

i=

= 0.45(3.38) + 0.03

= 1.55+0.03

= 1.55microns = 0.00155mm

Fundamental deviation for hole is _0‘(zero)

IT7 = 16i

= 16* 0.00155

= 0.0248mm

Basic size = 50.00mm

Maximum size = 0.248mm

Minimum size = 0.0mm

Tolerance = $50^{+0.248}_{+0.00}$

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

$= -2.5(38.72)^{0.34}$

$= -2.5*3.46$

$= -8.66$microns

$= -0.0086$mm

IT6 = 10i

= 10*0.00155

= 0.015mm

Basic size = 50.00mm Maximum size = 49.99mm Minimum size = 49.97mm Tolerance = $50^{-0.2416}_{-0.0086}$

2) Determine tolerance on the hole and shaft for a precision running fit designated by 25H7k6 i=$0.45\sqrt[3]{D + 0.001D}$ $diameter\ 25mm\ lies\ between\ 18 - 30mm\ standard\ ø$ set fundamental for deviation for hole is zero fundamental deviation for ‗k‘shaft - $2.5D^{0.34}$ & IT7=16i IT6= 10i

SOLUTION;

Given data:

D= 25H7k6

i=

Ø25mm lies between 18-30mm set fundamental deviation for ‗k‘shaft

$= -2.5D^{0.34}$

IT7 =16i IT6= 10i

D = Geometrical mean diameter D

$= \sqrt{18 * 30} = 23.23$

i=

= 0.45(2.85) + 0.023

= 1.2825+0.023

i = 1.305microns = 0.001305mm

Fundamental deviation for hole is

‗0‘IT7 = 16i

= 16* 0.001305

= 0.0208mm

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

= $-2.5(23.23)^{0.34}$ = -0.00728mm

IT6 = 10i

= 10*0.001305

= 0.01305mm

Basic size = 25.00 (-0.00728)

= 24.992mm

Maximum size = 24.992-0.01305

= 24.979mm

Minimum size = 0.0mm Shaft tolerance = $25^{-0.021}_{-0.007}$

3) Determine the type of fit after deciding the tolerance in the following 70H9c7 & ø step

(50 to 80) fundamental deviation for shaft $-11D^{0.41}$ IT7 = 16i, IT9 = 40i &

i= Data:

Ø70H9c7

Diameter step (50-80)

Fundamental deviation for shaft =$-11D^{0.41}$

IT7= 16i IT9= 40i

i=

Geometrical mean D =$\sqrt{50 * 80}$ = 63.24mm

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

= $0.45\sqrt[3]{63.24 + 0.001(63.24)}$

= 1.85microns

= 0.00185mm

Fundamental deviation for hole is zero

IT9= 40i

= 40*0.00185 = 0.074mm

Maximum size of the hole= 70.074mm

Minimum size of the hole= 70.00mm

Hole tolerance = $70^{+0.074}_{+0.00}$

Fundamental deviation for shaft

$= -11D^{0.41}$

$= -11(63.24)^{0.41} = -60.228$ microns $= -0.0602$mm

IT7= 16i

= 16*0.00185

= 0.0296mm

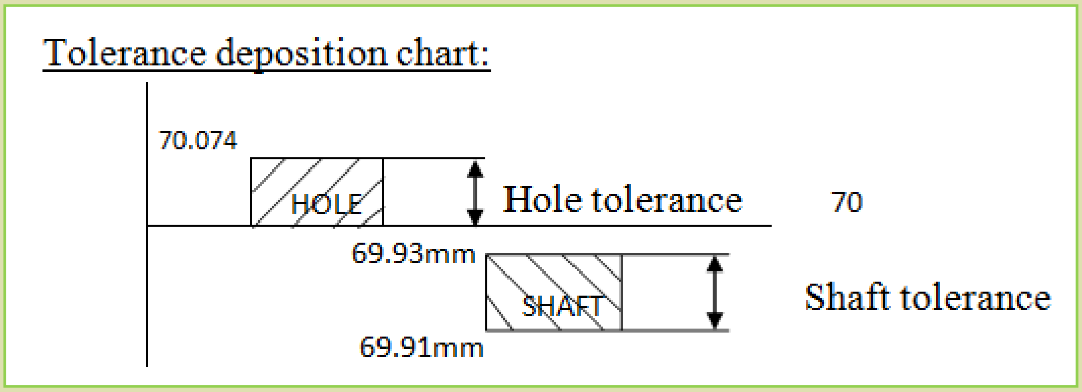
Maximum size of the shaft= 69.93mm

Minimum size of the hole = 69.91mm

Shaft tolerance = 0.0296

$70^{-0.0602}_{-0.0890}$

This is clearance fit. Because the maximum size of the shaft (69.93) is less than minimum size of the hole (70.00), so considering clearance fit.



4) Determine the type of fit after dividing and tolerance in the following & Ø66.5H7e9

step is (50 to 80) fundamental deviation for shaft $-11D^{0.41}$ IT7 = 16i, IT9 = 40i & i=

Given data:

Ø66.5H7e9

Diameter step (50-80)

Fundamental deviation for shaft =$-11D^{0.41}$

IT7= 16i IT9= 40i

i=

Geometrical mean D =$\sqrt{50*80}$ = 63.24mm

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

= $0.45\sqrt[3]{63.24} + 0.001(63.24)$

= 1.85microns

= 0.00185mm

Fundamental deviation for hole is zero IT7= 16i

= 16*0.00185

= 0.0296mm

Maximum size of the hole= 66.5296mm Minimum size of the hole= 66.500mm Hole tolerance = 0.0296

Fundamental deviation for shaft

= $-11D^{0.41}$

= $-11(63.24)^{0.41}$

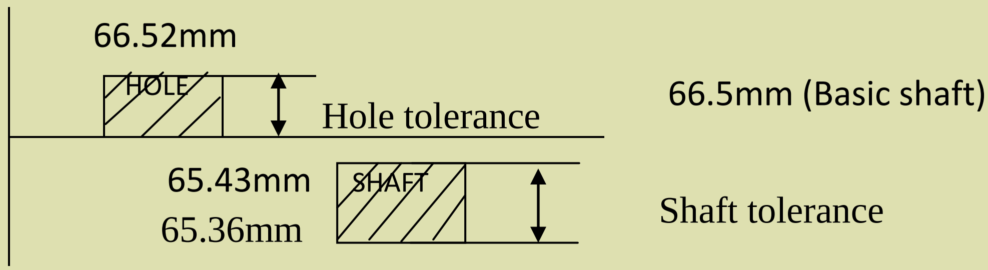
= -60.228 microns = -0.0602mm

IT9= 40i

= 40*0.00185 = 0.074mm

Maximum size of the shaft= 65.439mm Minimum size of the hole = 65.365mm Shaft tolerance = 0.074

Tolerance deposition chart:



[The above fit is clearance fit. Because the maximum size of hole is greater than minimum size of shaft]

5) Draw a tolerance deposition chart for 25 H7k6 pair of hole & shaft calculate the upper deviation of the hole & lower deviation of shaft, consider fundamental deviation for shaft, k= $0.6\sqrt[3]{D}$ and mention which type of fit.

Given data:

Basic size = Ø25, tolerance grade = H7k6

Fundamental deviation for shaft = $0.6\sqrt[3]{D}$

SOLUTION: The given basic size is falls in the 18-30mm standard dia step as per the ISI

Mean diameter (D) = $\sqrt{18 * 30}$ = 23.23mm

Unit tolerance (i) = $0.45\sqrt[3]{D + 0.001D}$

= $0.45\sqrt[3]{23.23 + 0.001(23.23)}$ i = 1.307mm

Tolerance grade of IT7= 16i = 16(0.0013) = 0.0208mm

Fundamental deviation of hole is zero

Minimum size of hole is equal to basic size

Minimum size of hole = 25.00

Maximum size of the hole = basic size + tolerance grade

= 25.00+0.0208= 25.0208mm

Hole tolerance = maximum size of hole- minimum size of hole

= 25.0208-25.00= 0.0208mm

Hole tolerance of limit = $Ø25^{+0.0208}$

Fundamental deviation of shaft = 0.6 $\sqrt[5]{D}$

$= 0.6\sqrt[5]{23.23}$

= 1.711microns

= 0.0171mm

Maximum size of the shaft = basic size + FD of shaft

= 25.00 + 0.0171

Shaft tolerance = maximum size of shaft – minimum size of shaft

= 25.0171- 25.00403

= 0.01307mm

Limits of tolerance for shaft = $Ø25^{+0.0171}$

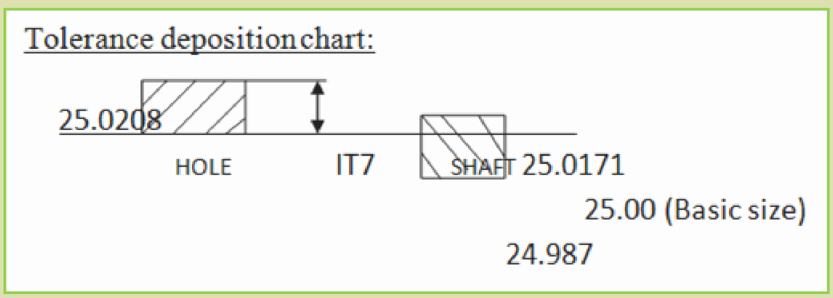
Maximum allowance = maximum size of shaft – minimum size of shaft

= 25.0208-25.00403

= 0.0165

Minimum allowance = 25.00-25.0171

= 0.0171



[The above H7k6 pair is transition fit. Because the maximum size of shaft is less than the maximum size of the hole but larger than the minimum size of hole]

6) For the fit Ø50 H7g6 running fit calculate the maximum & minimum size of both hole & shaft as well as maximum & minimum allowance Ø50 falls in the range of 30-50, consider the fundamental deviation to _g‘shaft -2.5D$^{0.34}$ & tolerance grade value is IT7= 16i, IT6= 10i

Given data:

Basic size = Ø50

Tolerance grade = H7g6 IT7 = 16i IT6 = 10i

FD for shaft = $-2.5D^{0.34}$

Limits of tolerance =?

Allowance =?

Basic size is falls in the 30-50 standard diameter

Mean diameter (D) =$\sqrt{30 * 50}$ = 38.72mm

Unit tolerance (i) = $0.45\sqrt[3]{D + 0.001D}$

$= 0.45\sqrt[3]{38.72 + 0.001(38.72)}$ i = 0.0152mm

Tolerance grade = (i) = IT7=16i= 16*0.0152= 0.24366mm

Fundamental deviation for hole is zero

Minimum size of hole = 50.00mm

Maximum size of hole = basic size + tolerance grade

= 50.00=0.24366

= 50.24366mm

Hole tolerance = maximum size of hole – minimum size of hole

= 50.24366-50.00= 0.24366mm

Fundamental deviation of shaft = $-2.5(38.72)^{0.34}$= -2.5*3.466= -8.666 =0.0866

Maximum size of shaft = Basic size + FD for shaft

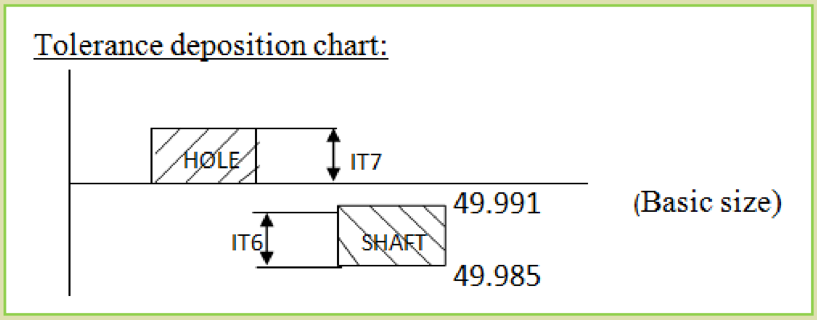
= 50.00 + 0.0866

= 49.911mm

Tolerance grade = IT6 = 10*0.0152=0.152mm

Minimum size of shaft = maximum size of shaft + tolerance grade

= 49.985mm



Minimum allowance = 0.0086mm

Shaft tolerance = 0.015mm, hole tolerance = 0.0249mm Maximum allowance = max size of hole – minimum size of shaft

= 50.0249 - 49.985

= 0.0486mm

∴ The above H7g6 pair is clearance fit, because the minimum size of hole is greater than maximum size of shaft

Questions

1. Define the following terms: unilateral tolerance, bi-lateral tolerance, basic size, limits.
2. Explain hole basis system and shaft basis system.
3. What is tolerance? Why it is essential.
4. What are plain gauges? Explain how gauges are classified.
5. Wright the types of gauges and explain anyone with a neat sketch.
6. Define the following terms: tolerance, allowance, deviation, interchangeability.
7. Define fit. Explain any two types of fits.
8. Explain the shaft basis system with a neat sketch.
9. What are gauges? Explain a plain gauge with a neat sketch.
10. Explain wear allowance on gauges.
11. Discuss the limitation of gauges.
12. Explain the hole basis system with a neat sketch.
13. What is fit? Explain the different types of fits with examples and tolerance

disposition charts.

14. Draw the conventional diagram of limits and fits and define the following terms: 1) Basic size 2) Upper deviation 3) Lower deviation 4) Fundamental deviation
15. Define Taylor‘s principle of limit gauges.
16. Explain clearance and interference fits with examples.
17. Write a note on gauge tolerance and wear allowance.
18. Explain with examples, the types of tolerance.
19. What is a gauge? What are the difference between gauge and a measuring instrument?
20. Name any 4 different types of gauges and their applications.
21. Define the following: zero line, Basic shaft, Hole.
22. Why the tolerance is needed? Explain.
23. Draw a neat sketch of snap gauge.
24. Describe the use of limit gauges. Explain ring gauge with the help of figure.
25. List five advantages of fixed gauges.
26. Explain clearance fit, interference, transition fit.
27. How do you designate tolerance? Explain with examples.
28. Why it is necessary to give a tolerance on an engineering dimension? Give an example of both the bi-lateral & uni-lateral tolerance.
29. For the fit Ø50H_7g_6 running fit, calculate the maximum & minimum sizes for both hole & shaft as well maximum & minimum clearance.
    a. Diameter 50 falls in the range 40 to 50
    b. Fundamental deviation for the_d‘ shaft = $-2.5D^{0.34}$microns
    c. Fundamental deviation for hole = 0
    d. IT7= 16i IT6 = 10i
30. For the fit Ø20H8d9, write the tolerance deposition chart and indicate all the required details. State the type of fit and justify your answer.
    a. Diameter 20 falls in the range 18 to 30
    b. Fundamental deviation for the_d‘ shaft = $-16D^{0.44}$microns
    c. Fundamental tolerance unit i = $0.45\sqrt[3]{D}+0.001D$

d. IT8=25i IT9 = 40i

31. Write short notes on the following

1. Interchangeability
2. Fundamental deviation
3. Classes and grades of tolerances
4. Maximum & Minimum metal condition
5. Types fit
6. Clearance
7. Basic size

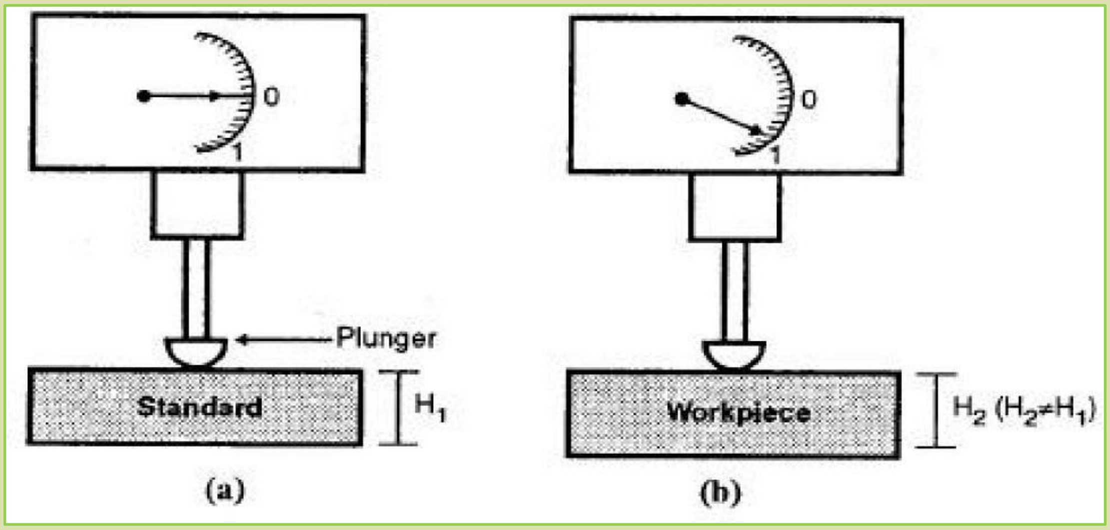
Useful Links

- https://www.youtube.com/watch?v=joBy4BoJszo
- https://www.youtube.com/watch?v=AP_T7hf5Wv0
- https://www.youtube.com/watch?v=-W92o67kGEo
- https://www.youtube.com/watch?v=zxyERl8KnnM&list=PL0uwpDY0Y8Q2aoPhDuEZLI1PVuKKUGb90
- https://www.youtube.com/watch?v=hRAFPdDppzs
- https://www.youtube.com/watch?v=KEeSQvMCPLg
- https://www.youtube.com/watch?v=IgyZVYKEHdo
- https://www.youtube.com/watch?v=WBuG-uBuiJ8
- https://www.youtube.com/watch?v=4U_KI-oye14

UNIT 3 - COMPRATOR

Introduction:

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 work piece. To check the height of the job H2, with the standard job of height H1.



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 is different, then the change in 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.

Displays it by using indicating devices, by which comparison can be made with some standard value.

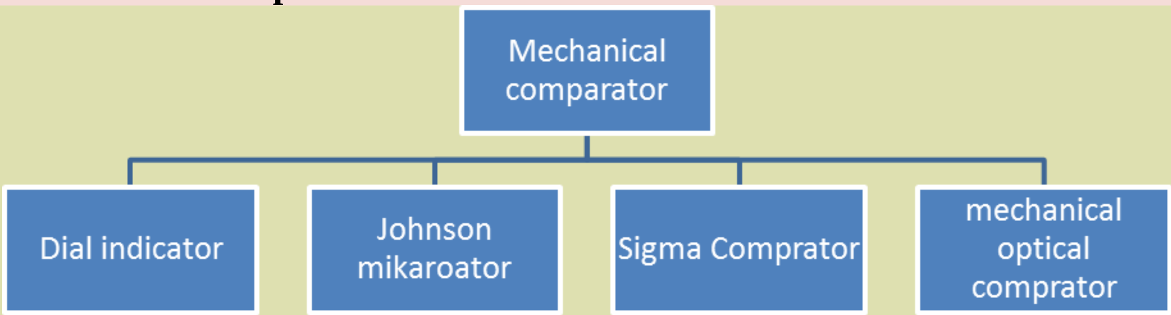
Classification

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.
14. It should be free from backlash and wear.

Mechanical Comparator:



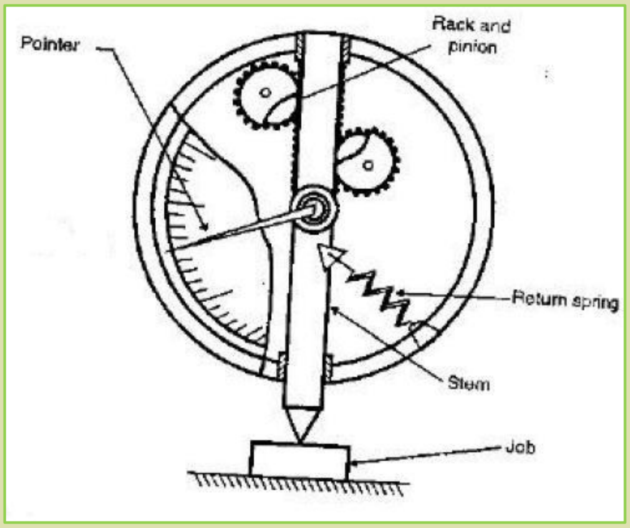
It is self-controlled and no power or any other form of energy is required. It employs Mechanical means for magnifying the small movement of the measuring stylus. The Movement is due to the difference between the standard and the actual dimension being checked. The method for magnifying the small stylus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

The various types of mechanical comparators are dial indicator, rack and pinion, sigma comparator, Johansson Mikroator.

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 wide range of standard measuring devices such as dial box gauges, portal dial, hand gauges, dial depth gauges, diameter gauges and dial indicator snap gauge corresponds to a spindle movement of 1 mm.

The movement mechanism of the instrument is housed in a metal case for its protection. The large dial scale is graduated into 100 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.

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, electricity etc.

Disadvantages of Mechanical Comparator:

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 ultimately the accuracy is less.

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

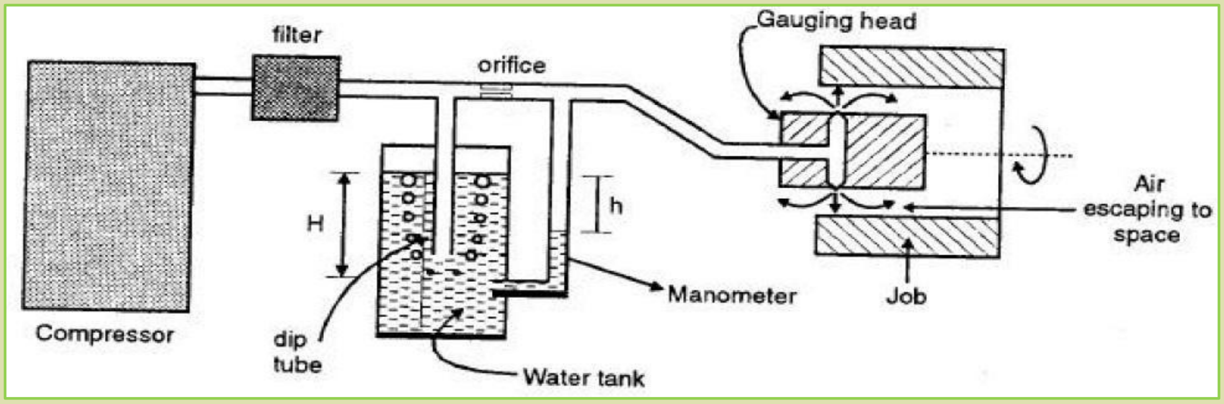
Pneumatic Comparators (Solex Gauge):

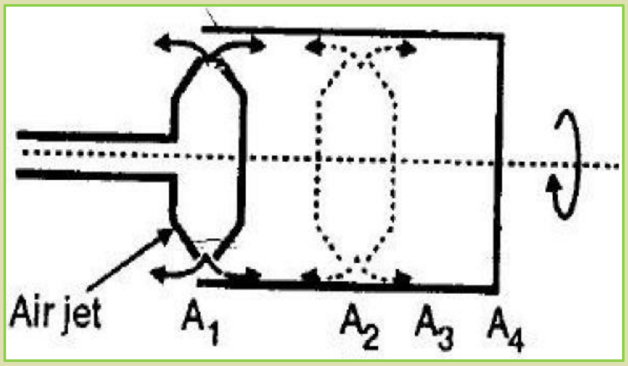
Principle:

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

Working:

As shown in Figure the air is compressed in the compressor at high pressure which is 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, at A1 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 positions along the length of the bore.





Any variation in the dimension changes the value of h, e.g. Change in dimension of 0.002 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 this makes 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 being

checked.
3. Different gauging heads are needed for different jobs.
4. Auxiliary equipment‘s 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 back pressure is linear, over only a small range of the orifice size variation.

Questions

1. What is comparator? Write different types of comparator.
2. With a neat sketch and explain working principle of pneumatic comparator.
3. What are comparators distinguish between comparators and measuring instruments.
4. Discus the merits and demerits of mechanical and pneumatic comparator.
5. What are the advantages and dis advantages of mechanical comparator.
6. What is comparator? What are advantages over measuring instrument.
7. With a neat sketch and explain working principle of mechanical comparator.
8. Why the comparators are needed? Explain with the help of neat sketch.
9. How the comparator helps in mass production? Explain with the help of neat sketch and examples.
10. A very soft component is to be checked by a comparator. Which comparator do you prefer? Explain that comparator with the help of neat sketch.
11. Explain the use of a mechanical comparator with a neat sketch.
12. Write the essential character of a comparator and mention its applications.
13. Explain the uses of pneumatic comparator with a neat sketch

Useful links

- https://www.youtube.com/watch?v=FoskEFBAq-s
- https://www.youtube.com/watch?v=wFytmRTEo04
- https://www.youtube.com/watch?v=F2boLvmtKBE
- https://www.youtube.com/watch?v=JILP_4GJJH0
- https://www.youtube.com/watch?v=njVBXjX625g
- https://www.youtube.com/watch?v=956wEr9Ir9s

UNIT 4 – ANGULAR MEASUREMENTS

Introduction:

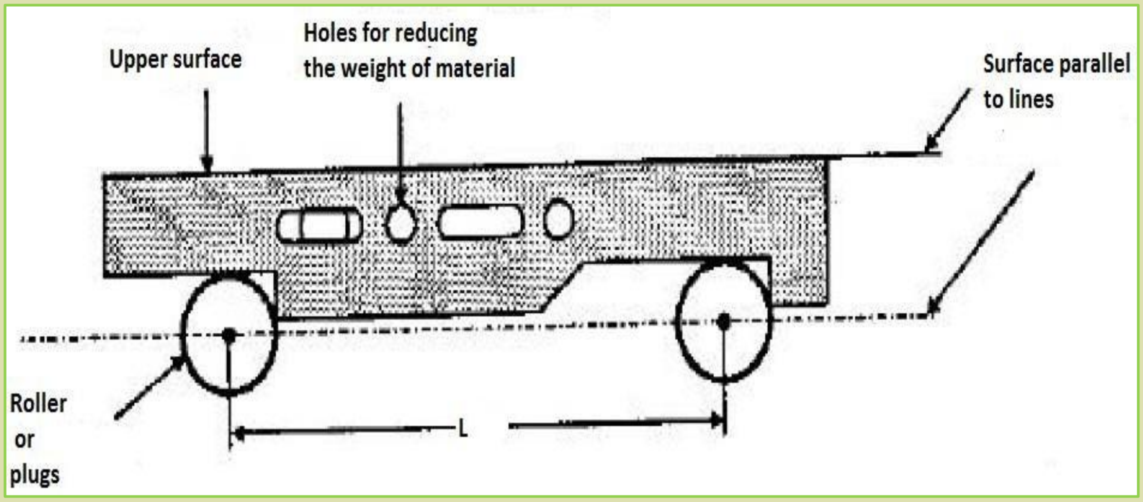
For measuring the angle, no absolute standard is required. The measurement is done in degrees, minutes and seconds. The measurement of angular and circular divisions is an important part of inspection. It is concerned with the measurement of individual angles, angular changes and deflections on components, gauges and tools. For precision measurement of angles more skill is required. Like linear measurement, angular measurements have their own importance.

The basic difference between the linear and angular measurement is that no absolute standard is required for angular measurement. There are several methods of measuring angles and tapers. The various instruments used are angle gauges, clinometers, bevel protractor, sine bar, sine centers, taper plug and ring gauges.

Sine Bars

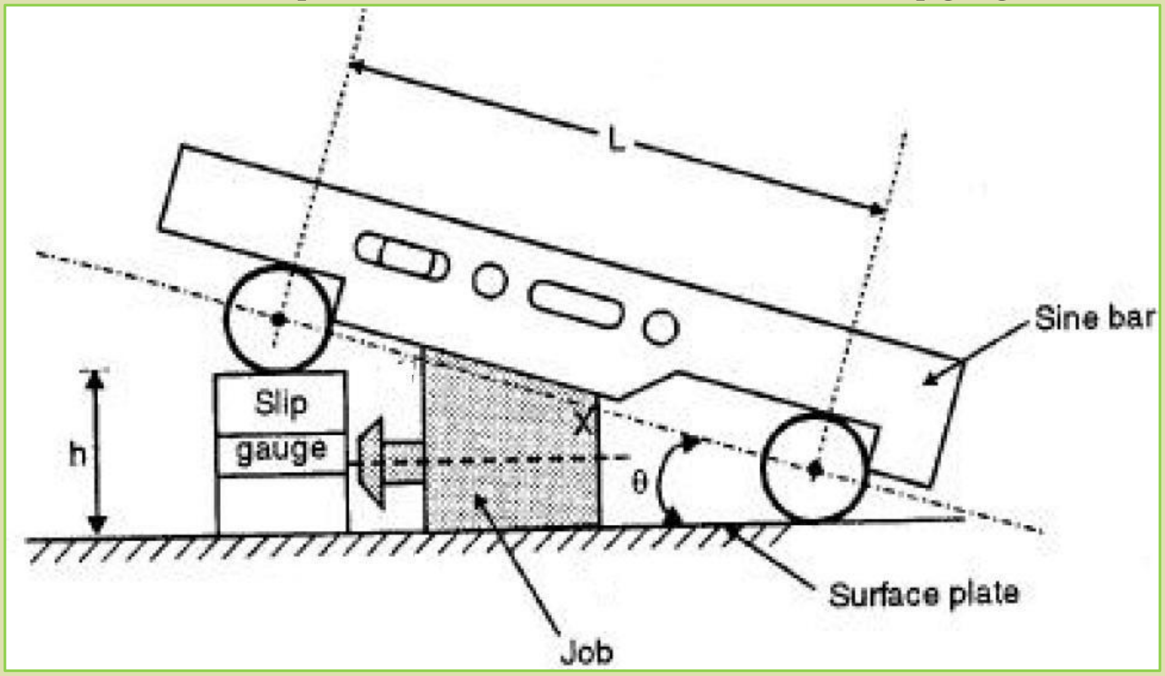
It is used for measurement of an angle of a given job or for setting an angle. They are hardened and precision ground tools for accurate angle setting. It can be used in conjunction with slip gauge set and dial gauge for measurement of angles and tapers from horizontal surface. As shown in Figure, two accurately lapped rollers are located at the extreme position. The center to center distance between the rollers or plugs is available for fixed distance i.e.100, 200, 250, 300 mm. The diameter of the plugs or roller must be of the same size and the center distance between them is accurate.

The important condition for the sine bar is that the surface of sine bar must be parallel to the center lines of the plug.



Principle of Working

As shown in Figure the taper angle θ of the job is to be measured by the sine bar. The job is placed over the surface plate. The sine bar is placed over the job with plug or roller of one end of the bar touching the surface plate. One end of the sine bar is rested on the surface plate and the other end is rested on the slip gauges.



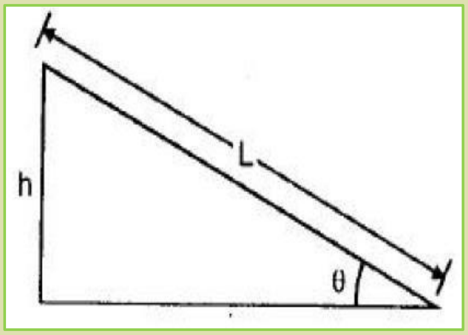
The angle of the job is then first measured by some non-precision instrument, such as bevel protector. That angle gives the idea of the approximate slip gauges required, at the other end of sine bar. And finally the exact number of slip gauges is added equal to height h, such that, the top most slip gauges touches the lower end of the roller. The height of the slip gauges required is then measured. Then the taper angle can be measured by making sine bar as a hypotenuse of right angle triangle and slide gauge as the opposite side of the triangle as shown in Figure

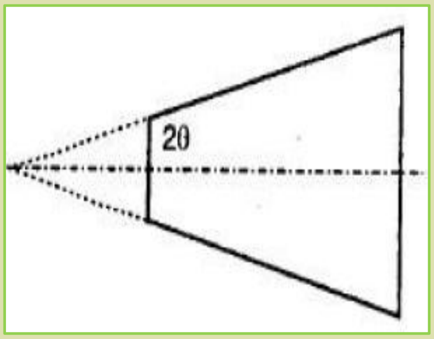
h = Height in mm

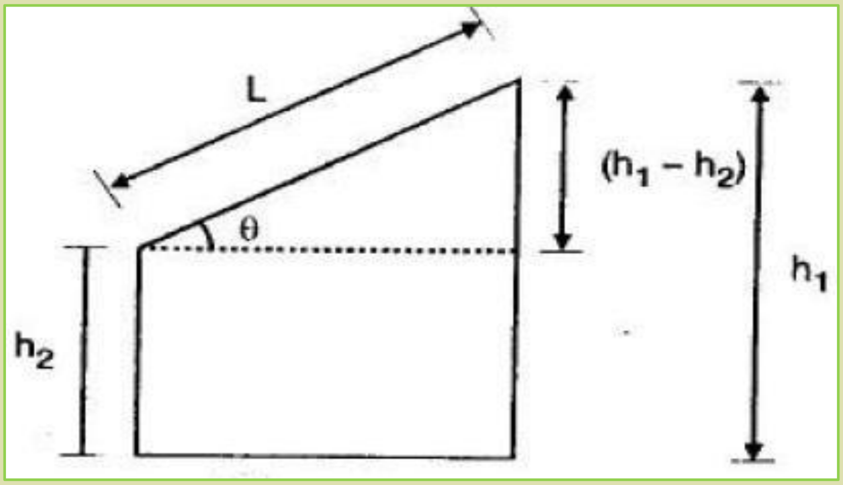
L = Center distance in mm

$\sin\theta$ = Opp / Hyp = (h/ L)

When the size of the job is large having taper then we use slip gauges for the both the side to find the taper angle of the job.







For a small component, the component or work piece can be placed over a sine bar as shown in Figure. The job is held on the sine bar with some suitable accessories. The dial indicators are provided at the top position and the reading is taken at h_1 position. The dial indicator is then moved to the right hand side and the reading is taken at position h_2. If there is a difference between readings at position $h_1$and h_2, then the height of the slip gauges is adjusted until the dial indicator shows the same reading at h_1 and h_2. Then the angle is calculated similar to previous method as

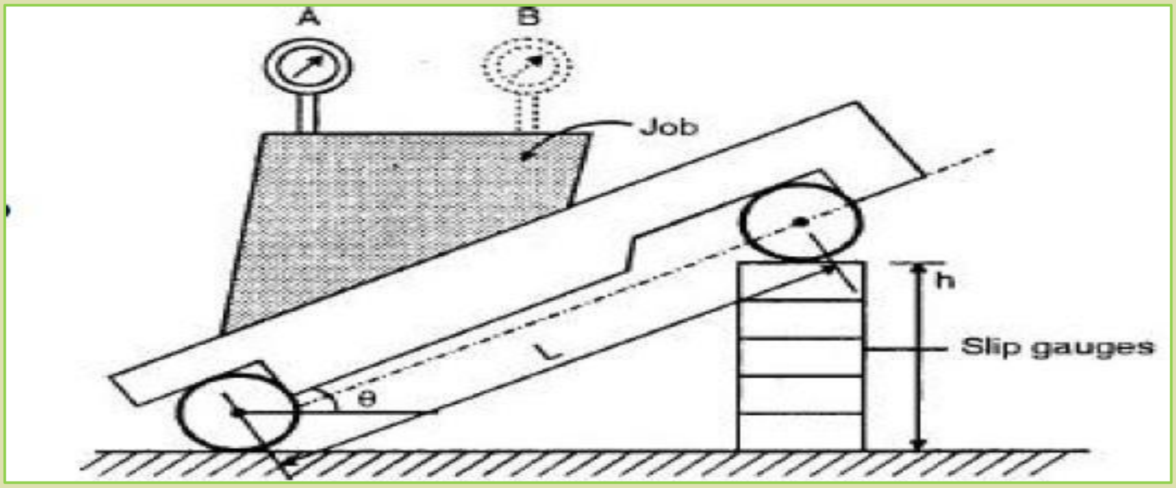
$\therefore$ Sinθ = Opp / Hyp = (h/ L)

Use of Sine Bar

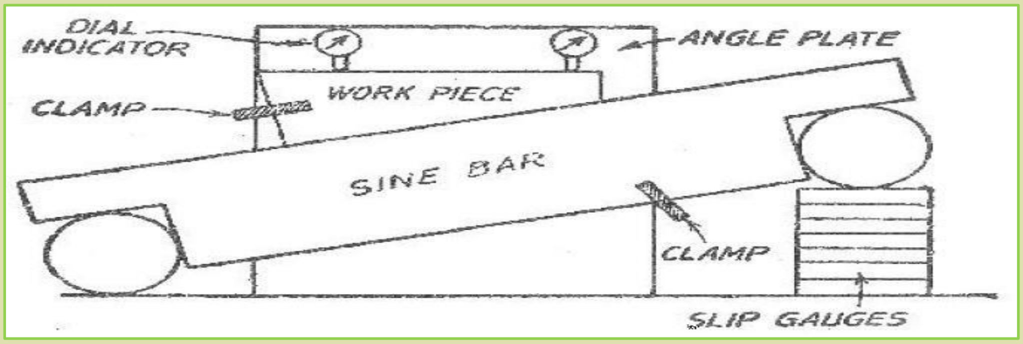
(1) Measuring known angles or locating any work to a given angle.

For this purpose the surface plate is assumed to be having a perfectly flat surface, so that its surface could be treated as horizontal. One of the cylinders or rollers of sine bar is placed on the surface plate and other roller is placed on the slip gauges of height h. Let the sine bar be set at an angle θ. Then sin θ = h/l, where l is the distance between the centers of the rollers. Thus knowing θ, h can be found out and any work could be set at this angle as the top face of sine bar is inclined at angle θ to the surface plate. The use of angle plates and clamps could also be made in case of heavy components. For better results, both the rollers could also be placed on slip gauges, of height h1 and h2 respectively

Then sin θ= (h2-h1)/*l*



(2) Checking of unknown angles



Many a times, angle of a component to be checked is unknown. In such a case, it is necessary to first find the angle approximately with the help of a bevel protractor. Let the angle be θ. Then the sine bar is set at an angle θ and clamped to an angle plate. Next, the work is placed on the sine bar and clamped to the angle plate as shown in Fig. and a dial indicator is set at one end of the work and moved to the other, and deviation is noted. Again slip gauges are so adjusted (according to this deviation) that dial indicator reads zero across the work surface.

If deviation noted down by the dial indicator is δh over a length l_ of work, then height of slip gauges by which it should be adjusted is equal to δh * (l/ l_).

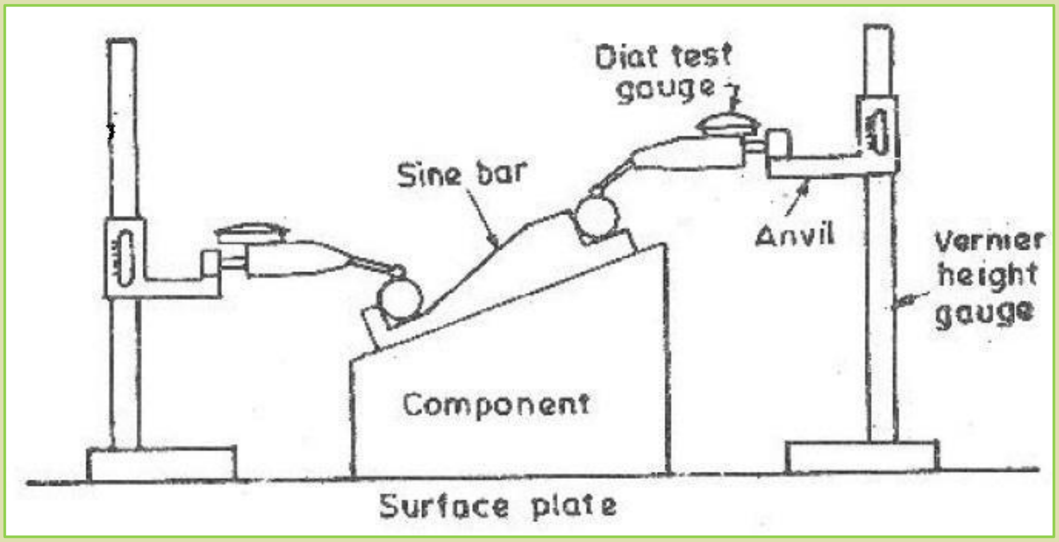
(3)Checking of unknown angles of heavy component

In such cases where components are heavy and can't be mounted on the sine bar, then sine bar is mounted on the component as shown in Fig.

The height over the rollers can then be measured by a vernier height gauge ; using a dial test gauge mounted on the anvil of height gauge as the dial indicator to ensure constant measuring pressure. The anvil on height gauge is adjusted with probe of dial test gauge showing same reading for the topmost position of rollers of sine bar.

The below shows the use of height gauge for obtaining two readings for either of the roller of sine bar.

The difference of the two readings of height gauge divided by the center distance of sine bar gives the sine of the angle of the component to be measured. Where greater accuracy is required, the position of dial test gauge probe can be sensed by adjusting a pile of slip gauges till dial indicator indicates same- reading over roller of sine bar and the slip gauges.



Advantages of sine bar:

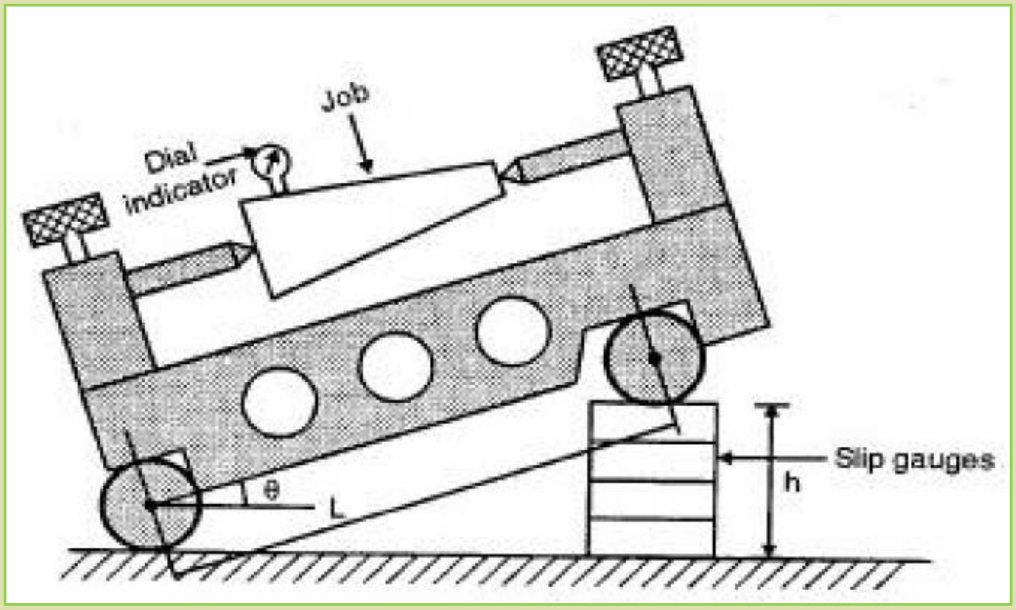
1. It is used for accurate and precise angular measurement.
2. It is available easily.
3. It is cheap.

Disadvantages:

1. The application is limited for a fixed center distance between two plugs or rollers.
2. It is difficult to handle and position the slip gauges.
3. If the angle exceeds 45°, sine bars are impracticable and inaccurate.
4. Large angular error may results due to slight error in sine bar

Sine Centers

It is the extension of sine bars where two ends are provided on which centers can be clamped, as shown in Figure. These are useful for testing of conical work centered at each end, up to 60°. The centers ensure correct alignment of the work piece. The procedure of setting is the same as for sine bar. The dial indicator is moved on to the job till the reading is same at the extreme position. The necessary arrangement is made in the slip gauge height and the angle is calculated as θ = Sin-1 (h/L).

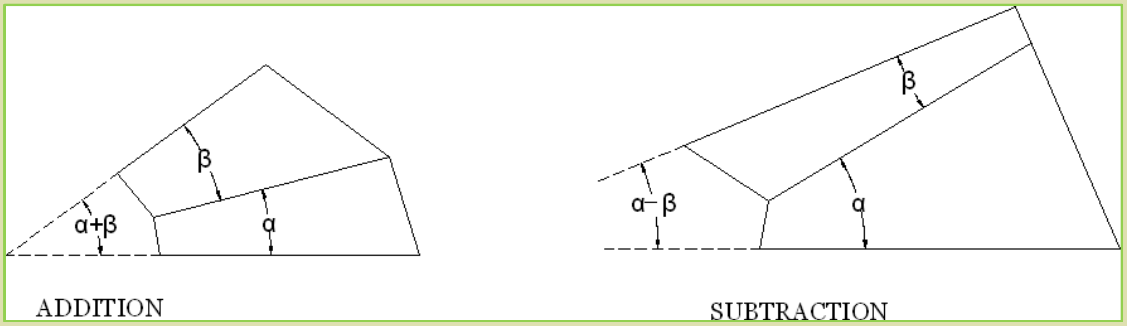


Angle gauges

These are used for setting and checking of angular surfaces. The measuring faces of gauges are lapped and polished to a high degree of flatness and accuracy like slip gauges.13 grades are available in a set and can be divided into three series.

Degree	1^0	3^0	9^0	27^0	41^0
Minutes	1'	3'	9'	27'	
Seconds	3"	6"	18"	30"	

All this gauges in combination can be added or subtracted thus making a large number of combinations possible. It is possible to set angles to the nearest 3".



Each angle gauges is marked with a symbol "<" which indicates the direction included angle. When angles of individual gauges are to be added up, symbol of all gauges should be in line.

Direct combination enables computation of any angle up to 81^{o} 40‘ 9‖ and angles larger than this can be made up with the help of the square block. However an additional gauge of 9^{o} can also be supplied with the set to obtain a full 90 angle without the use of the square

Difference between Linear and Angular measurement

Linear measurement	Angular measurement
1. In linear measurement line and standard and end standard are used.	1. There is no absolute standard for angular measurement.
2.Units used in linear measurement are mm, cm, m.	2. Units used in angular measurement are degrees and radians.
3. Line is a combination of points in a straight axis.	3. Angle is combination of two lines intersection at a point.
4. Linear measuring instruments are scales, vernier caliper, and micrometer.	4. Angular measuring instruments are Bevel protractor, Sine Bar, Angle gauges.

Questions

1. What is sine bar? Explain the procedure of measuring unknown angles sine bars.
2. Explain the sine table and sine center.
3. Explain with neat sketch applications of sine bars.
4. What are angle gauges? Explain the uses of angle gauges with examples.
5. How do you measure the 30° 45' 30" using angle gauges?
6. An angle of 33° 9' 15" is to be measured with the help of following standard angle gauges:

1˚	3˚	9˚	27˚	41˚
1’	3’	9’	27’	
3″	6″	18″	30″	

Show the arrangements of angle gauges with a neat sketch by selecting the minimum number of gauges.

7. With a neat sketch, explain the procedure of measuring unknown angles by using sine bars.
8. Distinguish between the angular measurements and linear measurements.
9. What are angle gauges? How to measure angle 38° 48' 24" with the help of angle gauges.
10. How do you measure angle of 25° using a combination of slip gauges and sine bar. Explain in detail.
11. Draw a neat sketch of sine center and explain.
12. Describe a method of check the angle of a piece tapered on one side by using two discs.
13. The approximate angle of a given component of length 50mm is 25° if +0.07mm deviation at slip built up is noted while using sine bar, and then what is the correct angle of the given component.
14. Select proper angle gauges for building following angles:
    20° 29' 54"
    32° 51' 24"

15. A 100mm sine bar is to be set to an angle of 32° 5' 6". Find the height of slip gauge required. Explain the procedure with a neat sketch.
16. Using angle gauges build up following angles:
    i. 26° 50' 30"
    ii. 35 °16 '42"

Useful links

- https://www.youtube.com/watch?v=dgkLbX4cqr4
- https://www.youtube.com/watch?v=8b4kmguf7K4
- https://www.youtube.com/watch?v=YaE9jK9sWYw
- https://www.youtube.com/watch?v=5CsyCzFTlnQ
- https://www.youtube.com/watch?v=BVtzM6YBwJQ
- https://www.youtube.com/watch?v=oclAazIhXPQ

UNIT 5 – SURFACE ROUGHNESS

Introduction:

With the more precise demands of modern engineering products, the control of surface texture together with dimensional accuracy has become more important. It has been investigated that the surface texture greatly influences the functioning of the machined parts. The properties such as appearance, corrosion resistance, wear resistance, fatigue resistance, lubrication, initial tolerance, ability 'to hold pressure, , load carrying capacity, noise reduction in case of gears is influenced by the surface texture.

Whatever may be the manufacturing process used, it is not possible to produce perfectly smooth surface. The imperfections and irregularities are bound to occur. The manufactured surface always departs from the absolute perfection to some extent. The irregularities on the surface are in the form of succession of hills and valleys varying in height and spacing. These irregularities are usually termed as surface roughness, surface finish, surface texture or surface quality. These irregularities are responsible to a great extent for the appearance of a surface of a component and its suitability for an intended application.

Factors Affecting Surface Roughness:-

(1) Vibrations
(2) Material of the work piece.
(3) Type of machining.
(4) Rigidity of the system consisting of machine tool, fixture cutting tool and work.
(5) Type, form, material and sharpness of cutting tool.
(6) Cutting conditions i.e., feed, speed and depth of cut.
(7) Type of coolant used.

Reasons for Controlling Surface Texture:-

(1) To improve the service life of the components.
(2) To improve the fatigue resistance.
(3) To reduce initial wear of parts.
(4) To have a close dimensional tolerance on the parts.
(5) To reduce frictional wear.
(6) To reduce corrosion by minimizing depth of irregularities.
(7) For good appearance.
(8) If the surface is not smooth enough, a turning shaft may act like a reamer and the piston rod like a broach.

Orders of Geometrical Irregularities:-

As we know that the material machined by chip removal process can't be finished perfectly due to some departures from ideal conditions as specified by the designer. Due to conditions not being ideal, the surface Produced will have some irregularities; these geometrical irregularities can be classified into four categories.

First Order:

The irregularities caused by inaccuracies in the machine tool itself are called as first order irregularities. These include:

(1) Irregularities caused due to lack of straightness of guide ways on which the tool most moves.

(2) Surface regularities arising due to deformation of work under the action of cutting forces, and

(3) Due to the weight of the material itself.

Second Order:

The irregularities caused due to vibrations of any kind are called second order irregularities.

Third order:

Even if the machine were perfect and completely free from vibrations some irregularities are caused by machining itself due to the characteristics of the process.

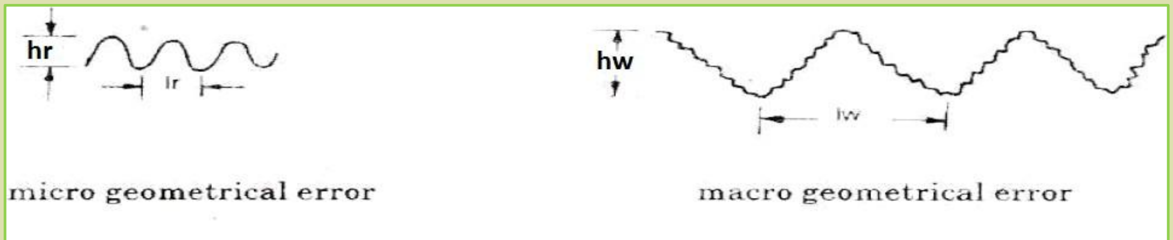
Fourth Order:

The fourth order irregularities include those arising from the rupture of the material during the separation of the chip.

Irregularities on the surface of the part:-

The irregularities on the surface of the part produced can also be grouped into two categories:

(i) Roughness or primary texture, (ii) Waviness or secondary texture



Micro and macro geometrical errors

(i) Primary texture (Roughness):

The surface irregularities of small wavelength are called primary texture or roughness. These are caused by direct action of the cutting element son the material i.e., cutting tool shape, tool feed rate or by some other disturbances such as friction, wear or corrosion.

These include irregularities of third and fourth order and constitute the micro-geometrical errors. The ratio l_r / h_r denoting the micro-errors is less than 50, where I_r = length along the surface and h_r = deviation of surface from the ideal one.

(ii) Secondary texture (Waviness):

The surface irregularities of considerable wavelength of a periodic character are called secondary texture or waviness. These irregularities result due to inaccuracies of slides, wear of guides, misalignment of centers, non-linear feed motion, deformation of work under the action of cutting forces, vibrations of any kind etc.

These errors include irregularities of first and second order and constitute the macro-geometrical errors. The ratio of I_w / h_w denoting the macro-errors is more than 50. Where, I_w = length along the surface and k_w = deviation of surface from ideal one

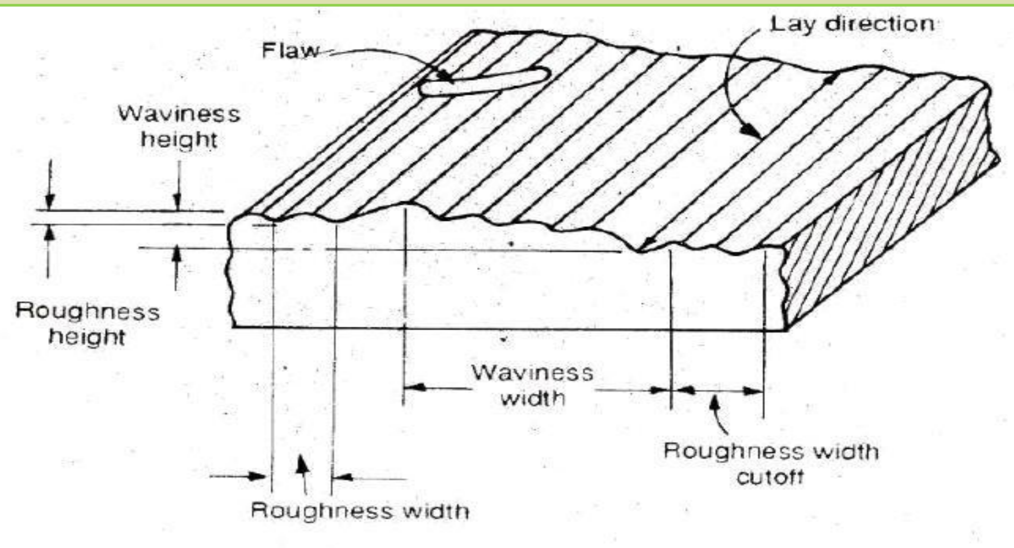
Elements of Surface Texture:-

The various elements of surface texture can be defined and explained with the help of fig which shows a typical surface highly magnified.

Surface: The surface of a part 'is confined by the boundary which separates that part from another part, substance or space.

Actual surface: This refers to the surface of a part which is actually obtained after a manufacture ring process.

Nominal surface: A nominal surface is a theoretical, geometrically perfect surface which does not exist in practice, but it is an average of the irregularities that are superimposed on it.



Elements of surface texture

Profile:

Profile is defined as the contour of any section through a surface, Roughness. As already explained roughness refers to relatively finely spaced micro geometrical irregularities. It is also called as primary texture and constitutes third and fourth order irregularities.

Roughness Height:

This is rated as the arithmetical average deviation expressed in micro-meters normal to an imaginary center line, running through the roughness profile.

Roughness Width:

Roughness width is the distance parallel , to the normal surface between successive peaks or ridges that constitutes the predominant pattern of the roughness.

Roughness Width cutoff:

This is the maximum width of surface irregularities that is included in the measurement of roughness height. This is always greater than roughness width and is rated in centimeters.

Waviness:

Waviness consists of those surface irregularities which are of greater spacing than roughness and it occurs in the form of waves. These are also termed as moon geometrical errors and constitute irregularities of first and second order. These are caused `due to misalignment of centres, vibrations, machine or work deflections, warping etc.

Effective profile:

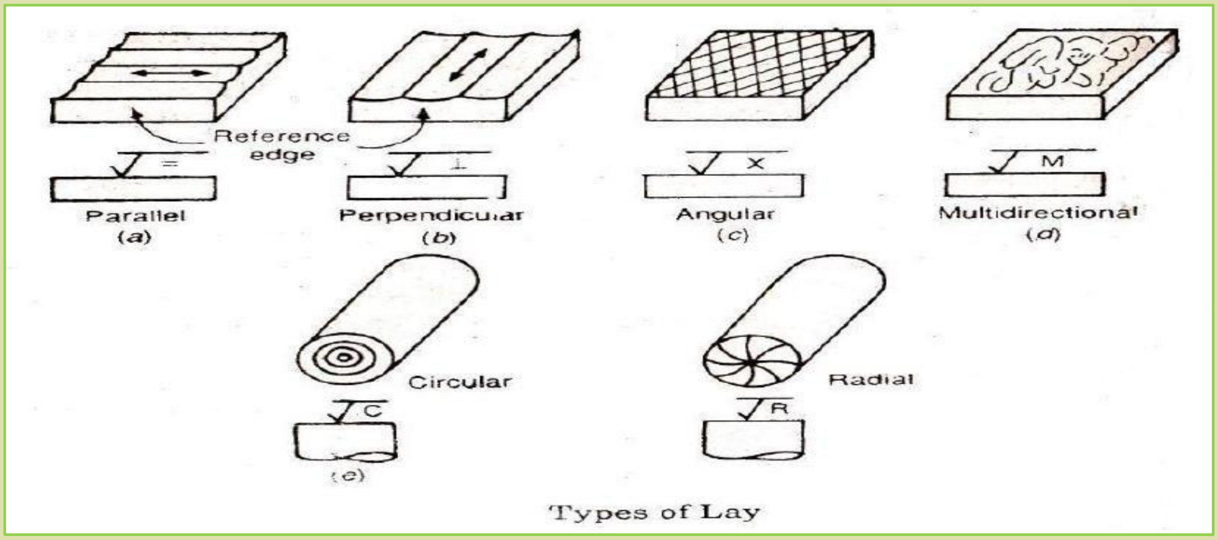
It is the real canter of a surface obtained by using instrument

Laws:

Flaws are surface irregularities or imperfections which occur art infrequent intervals and at random intervals. Examples are: scratches, holes, cracks, porosity etc. These may be observed directly with the aid of penetrating dye or other material which makes them visible for examination and evaluation.

Surface Texture:

Repetitive or random deviations from the nominal surface which forms the pattern on the surface. Surface texture includes roughness, waviness, lays and flaws.



Lay:

It is the direction of predominant surface pattern produced by tool marks or scratches. It is determined by the method of production used. Symbols used to indicate the direction of lay are given below **||** = Lay parallel to the boundary line of the nominal surface that is, lay parallel to the line representing surface to which the symbol is applied e.g., parallel shaping, end view of turning and O.D grinding.

⊥=

Lay perpendicular to the boundary line of the nominal surface that is lay perpendicular to the line representing surface to which the symbol is applied.
e.g., end view of shaping, longitudinal view of turning and O.D. grinding.

X =

Lay angular in both directions to the line representing the surface to which symbol is applied, e.g. traversed end mill, side wheel grinding.

M=

Lay multidirectional e.g. lapping super finishing, honing.

C=

Lay approximately circular relative to the center of the surface to which the symbol is applied
e.g., facing on a lathe.

R=

Lay approximately radial relative to the center of the surface to which the symbol is applied,
e.g., surface ground on a turntable, fly cut and indexed on end mill.

Sampling length:

It is the length of the profile necessary for the evaluation of the irregularities to be taken into account. It is also known as cut-off length. It is measured in a direction parallelogram general direction of the profile. The sampling length should bear some relation to the type of profile.

Evaluation of Surface Finish:

A numerical assessment of surface finish can be carried out in a number of ways. These numerical values are obtained with respect to a datum. In practice, the following three methods of evaluating primary texture (roughness) of a surface are used:

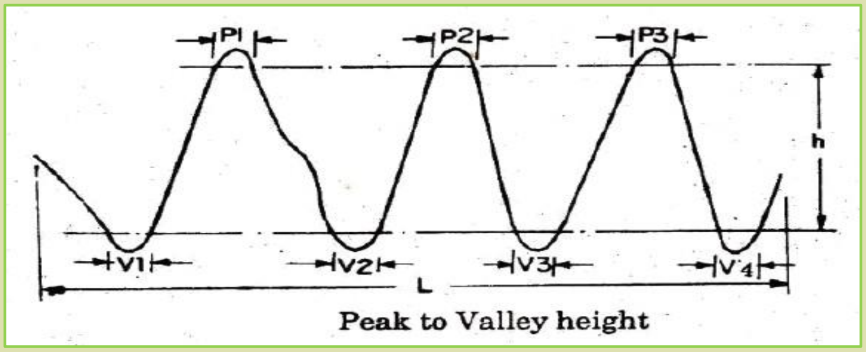
(1) Peak to valley height method

(2) The average roughness

(3) Form factor or bearing curve.

1.Peak to valley height method:

This method is largely used in Germany and Russia. It measures the maximum depth of the surface irregularities over a given sample length, and largest value of the depth is accepted as a measure of roughness. The drawback of this method is that it may read the same h for two largely different texture. The value obtained would not give a representative assessment of the surface.

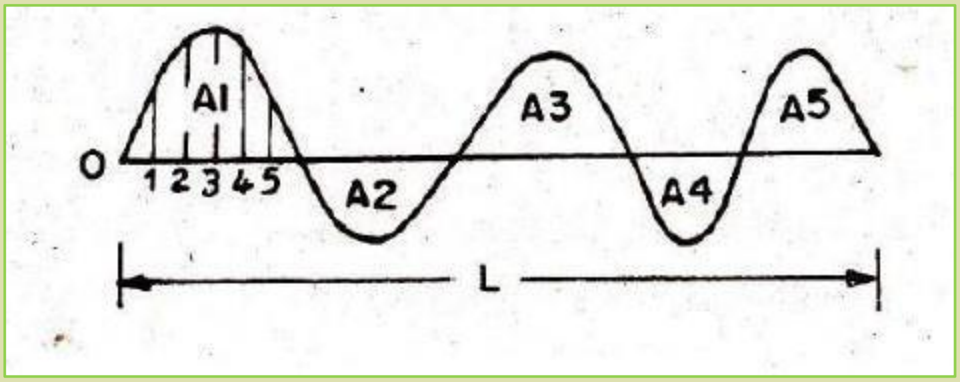


To, overcomes this PV (Peak to Valley) height is defined as the distance between a pair of lines running parallel `to the general _lay' of the trace positioned so that the length lying within the peaks at, the top is 5% of the trace length, and that within the valleys at the bottom is 10% of the trace length. This is represented graphically in Figure above.

2.The average roughness:

For assessment off average roughness the following three statistical criteria are used:

a) **C.L.A Method:** In this method, the surface roughness is measured as the average deviation from the nominal surface.



Centre Line Average or Arithmetic Average is defined as the average values of the ordinates from the mean line, regardless of the arithmetic signs of the ordinates.

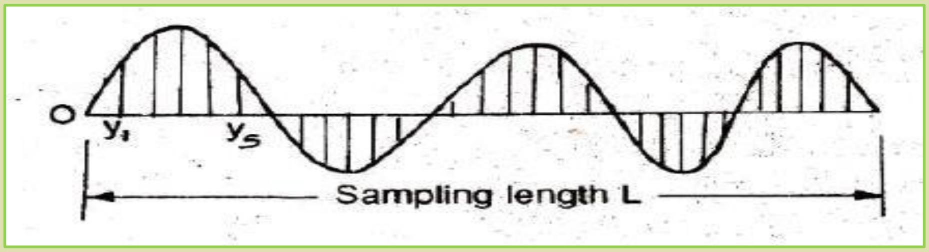
$$CLA\ value = \frac{h1+h2+h3+\cdots\ldots\ldots hn}{n} \qquad \text{(i)}$$

$$CLA = \frac{A1+A2+A3+\cdots\ldots\ldots An}{L} \qquad \text{(ii)}$$

$$= \sum A/L$$

The calculation of C.L.A value using equation (ii) is facilitated by the planimeter. CLA value measure is preferred to RMS value measure because its value can be easily determined by measuring. The areas with planimeter or graph or can be readily determined in electrical instruments by integrating the movement of the styles and displaying the result as an average.

(b) **R.M.S. Method:** In this method also, the roughness is measured as the average deviation from the nominal surface. Root mean square value measured is based on the least squares.



R.M.S value is defined as the square root of the arithmetic mean of the values of the squares of the ordinates of the surface measured from a mean line. It is obtained by setting many equidistant ordinates on the mean line (1, 2, 3 ….)and then taking the root of the mean of the squared ordinates.

Let us assume that the sample length _L‘is divided into _n' equal parts and 1, 2, 3 ….are the heights of the ordinates erected at those points.

$$RMS\ average = \sqrt{(1/n)\sum y1^2 + y2^2 + y3^2 + \cdots \ldots\ldots\ldots\ldots\ldots\ldots\ldots.\, yn^2}$$

Conventional Method for Designing Surface finish:

As per IS: 696 surface texture specified by indicating the following

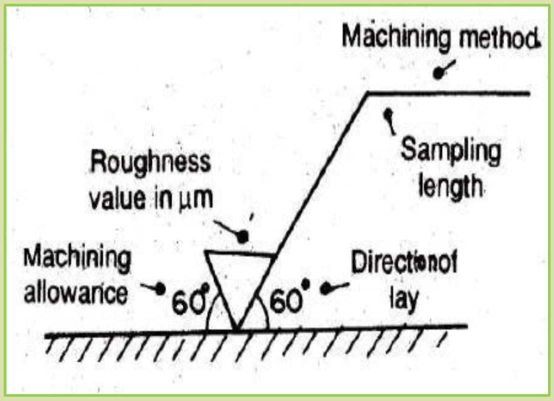
(a) Roughness value i.e., Ra value in mm

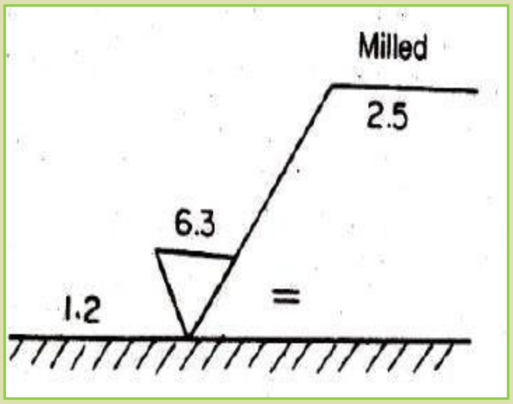
(b) Machining allowance in mm.

(c) Sampling length or instrument cut-off length in mm.

(d) Machining production method, and

(e) Direction of lay in the symbol form as = ⊥, X, M, C, R





Measurement of surface finish surfaces texture:

The methods used for ensuring the surface finish can be classified broadly into two groups.

1. Inspection by comparison.

2. Direct instrument measurement

1. Inspection by comparison methods.

In these methods, the surface texture is assessed by observation of the surface. These are the methods of qualitative analysis of the surface texture. The texture, e of the surface W be tested is compared with that of a specimen of known roughness ~value and `finished by similar machining processes.

Though these methods are rapid, the results are not reliable because they can be misleading if comparison is not made with the surface produced by similar techniques.

The various methods available for comparison are:

(i) Visual Inspection

(ii) Touch Inspection

(iii) Scratch Inspection

(iv) Microscopic Inspection

(v) Surface photographs

(vi) Micro-Interferometer

(vii) Wallace surface Dynamometer

(viii) Reflected Light Intensity.

(i) Visual Inspection:

In this method the surface is inspected by naked eye. This method is always likely to be misleading particularly when surfaces with high degree of finish are inspected. It is therefore limited to rougher surfaces.

(ii) Touch Inspection:

This method can simply assess which surface is more rough, it cannot give the degree of surface roughness. Secondly, the minute flaws can't be detected. In this method, the fingertip is moved along the surface at a speed of about 25 mm per second and the irregularities as small as 0.0125 mm can be detected. In modified method a tennis ball is rubbed over the surface and surface roughness is judged thereby.

(iii) Scratch Inspection:

In this method a softer material like lead, Bab bit, or plastic is rubbed over the surface to be inspected. The impression of the scratches on the surface produced is then visualized.

(iv) Microscopic Inspection:

This is probably the best method for examining the surface texture by comparison. But since, only a small surface can be inspected at a time several readings are required to get an average value. In this method, a master finished surface is placed under the microscope and compared with the surface under inspection. Alternatively, a straight edge is placed on the surface to be inspected and a beam of light projected at about 600 to the work. Thus the shadow is cast into the surface, the scratches are magnified and the surface irregularities can be studied.

(v) Surface photographs:

In this method magnified photographs of the surface are taken with different types of illumination to reveal the irregularities. If the vertical illumination is used then defects like irregularities and scratches appear as dark spots and flat portion of the surface appears as bright area.

In case of 'oblique illumination, reverse is the case. Photographs with different illumination are compared and the result is assessed.

(vi) Micro Interferometer:

In this method, an optical flat is placed on the surface to be inspected and illuminated by a monochromatic source of light. Interference bands are studied through a microscope. The scratches in the surface appear as interference lines extending from the dark bands into the bright bands. The depth of the defect is measured in terms of the fraction of the interference bands.

(vii) Wallace Surface Dynamometer:

It is a sort of friction meter. It consists of a pendulum in which the testing shoes are damped to a bearing surface and a predetermined spring pressure can be applied. The pendulum is lifted to its initial starting position and allowed to swing over the surface to be tested. If the surface is smooth, then there will be less friction and pendulum swings for a longer period. Thus, the time of swing is a direct measure of surface texture.

(viii)Reflected Light Intensity:

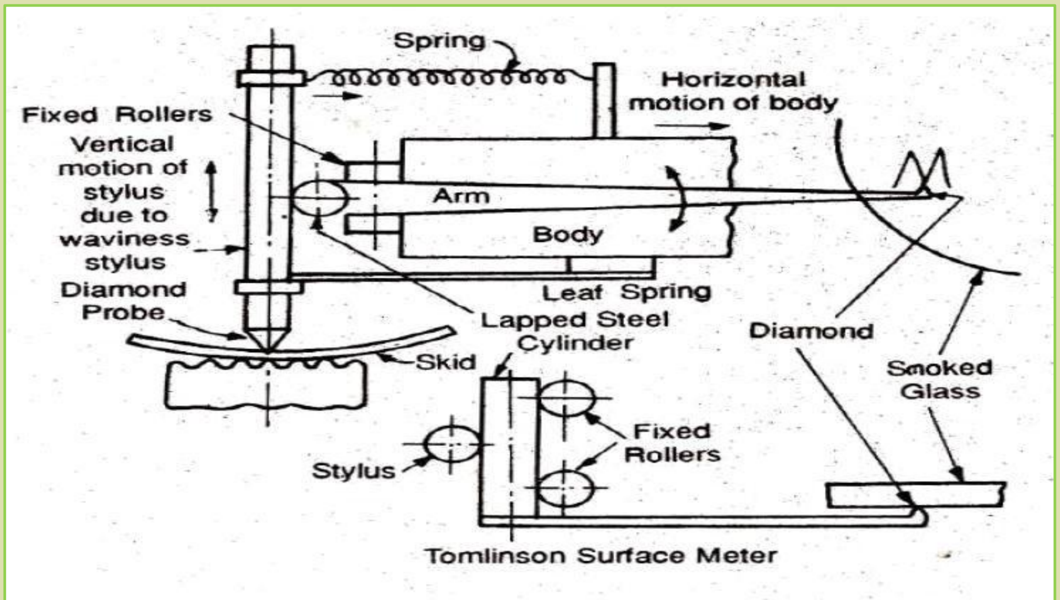
In this method a beam of light of known quantity is projected upon the surface. This light is reflected in several directions as beams of lesser intensity and the change in light intensity in different directions is measured by a photocell. The measured intensity changes are already calibrated by means of reading taken from surface of known roughness by some other suitable method.

2. Direct Instrument Measurement:

These are the methods of quantitative analysis. These methods enable to determine the numerical value of the surface finish of any surface by using instruments of stylus probe type operating on electrical principles. In these instruments the output has to be amplified and the amplified output is used to operate recording or indicating instrument

The Tomlinson surface meter:

The Tomlinson surface meter is a comparatively cheap and reliable instrument. It was originally designed by Dr. Tomlinson It consists of a diamond probe (stylus) held by spring pressure against the surface of a lapped steel cylinder and is attached to the body of the instrument by a leaf spring. The lapped cylinder is supported on one side by the probe and on the either side by fixed rollers. Alight spring steel arm is attached to the lapped cylinder. It carries at its tip a diamond scriber which rests against a smoked glass. The motions of the stylus in all the directions except the vertical one are prevented by the forces exerted by the two springs.



Tomlinson Surface Meter

For measuring surface finish the body of the instrument is moved across the surface by screw rotated by asynchronous motor. The vertical movement of the probe caused by surface irregularities makes the horizontal lapped cylinder to roll. This causes the movement of the arm attached to the lapped cylinder. A magnified vertical movement of the diamond scriber on smoked glass is obtained by the movement of the arm. This vertical movement of the scriber together with horizontal movement produces a trace on the smoked glass plate. This trace is further magnified at X 50 or X 100 by an optical projector for examination.

Advantages:

The main advantage of such instruments is that the electrical signal available can be processed to obtain any desired roughness parameter or can be recorded for display or subsequent analysis. Therefore, the stylus type instruments are widely used for surface texture measurements inspite of the following disadvantages.

Disadvantages:

1. These instruments are bulky and complex.
2. They are relatively fragile.
3. Initial cost is high.
4. Measurements are limited to a section of a surface.
5. Needs skilled operators for measurements.
6. Distance between stylus and skid and the shape of the skid introduce errors in measurement for wavy surfaces.

Questions

1. Explain surface finish inspection by comparison method.
2. Explain RMS value method for measuring surface roughness.
3. Briefly explain scratch inspection, tough inspection, visual inspection and surface photographs.
4. Define the following terms: actual surface, roughness, lay, R_a value.
5. What are the different methods of checking the surface finish by indirect method?Explain.
6. Explain the CLA and RMS method of evaluating the surface finish.
7. Explain the working principle of Tomlinson surface tester. With a neat sketch.

8\. Define the following terms: 1) Real surface 2) Geometrical surface 3) Effective surface 4) Waviness

8\. Explain the following terms: 1) Centre line of profile 2) CLA value

9\. Explain the following surface roughness symbols

1) = 2) ⊥ 3) X 4) M 5) C 6) R

Useful Links

- https://www.youtube.com/watch?v=dzhh82H2Nuk
- https://www.youtube.com/watch?v=Ab6QP1FscOc
- https://www.youtube.com/watch?v=AaK1xtUPIpE

UNIT 6 – MEASURING INSTRUMENTS

Introduction:

The Coordinate measuring machine has a precise movement in X Y Z co originates which can be easily controlled and measured .Each slide in these three directions is equipped with a precision linear movement Transducer gives digital display and senses positive and negative directions. These machines are manufactured in both manual and computer controlled modules.

The Measuring head incorporates a probe tip which can be different kinds like taper tip or ball tip etc.,

For measuring the distances between two holes the work piece clamped to the work table and aligned with the machines three mutually perpendicular axis X Y and Z measuring slides. The tapered probe tip is then seated in first datum hole and the probe position digital read out is set to zero. The probe is then moved to the successive holes at each of which the digital read out represents the co-ordinates part print hole. The machine is also equipped with automatic recording and data processing units which are essential when complex geometric and statistical analysis are carried out.

The various types of Co-ordinates measuring machines are:-

1. Cantilever type
2. Horizontal bore mill
3. Bridge type
4. Vertical bore mill
5. Floating bridge Type
6. Spherical Co-ordinate (R-θ) Measuring Machine

1. Canti lever type

The cantilever type is easiest to load and unload but it is most susceptible to mechanical error because of sag or deflection in Y-axis beam.

Cantilever type

2. Bridge type

Bridge type is more difficult to load but less sensitive to mechanical errors

Bridge type

3. Horizontal bore mill

Horizontal Boring mill types is best suited for large heavy work piece

Horizontal bore mill Type

4. Vertical bore mill

A vertical bore mill type is highly accurate but usually slower to operate.

Vertical bore mill type

5. Spherical measuring Machine

This machine having motion of their measuring heads in R,Q and θ directions are used for inspecting the parts that are basically spherical. In a spherical co-ordinate measuring machine both linear and rotary axes are incorporated.

Present day co-ordinate measuring machine are three axis read out type and work up to 10 microns accuracy and resolutions of 5 microns.

ADVANTAGES OF CMM:-

1. Faster rate of inspection
2. Improved accuracy
3. Minimization of operator error.
4. Reduced operator skill requirements.
5. Reduced need of fixtures & maintains costs.
6. Uniform inspection Quality.
7. Reduction of scrap.
8. Reduction in calculating & recording time & errors.
9. Reduction in set up time.
10. Simplification of inspection procedures etc;

POSSIBLE SOURCES OF ERRORS IN CMM;

1. The table of CMM may not have perfect geometrical from.
2. The table and the probes may not be in perfect alignment.
3. The probes may have degree of run out. So it should be located at the same rotational position.
4. The probes moving up and down in the Z-axes may have same perpendicularity errors.
5. There may be error in optical read out of digital system.
6. It is therefore very essential that CMM should be calibrated with master plates before using the machine.

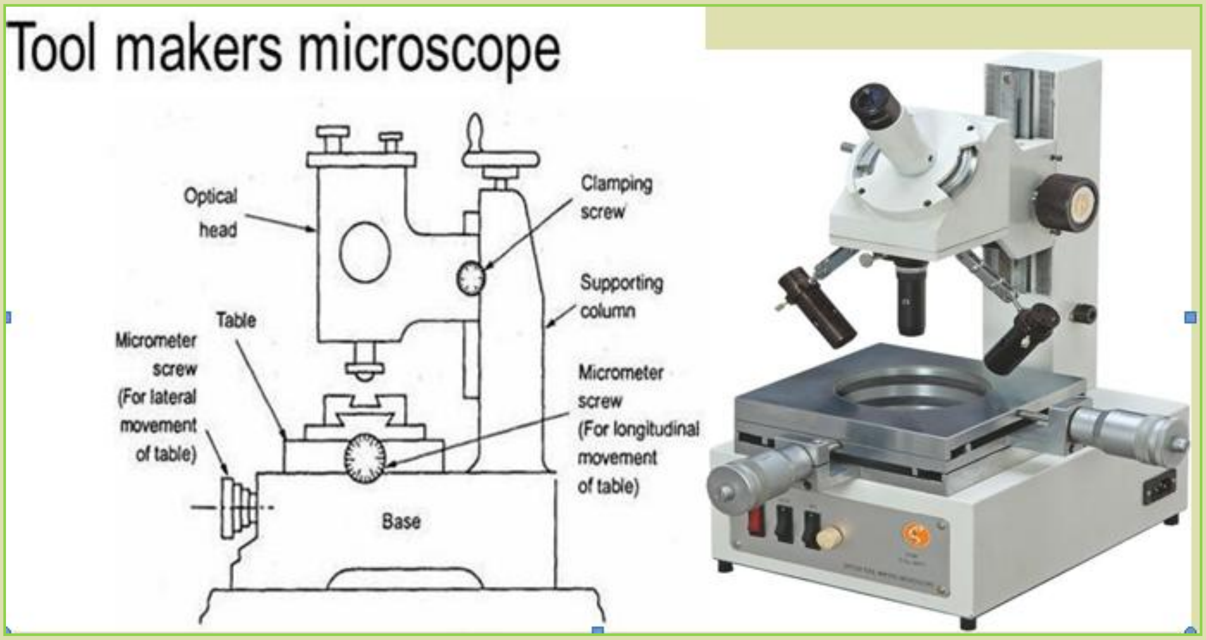
TOOL MAKERS MICROSCOPE

The tool makers microscope device its name from the fact that initially it was being used to measure different tool angles.

It consists a head which can slide along the guide ways of the vertical column and can be clamped with a screw at any position focusing is performed by adjusting the optical head the stage or table on which the work piece to be measured is kept incorporates in its self-transparent glass piece which is secured on heavy hollow base.

The table is equipped with a clips clamps and vices for holding the work pieces. It is also equipped with adjusting lighting arrangement to illuminate the work piece. A light source is incorporated at the back base from which a horizontal beam of light comes this beam of light is reflected at right angles by a mirror upwards too wards the table the light beam passes through the transparent glass plate of the table on which the work piece is placed.

The image of the work piece is adjusted and focused on the screen and first point on the work piece is made coincide with cross line on the screen. The reading from the longitudinal micrometer is noted. The work piece is then moved with cross line the micrometer reading is noted again the distance between the point is found out by finding the difference in two readings the angles can be measured setting the cross line.



Questions

1. Explain briefly CMM.
2. What are the advantages of CMM?
3. What are the types of CMM? Explain any one?
4. What are the errors occurred in CMM?

Useful links

- https://www.youtube.com/watch?v=Mr3wJ8QPJ8s
- https://www.youtube.com/watch?v=lZaWx8-oetQ
- https://www.youtube.com/watch?v=5GS6MAPx598
- https://www.youtube.com/watch?v=kX4aPWxvgcM
- https://www.youtube.com/watch?v=_lgihDfkvGI

UNIT 7 – TOTAL QUALITY MANAGEMENT

EVOLUTION OF QUALITY

The requirement for Quality Control dates back to the time when human race wanted to replicate an object. The desire to control quality is as old as human‘s ability to produce things the forerunning attempts to control quality resulted in rather crude replicas of original objects. These replicas were produced in a way that could easily be discerned by the necked eye.

As time passed, human‘s developed the competence to duplicate objects so that they become indistinguishable from one another. The drawback for this was that the assembly with any alternation or adjustment was not possible.

Eli Whitney conceived the idea of perfect interchangeability of parts. He emphasized that if proper raw material, methods and equipment are used and if workmen exercised the right amount of course, items can be produced somewhat in an identical manner. In 1799, he contracted to supply rifles to the army. Mr. Whitney was partially successful in getting each workman to make one part of the exact specification he could still do only selective assembly but did establish the fact that production time can be reduced.

Perhaps this was the germs of man production. It was not until the early 1800s that man began to realize the necessity of tolerance in parts. The interchangeability in industrial activity resulted in many problems on measurements. A Swedish engineer named Johansson conceived the idea of a hard metal block that could be machined and polished to exact dimension, which can be used as points of reference. These blocks were referred to as _Jo‘blocks.

In the middle of the 17th century, Pascal, the French philosopher and mathematician become quite talker by the games of chance. He formulated that theory of probability in association with Pierre Fermat. During the 1800s, considerable progress was made in the development of the sampling theory.

Modern quality control or statistical quality control (SQC) as we know it today started with invention of quality control chart by Walter A Shewhart of Bell Telephone Labs, USA in 1930s. Dr. Shewhart proposed the statistical methods could be effectively used for examining whether the items produced by any process were of uniform quality or not. The real impetus for the application of these methods on a massive scale resulted form the economic pressure for more efficient utilization of equipment and resources during World War II Dr. Shewhart wrote a book economic control of quality of manufactured products, which was published in 1931. The objective explicitly put-forth in the title was __Economic Control‘‘.

The influence of the US military services on the adoption of sampling acceptance techniques was well established. World War II was the catalyst that made the control charts applicable in the US. By applying quality control, the US was able to produce military requirements inexpensively and in high volumes.

The wartime standards published in those days was known as __Z–1 standards‘‘

British Standards

England also developed quality control at relatively early date, the application of which was evident in the adoption of British Standards 600 in 1935 on E.S. Pearson‘s statistical work. Later US Z-1 standards were adopted in there entirely as British standard were used in England during the time of war.

These standards stimulated technological advances in terms of production quantity, quality and cost. It would be an exaggeration to say that World War II was won by sing statistical quality control methods. Some of the statistical methods researched and utilized by the allied power were so effective that they were regarded as military secrets until the surrender of Nazi Germany.

The Japanese knew about the British standards 600 in the pre-war year and translated them into Japanese during the War Japanese effort in modern statistics was expressed in mathematical language which was difficult to understand.

Quality was controlled by inspection and not every product was sufficiently inspected. Hence, Japan had to compete with price and not with quality. It was literally the age of __Cheap and poor products from Japan.

Learning from US

Having faced defeat in World War II Japan lost all that it had and could not even feed people with food, clothing and shelter. They realized that if you make poor quality products then the troops so, it was a matter of life and death. It was at his critical juncture that the US occupational (USOF) having landed in Japan; ordered the Japanese telecommunication industry to learn the use of modern quality control and took steps to educate the industry.

This was the beginning of SQC in Japan in 1946. Quality control methods taught by the USOF were not modified for the Japanese. Though this created some problems the methods reached beyond the telecom industry. Japanese could really make tremendous progress by making heavy investments and by inviting great scholars like Dr. Deming in 1950 and Dr. Juran in 1954 the huge investment made in education and training at the crucial time paid very rich dividends in Japan.

These Japanese thus learn one bitter lesson that __if you make bad quality during war time, your country is overrun by enemy troops, so it is a matter of life and death. They eventually taught the world a lesson that if you make bad quality, during peace time, your country during peace time, your country is overrun by foreign products, which is a matter of life and sickness, commercial death, bankruptcy, impoverishment and what not.

The development of quality activities has spanned the entire of 20th century curiously significant changes in the approach to quality activities have occurred every 20 years. Quality activities have traversed a long path from operator Inspection (1900s) to verification of quality by supervisors (1920s) to establishment if quality control departments and 100% inspection (1940s) to statistical quality control (1960s) to TQC with statistical control (1980‘s) TQM and statistical problem solving (1990s).

DEFINITION

Total Quality Management (TQM) is an enhancement to the traditional way of doing business. It is a proven technique to guarantee survival in world-class competition. Only by changing the actions of management will the culture and actions of an entire organization be transformed.

TQM is for the most part common sense. Analyzing these words.

Total — made up of the whole
Quality — Degree of Excellence a Product or Service provides
Management — Act, art or manner of handling, controlling, directing etc.

TQM CONCEPTS

The above principles are bandied freely around in the above discussion. Its worth dwelling with each for a moment.

Be customer–focused means everything you do will be done by placing the customer in the centre. The company should regularly check customer's attitudes. This will include the external and internal customer concept.

Do it right first time so that there is no rework. This essentially means cutting down on the amount of defective work.

Constantly improve, this allows the company gradually to get better. One of the axioms use by TQM people is ‗A 5% improvement in 100% of the areas is easier than a 100% improvement in 5% of the areas.

Quality is an attitude the attitude is what differentiates between excellence and meritocracy. Therefore it's very important to change the attitude of the entire workforce *i.e.*, basically the way the company works company's work culture.

Telling the staff what is going on means keeping the entire workforce informed about the general direction the company is headed in typically this includes them briefings, one of the main elements to TQM.

Training and education of the workforce is a vital ingredient, as untrained staff tends to commit mistakes. Enlarging the skill base of the staff essentially makes them do a wider range of jobs and do them better. In the new system of working under TQM educating the staff is one of the principles.

Measurement of work allows the company to make decisions based on facts, it also helps them to maintain standards and keep processes within the agreed tolerance levels.

The involvement of senior management is essential. The lack of which will cause the TQM program to fail.

Getting employees to make decision on the spot so that the customer does not face any inconvenience in empowering the employees.

Mailing it a good place to work. In many an organization there exists a lot of fear in the staff, the fear of the boss, fear of mistakes of being sacked. TQM program is any company filled with fear cannot work; therefore fear has to be driven out of the company before starting of TQM program.

Introduce team working, its boosts employee morale. It also reduces conflict among the staff. It reduces the role of authority and responsibility, and it provides better more balanced solutions. In a lot of companies teamwork is discouraged, so TQM programs must encourage it.

Organize by process, not by function. This concentrates on getting the product to the customer by reducing the barriers between the different departments.

THE DEMING'S PHILOSOPHY

Dr. W. Edward-Deming was a protégé of Dr. Walter Shewhart, who pioneered statistical process control (SPC) at Bell Laboratories. He spent one year studying under Sir Ronald Fisher, who pioneered design of experiments.

Dr. Deming is credited with providing the foundations of the Japanese quality miracle and resurgence as an economic power. He developed the following 14 points as a theory for management for improvement of quality, productivity and competitive position.

1. Create and publish the Aims and Purposes of the Organization

Management must demonstrate constantly their commitments to this statement. It must include investors, customers, suppliers, employees, the community and a quality philosophy. Organization must develop a long-term view of at least 10 years and plan to stay in business by setting long-range goals. Resources must be allocated for research, training and continuing education to achieve the goals. A family organizational philosophy is developed to send the message that everyone is part of the organization.

2. Learn the New Philosophy

Top management and every one must learn the new philosophy. Organizations must seek never ending improvement and refuse to accept non conformance customer satisfaction is the number one priority, because dissatisfied customers will not continue to purchase non confirming products and service. Everyone in the organization, including the union, must be involved in the quality journey and change his or her attitude about quality.

3. Understand the Purpose of Inspection

Management must understand that the purpose of inspection is to improve the process and reduce its cost. Statistical evidence is required of self and supplier every effort should be made to reduce and then eliminate acceptance sampling.

4. Stop Awarding Business based on Price Alone

The organization must stop awarding business based on the low bid, because price has no-meaning without quality. The goal is to have single suppliers for each item to develop a long-term relationship of loyalty and trust thereby providing improved products and service.

5. Improve Constantly and forever the System

Management must take more responsibility for problems by actively finding and correcting problems so that quality and productivity are continually and permanently improved and costs are reduced.

The focus is on preventing problems before they happen variation is expected but these must be a continual striving for its reduction using control charts.

6. Institute Training

Each employee must be oriented to the organization philosophy of commitment to never-ending improvements management must allocate resources to train employees to perform their jobs in the best manner possible flourish.

7. Drive out fear, Create Trust, and Create a Climate for Innovation

Management must encourage open, effective communication and teamwork. Fear is caused by a general feeling of being powerless to control important aspects of one‘s life. It is caused by a lack of Job security, possible physical harm, performance appraisals, and ignorance of organization goals, poor supervision and not knowing the job.

8. Driving fear out of the work place involves managing for success.

When people are treated with density, fear can be eliminated and people will work for the general good of the organization. In this climate, they will provide ideas for improvement.

9. Optimize the Efforts of Teams, Groups and Staff Areas

Management must optimize the efforts of teams, work groups and staff areas to achieve the aims and purposes of the organization. Barriers exist internally among levels of management, among departments, within departments and among shifts. To break down the barriers, management will need a long-term perspective. All the different areas must work together. Attitudes need to be changed; communication channels opened project teams organized and training in team work implemented.

10. Eliminate Exhortations for the Work Forces

Exhortations that ask for increased productivity without providing specific improvement methods can handicap an organization. They do nothing but express managements desires. They do not produce a better product or service, because the workers are limited by the system.

10. *(a)* **Eliminate Numerical Quotas for the Work Force**

Instead of quotas, management must learn and Institute methods for improvement. Quotas and work standards focus on quantity rather than quality. They encourage poor workman ship in order to meet their Quotas. Quotas should be replaced with statistical methods of process control.

10. (*b*) Eliminate Management by Objective

Instead of management by objective, management must learn the capabilities of the process and how to improve them. Internal goals set by management, without a method are a burlesque.

11. Remove Barriers that Rob People of Pride of Workmanship

Loss of pride in workmanship exists throughout organizations because

(1) Workers do not know how to relate to the organization's mission.
(2) They are being blamed for system problems.
(3) Poor designing leads to the production of ‗‗Junk''.
(4) Inadequate training is provided.
(5) Punitive supervision exists.
(6) Inadequate or ineffective equipment is provided for performing the required work.

12. Teach and Institute Leadership

Improving supervision is management‗s responsibility. They must provide supervision with training in statistical methods and these 14 points so the new philosophy can be implemented. Instead of focusing on a negative. Fault-finding atmosphere, supervisors should create a positive, supportive one where pride in workmanship can restore pride will require a long term commitment by management.

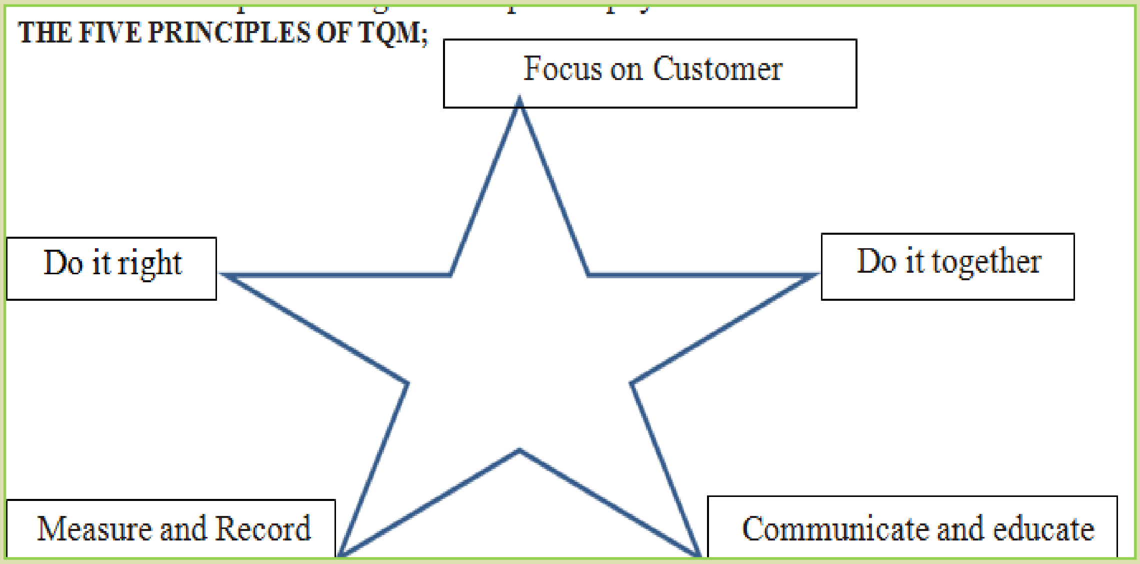
When workers are proud of their work, they will grow to the fullest of their job. By restoring pride, everyone in the organization will be working for the common good. A barrier for people on salary is the annual rating of performance.

13. Encourage Education and Self-improvement for Everyone

What an organization needs is people who are improving with education. A long-term commitment to continuously train and educate people must be made by management Deming‗s 14 points and the organization‗s mission should be the foundation of the education program.

14. Take Action to Accomplish the Transformation

Management has to accept the primary responsibility for the never -ending improvement of the process, it has to create a corporate structure to implement the philosophy. A cultural change is required from the previous ‗business as usual‘‘attitude. Management must be committed, involved and accessible if the organization is to succeed in implementing the new philosophy.



1. Concentrate on the customer be focused
2. Do it right
    a) Do it right first time
    b) Constantly improve
    c) Quality is an attitude not a inspection process
3. Communication and educate Tell staff what is going on Educate and train.
4. Measure and record work
5. Do it together
    a) Top management must be involved
    b) Empower the staff
    c) Make the business a good place to work
    d) Organize by process not function

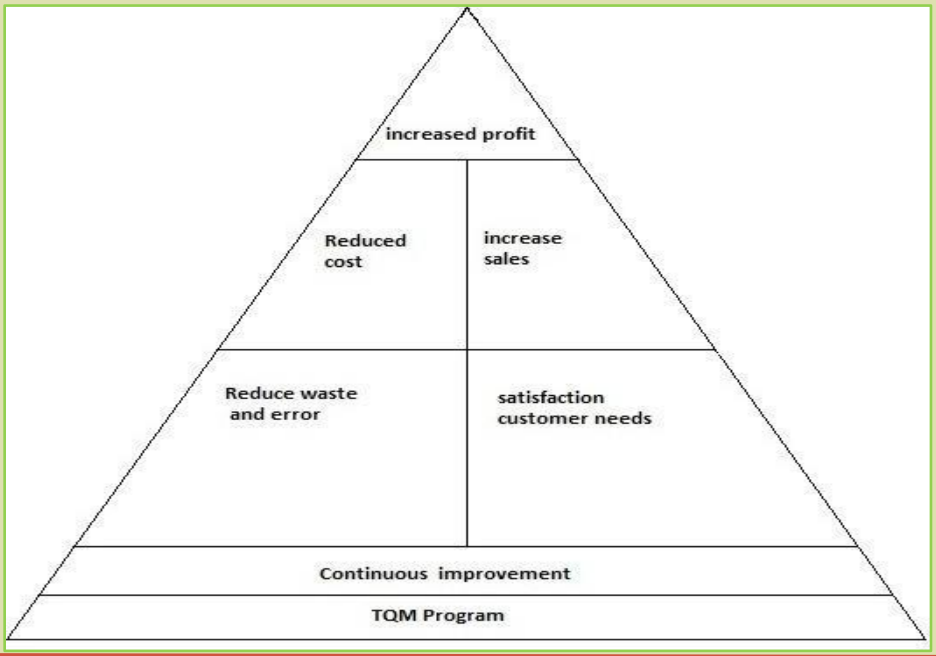
Benefits of TQM

A. Customer
1. Lesser problem with product and service
2. Better customer care
3. Greater satisfaction

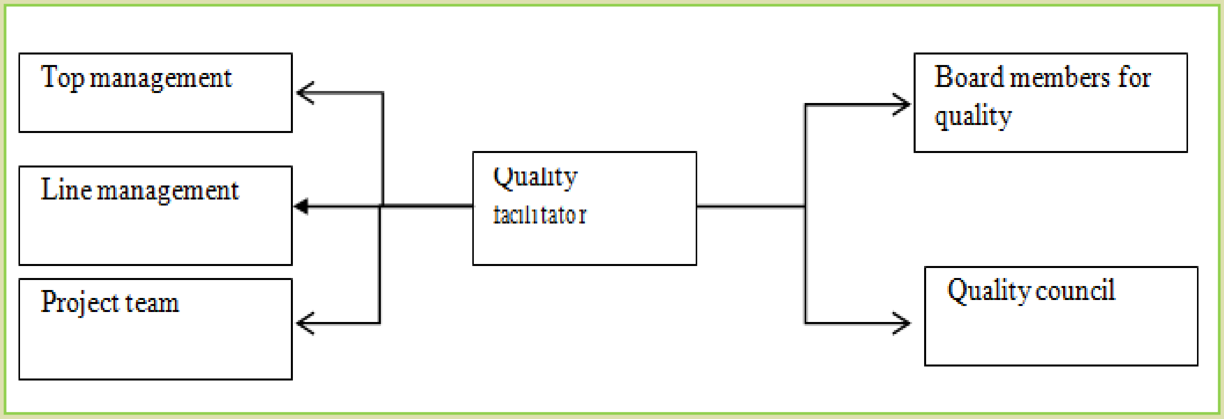
B. To the company
1. Quality improves
2. Motivates staff
3. Increase productivity
4. Reduce cost
5. Reduced defects
6. Resolve problems faster
7. Make company a leader
8. Makes team works among the staff
9. Make company customer focused
10. Reduced resistance to change

C. To the staff
1. Empowerment
2. More training, more skills, more recognition.

TQM ORGANIZATION



TQM Program creates continuous improvement. This leads to reduction in errors and waste, which in turn leads to customer satisfaction. The benefit of this to the company is in the form of reduced costs and increased sales, which basically means increased profits.



Questions

1. What is TQM?
2. What are the advantages of TQM?
3. Explain the principles of TQM.
4. Explain Deming's philosophy on Total Quality Management.
5. Explain TQM organization.

UNIT 8 – LEADERSHIP

INTRODUCTION

Leadership requires a keen understanding of human nature — the basic needs, wants and abilities of people. To be effective: a leader needs to know and understand the following:

1. People, paradoxically, need security and Independence at the same time.
2. People are sensitive to external rewards and punishments and yet are also strongly self-motivated.
3. People like to hear a kind word of praise.
4. People can process only a few facts at a time.
5. People trust their gut reaction more than statistical data.
6. People distrust a leader‗s rhetoric if the words are in constituent with the leader‗s actions.

CHARACTERISTICS OF QUALITY LEADERS

There are 12 behaviors or characteristics the successful leaders demonstrate.

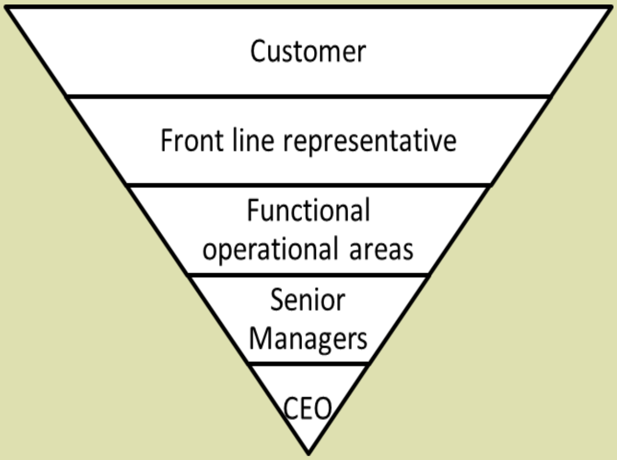
1. They give priority attention to External and Internal customers and their needs.
2. They empower, rather than control, sub-ordinates; leaders have trust and confidence in the performance of their subordinates. They provide the resources, training and work environment to help subordinates do their jobs.
3. They emphasize improvement rather than maintenance. There is always room for improvement, even if the improvement is small.
4. They emphasize prevention. ‗‗An ounce of prevention is worth a pound of cure is certainly true. It is also true that perfection can be the enemy of creativity. There must be a balance between preventing problems and developing better but not perfect, processes

5. They encourage collaboration rather than competition when functions areas department or work groups are in competition, they may find subtle ways of working against each other or withholding information.
6. They train and coach rather than direct and supervise. As coach they help their subordinates learn to do a better job.
7. They learn from problems. When a problem exists. What caused it? And how can we prevent it in the future are the questions asked by leaders.
8. They continually try to improve communications; they make it evident that TQM is not just a slogan. Communication is two way-ideas will be generated by people when leaders encourage them and act upon them. Communication is the glue that holds a TQM organization together.
9. They continually demonstrate their commitment to quality. They let the quality statement be their decision making guide.
10. They choose suppliers on the basis of quality not price. Suppliers are encouraged to participate on project teams and become involved. Leaders know that quality begins with quality materials and true measures are life cycle cost.
11. They choose suppliers on the basis of quality not price. Suppliers are encouraged to participate on project teams and become involved. Leaders know that quality begins with quality materials and true measures are life cycle cost.
12. They encourage and recognize team effort. They encourage, provide recognition and reward individuals and teams. This action is one of the leader‘s most powerful tools.

ROLE OF TQM LEADERSHIPS

Customer’s Satisfaction

Introduction: The most important asset of any organization is its customers. An organizations success depends on how many customers, it has, how much they buy, and how often they buy satisfied customers will increase buy more and buy more frequently. The following Figure shows organizational diagram and how important customer to an organization.



Increasingly, manufacturing and service

organization are using customer satisfaction as a measure of quality. The importance of customer satisfaction is not only due to national competition but to worldwide competition.

Understanding the customer‘s needs and expectation is essential to winning new business and keeping existing business. An organization must give its customer a quality product or service that meets their needs at a reasonable price. This includes on-time delivery and outstanding service.

The most successful TQM programs begin by defining quality from the customer perspective quality means meeting or exceeding the customer‘s expectations it is most important consideration, because satisfied customers will lead to increased profits.

CONTINUATION PROCESS IMPROVEMENT

Introduction: We must strive to achieve perfection by continuously improving the business and production process.

We continuously improve by

- Viewing all work as a process, it is associated with production or business activities,
- Making all our processes effective, efficient and adaptable, Maintaining constructive dissatisfaction with the present level of performance,
- Eliminating waste and rework wherever it occurs.
- Eliminating non conformities in all phases of every one‘s work, even if the increment of improvement is small.
- Using bench marking to improve competitive advantage
- Innovating to achieve break thoroughly
- Holding gains so there is no regression
- In cooperating lessons learned into future activities.
- Using technical tools such as statistical process control (SPC), experimented design, bench marking, quality function deployment (QFD). etc.

Continuous process improvement is designed to utilize the resource of the organization to achieve a quality-driven culture.

Juran's Trilogy

Process improvement involves planning. One of the best approaches is the one developed by Dr. Joseph Juran. It has three components: planning, control and improvement.

Planning

The planning component begins with external customers. Marketing determines the external customers and all organizational personnel determine the internal customers.

Once the customers are determined, their need is discovered. This activity requires the customers to state needs in their own words and from their own viewpoint. Ex : a stated need may be an automobile, whereas the real need is transportation or a status symbol. In addition internal customers may not wish to voice real needs out of fear of the consequence one might discover their needs by (1) being a user of the product or service (2) communicating with customers through product or service satisfaction and dissatisfaction information (3) simulation is the laboratory.

The next step in the planning process is to develop product and or services features that respond to customer needs, meet the needs of the organizations and its suppliers, are competitive and optimize the costs of all stake holders.

The fourth step is to develop the process able to produce and or service features. This step is also performed by a multifunctional team with a liaison to the design team of particular concern will be the __scaling up‘‘from the laboratory or prototype environment to the real process environment.

Transferring plans to operations is the final step of the planning process. When training is necessary, it should be performed by members of the process planning team. Process validation is necessary to ensure, with a high degree of assurance that a process will consistency produce a product or service meeting requirements.

Control

Control is used by operating forces to help meet the product, process and service requirement. It uses the feedback loop and consists of the following steps.

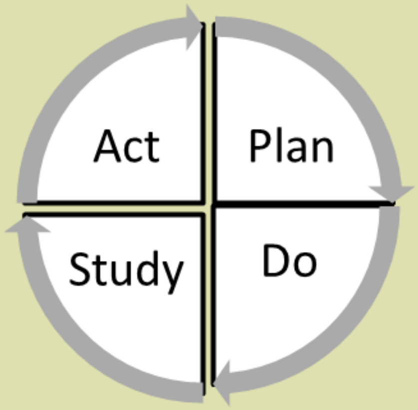
1. Evaluate actual operating performance

2. Compare actual performance to goals
3. Act on the difference

Statistical process control is the primary technique for achieving control. The basic statistical process control (SPC) tools are Pareto diagrams, Flow-diagrams, Cause and Effect diagrams, Check sheet, Histogram, Control charts and Scatter diagrams.

The PDSA Cycle

The basic Plan-Do-Study-Act (PDSA) cycle was first developed by Shewhart and then modified by Deming. It is an effective improvement technique it is illustrated in Figure.



The four steps in the cycle are exactly as stated. First, plan carefully what is to be done. Next, carryout the plan (do it). Third, study the results. Did the plan work as intended or were the results different finally, act on the results by identifying what worked as planned and what didn‘t. Using the knowledge learned, develop an improved plan and repeat the cycle. The PDSA cycle is a simple adaptation of the more elaborate problem solving method.

SIX SIGMA (6σ) QUALITY

An Overview:

6 Sigma‘is used to designate the distribution or spread about the mean (average) of any process. Sigma (σ) is another word for standard deviation. For a business or manufacturing process, the sigma value is a metric that indicates how well that process is performing. The higher the sigma value, (2σ, 3σ, 4σ etc.) the better the process Sigma measures the capability of the process to perform defect-free-work. A defect is anything that results in customer dissatisfaction. With 6σ , the common measurement index is

_defects-per-unit‘, where unit can be virtually anything–a component, a piece of a material, a line of code, an administrative form, a time frame, a distance, etc. The sigma value indicates how often defects are likely to occur. The higher the sigma value, the less likely a process will produce defects. As sigma value increases, costs go down, cycle time goes down, and customer satisfaction goes up. A 6σσ process simply means that between the target specification and the tolerance limit six standard deviations can be fitted-in,

(Fig. below explains clearly the difference between the 3σ and the 6σ process). Further, a 6σ process capability means 3.4 ppm defects or 99.99966% good.

Our process is the reality. When we draw the histogram of our process output we come to know how we are; we can, then, calculate the sigma (σ) value of our process. When we place the tolerance limits, as decided by the competition, on our curve (normally distributed) we come to know where we are. We may be at 2σ or 3σ, etc. We now start our journey towards 6σ. In other words we have to shrink the variability of our process to such an extent, that the value of sigma of the process reduces to a new low, which can be fitted ± 6 times within the same tolerance limits. This is Quality Improvement. Such an improved process hardly produces any defect.

The Practical Meaning of six sigma

99% Good (3.8 σ)	99% Good (6 σ)
• 20,000 lost articles of mail/hour • Unsafe drinking water 15min./day • 5,000 incorrect surgical procedures/week • 2 short or long landings at airports/day • 2,00,000 wrong drug prescriptions/year • No electricity for almost 7 hrs/month	• Seven articles lost/hour • Unsafe drinking water 1 min./7months • 1.7 Incorrect surgical procedures/week • One short or long landings/5 years • 68 Wrong prescription/year • One hour without electricity/3-4 years

Six σ σ As a Goal (Distribution shifted ± 1.5σσ)

Sigma level	Defects in PPM	Yield in %
2 σ	308,538	69,1462
3 σ	66,807	93,3193
4 σ	6,210	99,3790
5 σ	233	99,9767
6 σ	34	99,99966

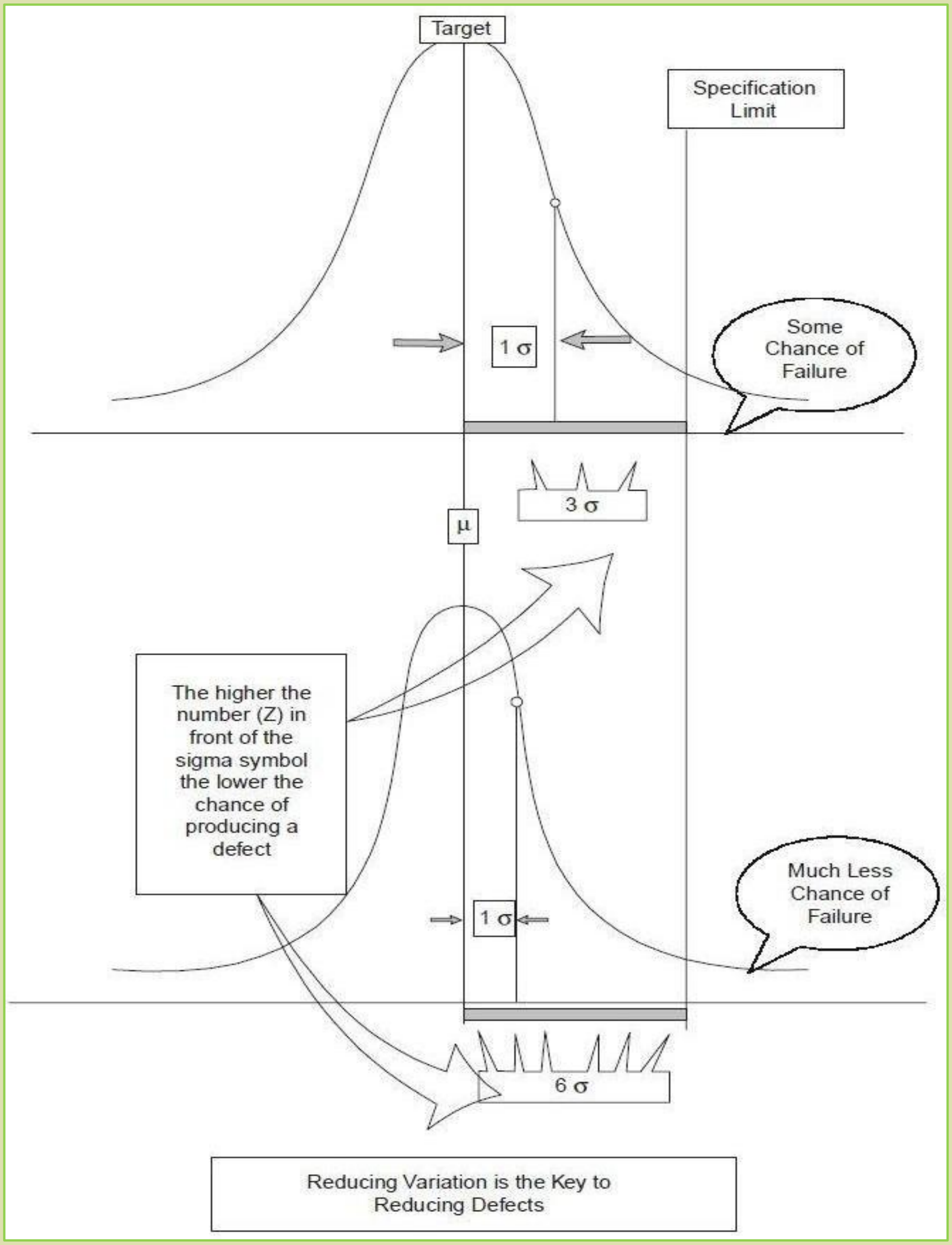
6σ According to Dr. Mikel J. Harry, CEO of Six Sigma Academy, Phoenix, USA

- First, it is a statistical measurement. It tells us how good our products, services and processes really are. It allows us to draw comparisons with other similar or dissimilar products, services and processes. We can see where we need to go and what we must do to get there. In other words, 6σ helps us establish our course and gauge our pace in the race for total customer satisfaction.

- When we say a process is 6σ, we are saying it is best in class. Such a level of capability will only yield 3.4 instances of nonconformance out of every million opportunities for nonconformance. On the other hand, when we say that some other process is 4σ , we are saying it is average. This translates to 6,210 non-conformities per million opportunities for nonconformance. In this sense, the sigma scale or measure provides us with a __goodness micrometer‘‘for gauging the adequacy of our products, services and processes.

- Second, it is a business strategy. It can greatly help us gain a competitive edge. The reason for this is very simple — as you improve the sigma rating of a process, the product quality improves and costs go down. Naturally, the customer becomes more satisfied as a result

- Third, it is a philosophy. It is an outlook, a way that we perceive and work within the business world around us. Essentially, the philosophy is one of working smarter, not harder. This translates to making fewer and fewer mistakes in everything we do — from the way we manufacture products to the way we fill out a purchase order. As we discover and neutralize harmful sources of variation, our sigma rating goes up. Again, this means that our process capability improves and the defects (mistakes) go away.



6σ Breakthrough Methodology of Quality Improvement

The methodology is not very unique. It is a slight variant of the methodologies given by many quality gurus. There is nothing breakthrough in the methodology as such. But the solutions/results, we obtain by following these systematic methodologies are really break-through. The improvement is not just in percentages but in manifold (say 100 times, 1000 times etc.)

The methodology consists of five steps namely

Define (D),
Measure (M),
Analyze (A),
Improve (I) and
Control (C).

Brief explanations for the same are as follows.

Define

The problem which requires breakthrough solution has to be defined clearly in measurable terms. The problem selected should be vital to the customer and should have relevance to the company‘s business. In other words it should ensure great customer satisfaction as well as rupee savings to the company. If the company has developed its Business Strategies, the problem should fall under any one of them. Generally any customer expects defect free products/services and timely deliveries. Majority of the problems will fall under these two categories. Defining the problem in manufacturing area is easier when compared to service areas.

Measure

The second most important step is measurement. We have to measure in terms of numbers to know where we are, and to decide where we go. To quote Dr. Mikel J. Harry — ‗If you can‘t express your process in the form of numbers you don‘t really know much about it. And if you don‘t know much about it, you can‘t control it. And, if you can‘t control it, you are at the mercy of chance. And, if you are at the mercy of chance, why bother with it? Hence we must learn the language of numbers‘‘.

Data is as good as the system that measures it. Hence, before collecting the data a measurement system analysis has to be done and if it is not to the satisfactory level, corrective action has to be taken before measuring the data.

Data is of two kinds: Discrete & Continuous.

Continuous data is more amenable for Statistical analysis than and hence as far as possible attempts should be made to convert the discrete data into continuous data. After collecting the data (discrete) on defects and counting the opportunities to make the defects, we can calculate the defects per opportunity (dpo), which is nothing but the probability of making the defects. From the statistical tables we can find out the corresponding _Standard normal deviate', *i.e.*, the Z value or the sigma value.

If it is a continuous data we can find out the sigma value by calculating the mean and the standard deviation of the process and knowing the specification limits. With this we can statistically define the problem.

After defining the problem a cause and effect diagram has to be constructed through brainstorming and segregate the causes into experimental and non-experimental causes. Solutions have to be found and implemented through Standard Operating Procedures (SOP) for the non-experimental causes at this stage itself, which brings down the variability of the process to a great extent. The experimental factors can be carried forward to the next phase-analysis.

Analyze

Statistical analysis has to be carried out at this stage to identify the vital experimental causes. Tests have to be conducted to find out whether the causes (factors) really make statistically significant difference in the effects (responses) when the levels of these factors are changed. The tools used are T -test, F-test, ANOVA, Chi-Square, correlation and Regression. A graphical analysis called multi-vari analysis is also done to segregate the variation of the response into with-in piece, between pieces and over time variations. After identifying the vital few experimental factors they have to be carried forward to the next phase-Improve.

Improve

In this phase we will be optimizing the response. In other words we will be hitting the target value by experimenting with the level settings of the vital few factors.

This is called Design of Experiment. There are various stages like Screening design/fractional factorial design, full factorial, full factorial with replication, Central composite design, Method of Steepest ascent, Evolutionary process (EVOP), Taguchi‘s method etc. Finally we will be tolerancing the factors at the required levels.

In order to conduct the DOE, thorough planning is necessary, because the DOE is time consuming and sometimes costly.

Control

The last phase is to hold the gains that have been obtained from the improve phase. Unless we have good control we are likely to go back to the original state. ‗Statistical Process Control‘(SPC) has to be employed to control the gains. There are various kinds of tools.

Conclusion

This article has only tried to explain the meaning of ‗six sigma‘, without going into the depth of statistics. In effect the ‗six sigma‘Quality improvement methodology is a strategic bridge between the Quality Philosophy and the statistical tools available, which heavily depends on the Management drive and rigorous practice for its sustenance. To be fairly conversant with this methodology, one has to undergo a minimum of 10 days classroom training and then execute at least one real improvement project.

Once the methodology is familiar. I am sure, one will not stop improving. ‗Six sigma‘ is not just a fad ; it has yielded rich dividends in companies like MOTOROLA, GENERAL ELECTRIC, ALLIED SIGNAL, etc. It is now catching up in India and I can mention at least two major companies, *viz*., M/S BHARAT ELECTRONICS LTD and M/S WIPRO, which are rigorously practicing.

Questions

1. What are the characteristics of quality leader?
2. What is the Role of quality leader?
3. Explain Continuous improvement.
4. Explain PDSA Cycle.
5. Explain Six Sigma with example.

UNIT 9 – STATISTICAL PROCESS CONTROL

Introduction:

One important tool in statistical quality control is the Shewhart control chart, the simplicity of the control chart, many engineers, production personnel and inspectors. Used for the entirely new point of view. Measured quality of __Manufactured Product is always subject to a certain amount of variation as a result of chance. Some stable __system of chance causes is inherent in any particular scheme of production and inspection. Variation within this stable pattern is inevitable. The reason for variation outside this stable pattern may be discovered and corrected.

The power of the Shewhart technique lies in its ability to separate out these assign-able causes of quality variation. Moreover, by identifying certain of the quality variation as inevitable chance variations, the control chart tells when to leave a process alone and thus prevents unnecessarily frequent adjustments that tend to increases the variability of the process rather than to decrease it.

The control chart technique permits better decisions on engineering tolerances and better comparisons between alternative designs and between alternative production methods.

One of the best technical tools for improving product and service quality is statistical process control (SPC). There are seven basic techniques. The word statistical is some-what of a misnomer the first four technique are not really statistical.

7 QC TOOLS

What is QC problems — Solving

In our daily work, there are times when these thoughts come to our mind __every-time I do this, job, there are many failures or __This is tiring. Isn't there is a better way of doing it? ''In such situations, one may choose to improvise or solve it by oneself. But there are times when we cannot.

In such a situation, the people in the same workplace, facing a similar problem can gather, and the combined wisdom can result in good solutions. Instead of thinking alone, get the co-operation of others to solve it, and there will be improvements in work and increase in work efficiency. This will further result in workplace improvements and the development of the company. This also signals the employees, contribution to the company.

There are two ways of approaching problem-solving. These are the emergency measures and preventive measures. For example, when company .A lodges a claim, we will immediately apologies emergency measures. In this instance the measures taken are of great importance. However, it is also important that we make certain that preventive measures are taken against the cause of the claim.

The problems (theme) at the workplace are, for example, defective goods, occurrence of accidents, transitional production plans and sales plans, deformities and abnormalities.

At times, the main cause is hidden and we may still find that efficiency is low and there are a lot of dissatisfied customers.

Do not be content with this condition. Aim for even higher goals and keep taking up preventive measures. That is what QC Problem-Solving is all about.

7 QC Tools

The Samurai warrior had seven tools, such as a sword, helmet, bow guard and arrow and so on; he would never venture anywhere without these tools, which he needed for protection and success. In a similar vein, the seven quality control tool are essential for to-day's workers, engineers, professionals, and managers.

1. Pareto Diagram.

The Pareto principle was named after the Italian economist who had developed certain mathematical relationships of vital few and trivial many as applied to distribution of wealth. In studying the problems, it can be generally observed that 80% of the problems result from only 20% of the potential causes.

The primary purpose and use of Pareto diagrams is to focus improvement efforts on the most important causes by identifying the vital few and trivial many causes

The Pareto Chart indicates the following:

1. What are the problems,
2. Which problem needs to be tackled on priority?
3. What percentage (%) of the total does each problem present.

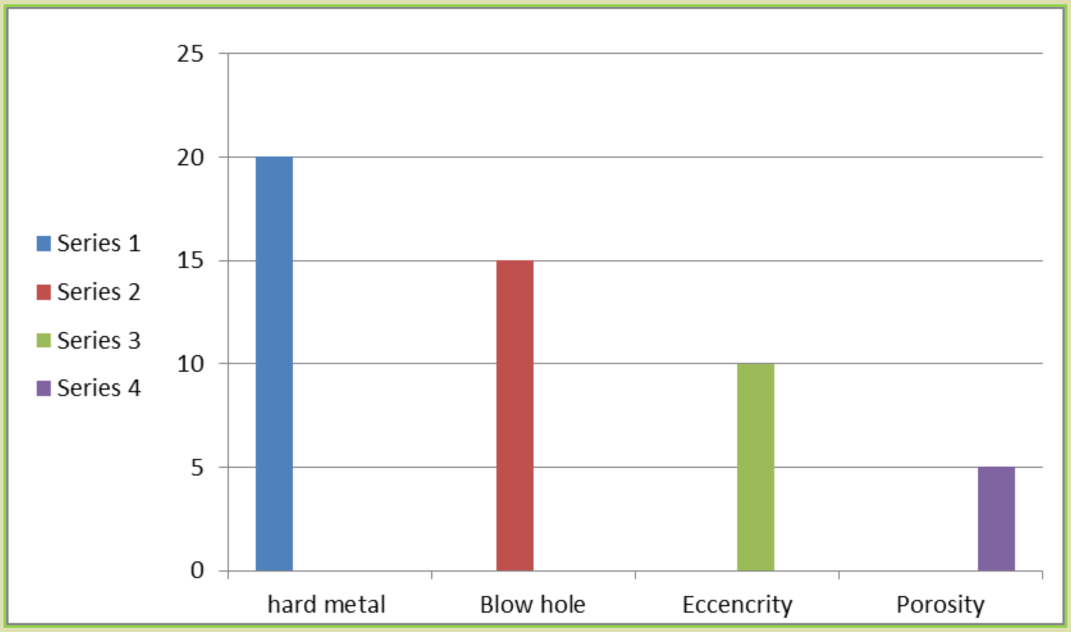
Areas of Application

Sales — Customer complaints analysis, warranty costs, Market Share
Production — Analysis of Non-conformance, machine and men Utilization
Maintenance — Machine down time, break down, spares requirement.
Safety — Injury types and causes
Finance — Costs, etc.

How to construct Pareto Diagram

1. Select the problem area (say customer complaints).
2. Decide the method and the period for data collection.
3. Arrange the data of the items in the descending order.
4. Draw axis on graph with the scale of unit indicated.

5. Draw the bar graph in the descending order.



2. Histogram

A histogram is a bar graph which shows the frequency distribution of the data of a group about the central value. The histogram is an important diagnostic tool because it gives a __Birds'-eye-view''of the variation in a data set.

A histogram can be used for

1. Comparisons of process distribution before and after the improvement action (production, vendor performance, administration, purchase, inspection, etc.)

2. Comparison of different groups (production, vendor to vendor difference etc.)

3. Relationship with specification limits.

3. Cause and Effect Diagram

A cause and effect diagram (also known as Ishikawa diagram or fishbone diagram) in a pictorial representation of all possible causes which are supposed to influence and __effect‘‘which is under consideration.

For every effect there are likely to be several causes. They can be classified under men, methods, materials, machines, policies, procedures, plant etc. These categories are only suggestions. You may use any category that emerges or helps people think creatively.

Steps in Constructing a Causes and Effect Diagram

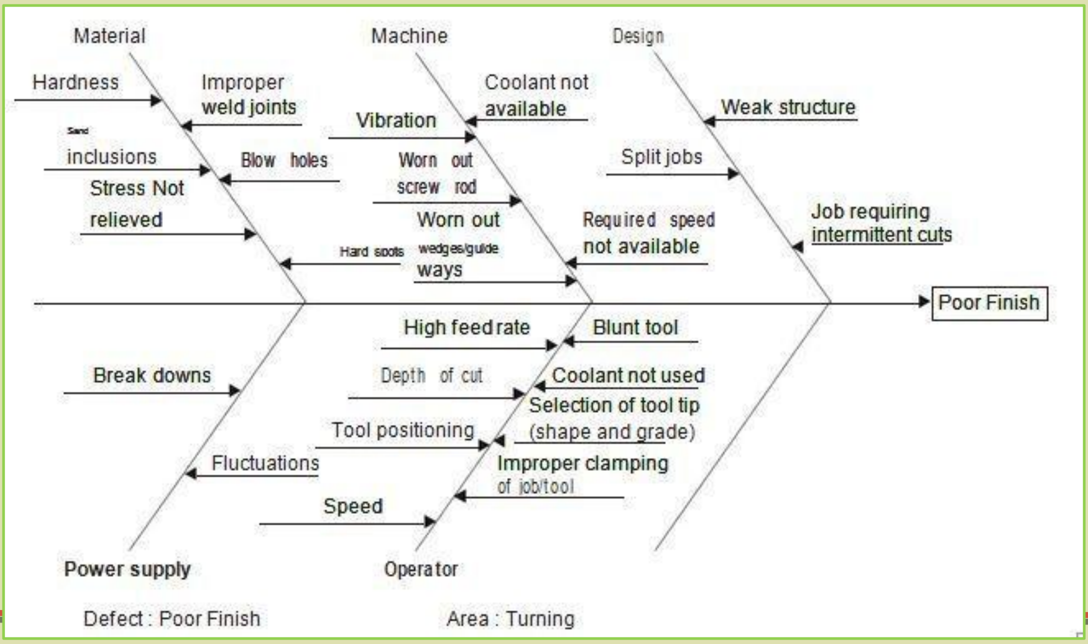
Address to the member the problem or the __Effect‘‘ in question and ask the members what the possible causes could be adopt structured brain storming method (in brain storming encourage ideas, never criticize, allow to develop on other ideas, write all ideas on a flip chart or black board).

Start constructing the diagram. Write the effect or the problem on the right hand side in a rectangular box.

Cluster the causes of the effect under large heading and write against bones.

Interpretation of C and E Diagram

- In order to find most basic cause of the problem
- Look for causes that appear repeatedly.
- Reach a team consensus
- Gather data to determine the relative frequencies of the different causes.



PROCESS CAPABILITY

The first priority is to bring a process into a state of statistical control. That is to say, make the process stable and therefore predictable.

(a) But this is not enough; there is more to be done. Once we have concluded that a process is in statistical control (by the absence of special causes on the control charts) there could still be two possible conditions prevailing, i.e. the process is stable (i.e., in control) and capable. In other words it continually produces parts which are acceptable.

(b) The process is stable and incapable, i.e., it continually and predictably produces parts which are not acceptable.

Obviously, it is the first alternative we want. So there must be some examination to test for the inherits capability of the process.

This is done by comparing the output which the process can be expected to produce under normal and random conditions with that required by the customer.

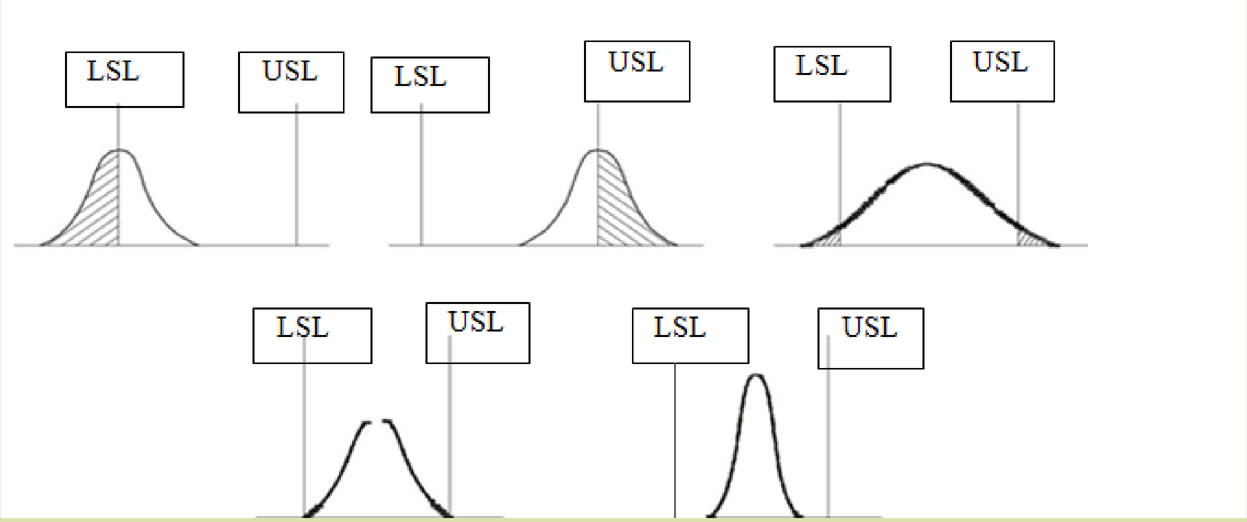
The natural spread of a process is the distribution of parts produced when the process is operating in statistical control and being affected only by random variations. So if we ran a process and measured every individual part produced the distribution would more than often follow the normal bell-shaped curve with a standard deviation of σ

To determine this, we must compare the process spread with the design requirements, i.e., the tolerance. The tolerance is, of course, the difference between the upper specification limit (USL) and the lower specification limit (LSL).

The following diagrams illustrate the output distribution from five different processes.

Processes 1 and 2 are producing components beyond the specification limits (either too low or too high). This is because the process is wrongly set. Adjustment of the setting will bring the distribution within the specification limits.

On the other hand, process 3 is producing unacceptable parts which are both too high and too low. This is because the process spread is too wide. No end of adjustment to the setting will cure this problem. The piece-to-piece variability must be reduced to make the process capable of producing acceptable parts.



Process 4 is just capable of producing acceptable parts. Process 5 is the best. This is the objective : to reduce the spread about a center line which is on target setting. For a variable process where we draw average/range charts the measure of capability can be indicated by capability indices.

There are two indices and we shall deal with each in turn.

Questions

1. What s SQC?
2. What are the seven quality tools for Problem ?Explain any one
3. What is Cause and Effect diagram
4. What is Process Capability?
5. What is histogram?

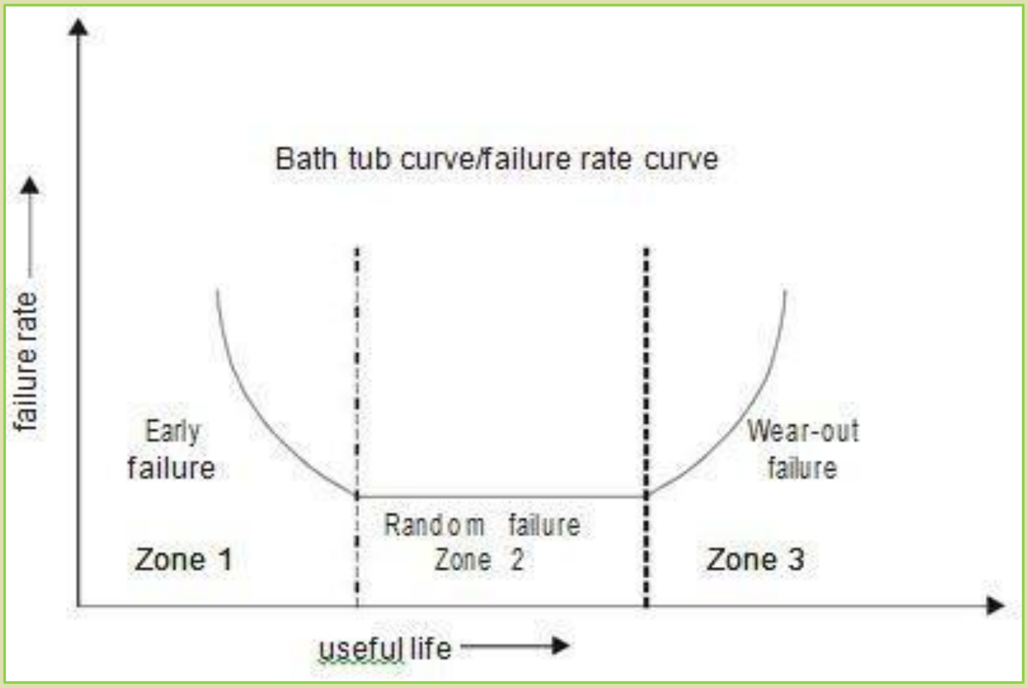
UNIT 10 – RELIABILITY AND LIFE TESTING

DEFINITION:

Reliability is the probability that a device will perform its intended function satisfactory without failure, for the stated period of time, under the specified operating conditions.

In the above definition, there are 4 factors which are essential to the concept of reliability.

(a) It is a probability.
(b) It is associated with time.
(c) Satisfactory performance is required.
(d) Operating environment should be defined



Zone 1 — Early Failure Period

It is characterized by a high initial failure rate, gradually dropping off to a low failure rate. By the end of the failures in this zone are due to one or more of the foll assignable causes:

1. Design deficiency.
2. Manufacturing error.
3. Raw material defects.
4. Wrong maintenance practices.

Zone 2 — Random Failure Period

It is characterized by a more or less constant failure rate. This is the rate at which the normal usage of the product occurs without any expectation of failures.

Failures in this zone are due to chance causes.

Zone 3 — Wear Out Failure Period

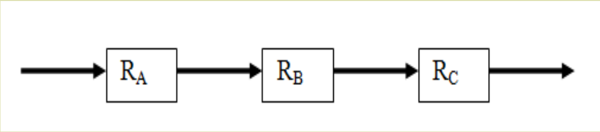
It is characterized by a gradual increase in failure rate. Failures in this zone are due to one or more of the following:

1. Ageing
2. Reduction in physical strength properties
3. Wear and tear.

Systems Reliability

1. System connected in series
2. System connected in parallel

System connected in series follows a multiplication law of probability.

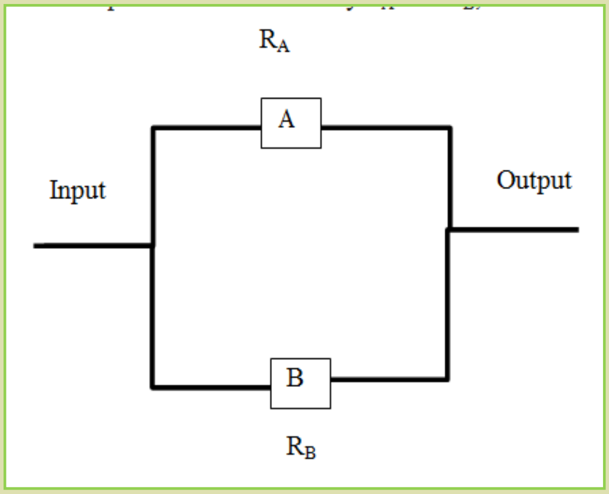


If a system consists of 3 components A, B, C in series, then the reliability of the system,

$$R_S = R_A . R_B . R_C$$

System Connected in Parallel

Here the function of A can be done by B or vice versa. If the system consists of components A and B in parallel with reliability R_A and R_B, then the reliability of the system,



$R_S = [1 – (1 – R_A)(1 – R_B)]$

If *n* components are connected in parallel,

$R_S = [1 – (1 – R_A)(1 – R_B) .... (1 – R_n)]$

If $R_A = R_B = ... R$, then

$R_S = [1 – (1 – R^n)]$

Also $(1 – R_S) = (1 – R^n)$

Prove that the failure rate of the system = the sum of the failure rates of the components of the system.

REDUNDANCY

(Parallel connection increases the reliability when compared to series connective.) One of the methods for improving the reliability of the system is by utilizing the concept of redundancy. To enhance reliability of the system, quite often addition units are built into the system to perform the same function. In such a system, one component failure will not necessarily cause the system failure, since additional components are available to perform the same function

Redundancy is defined as the characteristic of a system by virtue of which marginal component failures are prevented from causing system failures due to the presence of additional components.

In order to increase the reliability of the system, select the component which has the least reliability and then arrange it parallelly.

Definition of Improvement Factor

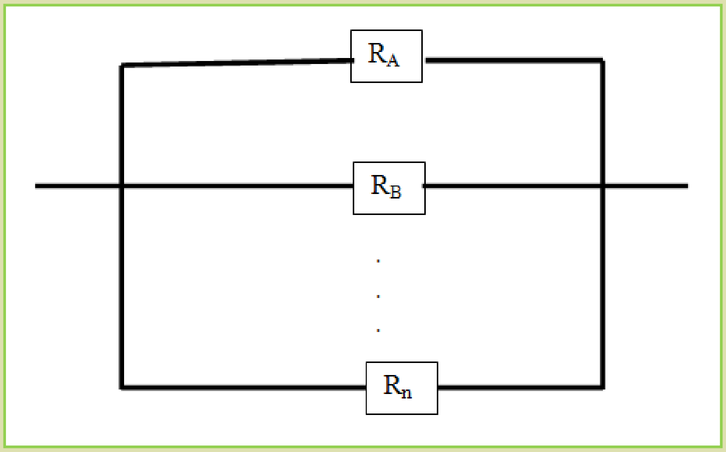
In the case of _*n*‘parallel redundancies, the improvement factor,

$$IF = \frac{1 - R}{1 - Rs}$$

Where (1 – R) = Unreliability of each component.

(1 – RS) = Unreliability of the system.

If _*n*‘components are connected in parallel with the same reliability as shown in figure below:



RS = 1 – [(1 – RA)(1 – RB) ....(1 – R*n*)]
Since RA = RB = ...Rn

$\therefore$ 1 – RS =

$$IF = \frac{1-R}{1-Rs}$$

$$IF = (1-R)/(1-R)^n$$

$$\therefore IF = (1-R)^{1-n}$$

Let (1 – R) = Q,

Then $IF = Q/Q^n$

Questions

1. What is Life Testing? Why it is necessary?
2. What is reliability and life testing?
3. Explain Failure rate curve.
4. Explain System reliability.
5. What is Redundancy?

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