DEPARTMENT OF MECHANICAL ENGINEERING

7TH SEMESTER

COURSE CODE – BME 420

LECTURE NOTES ON

SUB : METROLOGY, QUALITY CONTROL AND RELIABILITY

SYLLABUS

Module- I

Introduction:

1. Need of inspection, sources of errors, basic types of errors precision and accuracy. Method of estimating accuracy and precision , standard and their evolutions. (4)
2. simple measurement tools: Rules, calipers, height gauges, micrometers, depth gauge dial indicator, slip gauges, sine bar.(4)

Module-II

3. Limit, fits and tolerance and gauge design: Basic concepts of limit fits and tolerance interchangeability and selective assembly, ISO system of tolerance, Taylor's principle of gauge design, Gauge design- basic design rules for plug and ring gauges. (6)
4. Interferometers: Types of light sources and interferometers, Types of scale and grading, optical flats.(4)

Module-III

5. Screw thread measurement : Standard thread profiles, effective diameter, measurement of effective diameter by 2 wires and 3 wires methods. Best wire size (5)
6. Surface roughness: Source of surface irregularities in manufacturing. Roughness and waviness RMC and CLA values measurement of surface roughness using Taylor Hobson's Talysurf. (5)

Module- IV

7. Statistical quality control: Frequency distribution, process capability variables and attributes control chart (X & R chart) for variables, control chart for attributes (p,np and C chart) OC curve single and double sampling plan.(7)
8. Reliability: Definition, relationship of reliability with maintainability and availability, failure data analysis- bath tub curve, system reliability, reliability improvement.(5)

Reference Books:

1. Engg. Metrology by R.K. Jain, Khanna pub.
2. A text book of metrology by M.Mahajan Dhanpat rai and co pvt Ltd.
3. Statistical quality control by M.Mahajan Dhanpat rai and co pvt Ltd.
4. Reliability Engg. By L.S.S.Srinath East west press

BME 420: METROLOGY QUALITY CONTROL & RELIABILITY

MODULE-I -CHAPTER-1 -INTRODUCTION

Definition of Metrology?

Ans: Science of measurement/pure science of measurement

Engineering metrology (Defn):- Measurement of dimension: length thickness , diameter, taper angle flatness straightness profiles and others.

Ex: slideway for machine tool(lathe) it must have specific dimension angle and flatness for its desired function.

Inspection (Defn) checking the dimension of other defects of a part which has already being produced.

New of inspection

1. To ensure that the part material or a component conforms to the established standard. For dimensional control as per specification.
2. To meet the interchangeability of manufacture.
3. To control the performance of man/mk/process.
4. It helps in the process of quality control.
5. It protects the customers in accepting family products.
6. It helps in mass production of assembled part.
7. It helps to assemble various parts produce at different station/place.
8. It provides the means of finding out shortcoming in manufacture.

Sources of errors

1. Calibration error

Each measures instrument should be calibrated with a standard one at certain time interval (may be once in a year once in every 6 months)

If the above procedure is not followed the instrument may give erroneous result, it is called calibration errors.

2. Environmental error

These errors are due to surrounding in pressure temperature and humidity. Internationally agree standard value of temperature pressure are :

(i) Temperature= 20 c

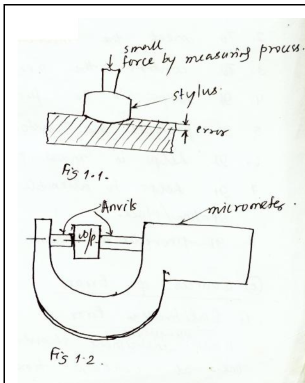
(ii) Pressure = 760 mm of Hg + 10 mm of Hg vapour pressure.

If the ambient condition various from the above standard valves the measured value will be erromeous.

3. Contact pressure/ stylus pressure

Errors are also introduced due to pressure exerted at stylus. It is more prominent in case of soft work piece.

Ideally the stylus should touch the top surface of w/p. due to stylus pressure both deformation & deflection of w/p take place. This type of errors are also induced when the force applied on the anvils of micrometer varies.



4. Error due to supports

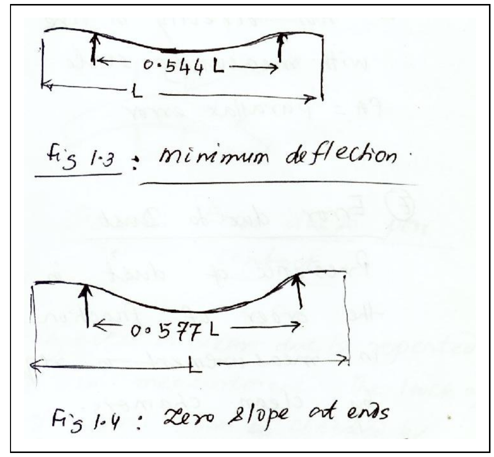


Fig 1.3 : minimum deflection

Fig 1.4 : Zero slope at ends

The elastic deformation/ deflection of a long measuring bar due to position of support cause error in measurement. So G.B Airy found out the position of supports to give minimum error.

Two support conditions are:

(i) for minimum deflection(fig 1.3)

(ii) for zero slope at ends (fig 1.4)

5. Error due to alignment

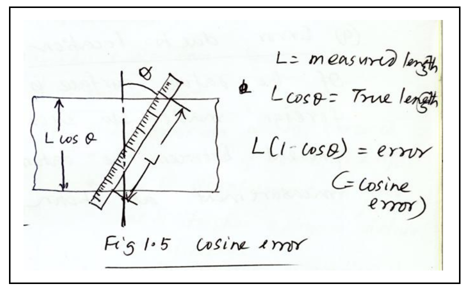
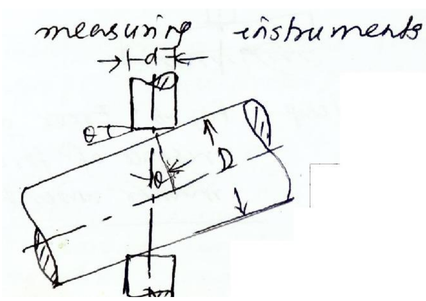


Fig 1.5 cosine error

Abbe's alignment principle should be followed to avoid error due to alignment. According to this principle the axis of measurement should coincide with measuring instruments.



If D= True dia

L= Apparent length

α = micrometer arivil dia

Then D= L cos θ - α sinθ

Error= L-D= L $L - L\cos\theta - dsign\theta$

Fig 1.6 sin & cosine error both

6.Parallax error

occur when line of vision is not directly in line with measuring scale PA= parallax error

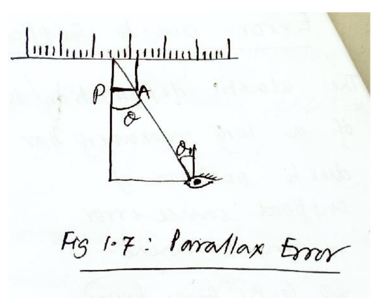


Fig 1.7 : Parallax Error

7.Error due to dust

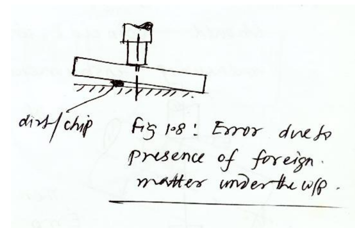
Presence of dust in the atmosphere change reading in the order of fraction of micron. When high accuracy in measurement is required dust should be cleaned by clean chamois.

8.Error due to vibration

The instrument anvil will not give consistent and repetitive reading if it is subjected to vibration. So the measurement should be taken away from the source of vibration.

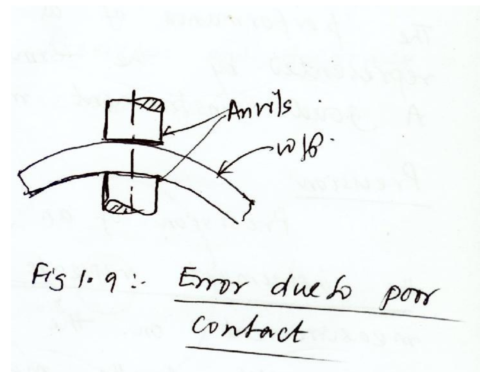
9. Error due to location

if the datum surface is not perfectly flat or if any foreign matter such as dirt chip etc are present between the datum and w/p error occurs in measurement as shown in fig 1.8.



10. Error due to poor contact

The measured dimension will be greater than the actual dimension due to poor contact as shown in fig 1.9.



ii. Error due to wear in gauges

The anvil of micrometer is subjected to wear due to repeated use and lead to error in measurement. The lack of parallelism due to wear of anvil can be checked by optical flat.

c. Basic types of error

Basically errors are of 2 types

i) Controllable (or systematic) error

ii) Uncontrollable (or Random) error

COMPARISON BETWEEN SYSTEMATIC & RANDOM ERROR

Systematic error	Random error
i. This error includes calibration error contact pressure error variation in atmospheric conditions parallax misalignment zero error etc.	i. This error is due to error in the position of standard & w/p due to displacement of lever joint due to friction & play in instrument linkage due to improper estimation in judging fractional part of a scale division etc.
ii.These error result from improper conditions/procedure	ii. These errors are interest in measuring system
iii. These errors are repetitive and constant in nature.	iii. These errors are no consistent & non repetitive
Iv Except personal error all other errors can be reduced/eliminated /controlled	iv. These errors can't be eliminated

3. PRECISION AND ACCURACY

The performance of a measuring instrument is represented by the terms precision and accuracy. A good instrument must be precise and accurate.

PRECISION

Precision of an instrument is the extent to which the instrument repeats its result while making repeat measurement on the same unit of product. It is the repeatability of the measuring process. It refers to the repeat measurement for the same unit of product under identical condition. It indicates to what extent the identically performed measurement agree with each other. If the instrument is not precise it will give widely varying results for the same dimension when measured again and again.

The set of observations will scatter about the mean. The scatter of these measurement is designated as (= the standard deviation) it is used as an index of precision. The less the scattering the more precise is the measurement. Thus lower the value of the more precise is the measurement.

ACCURACY

Accuracy of an instrument is the extent to which the average of a long series of repeat measurement made on the same unit of product differs from the true value of the product. The difference between the true value and the measured value is known as error of measurement.

It is practically difficult to measure exactly the true value. Therefore a set of observation is made whose mean value is taken as the true value of the quality measured,

The distinction between precision and accuracy is represented with the help of following figures.

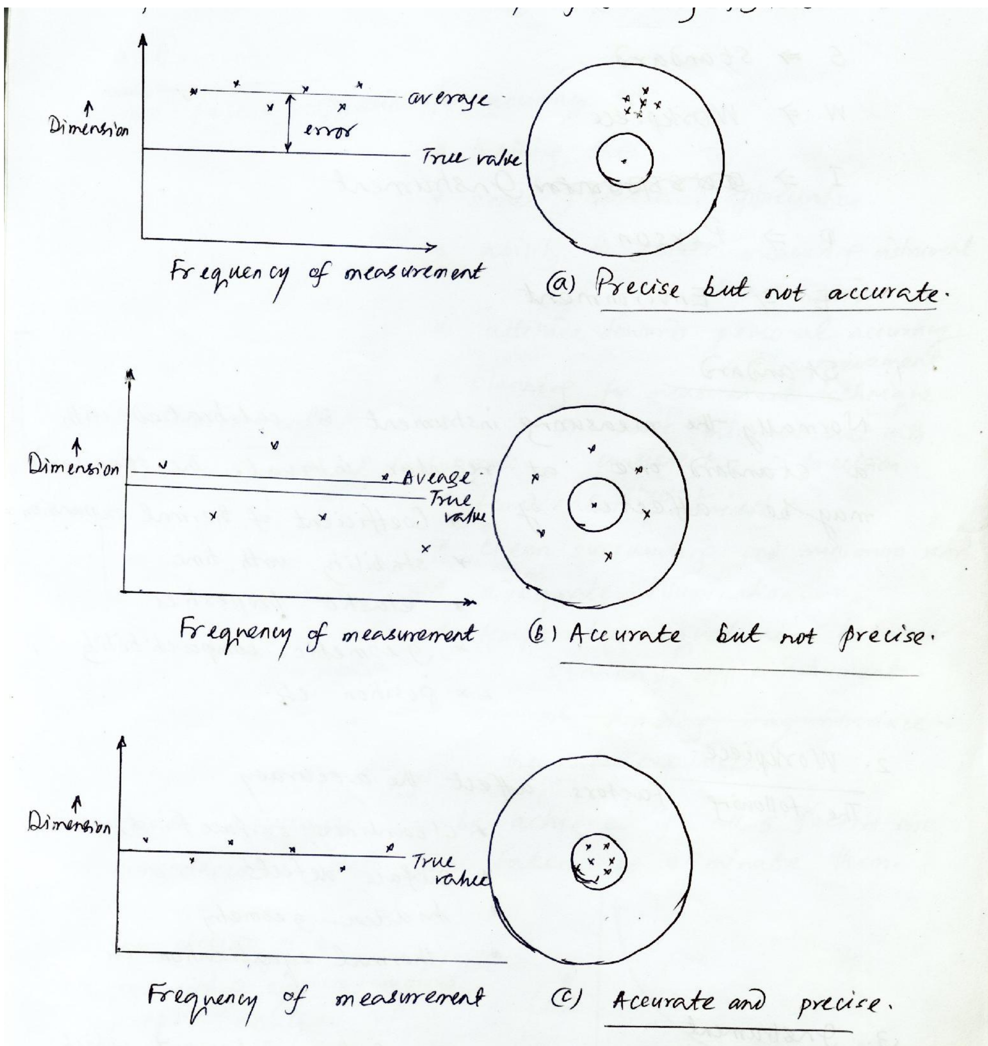


Fig 1.10 : Precision and Accuracy

FACTORS AFFECTING ACCURACY OF A MEASURING SYSTEM

The accuracy of an instrument depends on 5 basic elements (SWIPE)

S- Standard

W- Workpiece

I- Instrument

P= Person

E- Environment

1. Standard

Normally the measuring instrument is calibrated with a standard are at regular interval. The standard may be affected by

- Coefficient of thermal expansion
- Stability with time
- Elastic properties
- Geometric compatibility
- Position etc

2. Work piece:

The following factors affect the accuracy

- Cleanliness surface finish etc.
- Surface defects
- Hidden geometry
- Thermal equalization etc

3. Instrument

The inherent characteristics of the instrument which affect the accuracy are

- Inadequate amplification
- Scale error
- Effect of friction backlash hysteresis etc
- Deformation while handling heavy w/p
- Calibration error
- Repeatability & readability

4. Person

The factors responsible for accuracy are

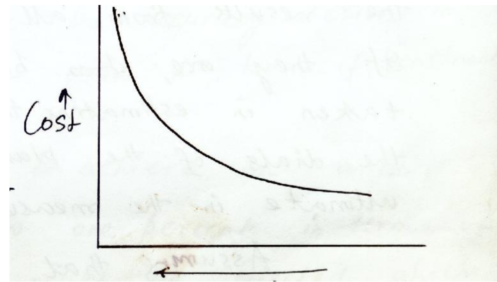
- Training skill
- Sense of precision appreciation
- Ability to select measuring instrument & standard
- Attitude towards personal accuracy achievement
- Planning for measurement technique to have minimum just with consistent in precision.

5. **Environment**

- The environmental factor are:
- Temperature press humidity
- Clean surrounding and minimum vibration
- Adequate illumination
- Temperature equalization between standard w/p & instrument

Higher accuracy can be achieved if all 5 factors are considered & steps are taken to eliminate them

The design of a measuring system involves proper analysis of cost accuracy consideration the general characteristics of cost of accuracy is shown in fig 1.11



C.Method of estimating accuracy & precision

The mean value and the standard deviation of a set of measurement on a single product represent the repeatability or precision of the measuring process. If X, X, X ---- X are the measured values, the arithmetic mean= $\bar{X}\sqrt{X_1+}X_2+-------+X_3$

=

Standard deviation $r=+\frac{\sqrt{E(X_2-\bar{X})^2}}{N}$

The actual value is only one however the measured value may varies from one measurement to another due to various sources of errors.

Method of estimating the accuracy and precision can be explained by the following.

The planimeter experiment is an excellent demonstration for estimating accuracy and precision. Suppose that there is a standard are and unknown area U which are alternately traced. From each such pair of tracings an individual measurement of the unknown area can be obtained. Of course the procedure may be altered such as S-U-U-S-S-U-U-S etc. it is highly unlikely that the results from all such pairs will be agreement if they are it is because not enough care has been taken in estimating the fraction of divisions in reading the dials of the planimeter. It this is the case the ultimate in the measuring process has not being achieved.

Assuming that the results are in disagreement the mean or average may be calculated. Also the standard deviation. This yields information about the repeatability or precision of the measuring process.

Now in doing this the question arises. Have the uncertainties in the measurement procedure been fully explored? It the outlines of the unknown and the standard were always traced in a clockwise direction would the same results have been obtained by tracing them in a counter clock wise direction? Let us try this. It is likely that the results from the two procedures clockwise and counter clock wise will be different but are they significantly different? There are statistical tests which help to decide this question if the axiom of alikeness between the standard and the unknown has been adhered to perhaps it could not be achieved completely. As a check the shapes of the areas can be varied. If the unknown area is roughly rectangular in shape the standard area can be made triangular. Are the measurement now the same or significantly different as determined by practical test. This will show how closely the principle of alikeness must be adhered to in order to achieve the accuracy desired in measuring the unknown area in terms of constructed standards.

If it is desired to achieve an area measurement accurate to one percent in terms of standard. A procedure must be selected which yields a standard deviation for a series of measurement. Some what smaller than this for minor variation in the conditions such as clockwise counter clockwise direction and sizes and shapes of the standard as compared with unknown. If large variations in these conditions do not yield appreciably different standard deviations or mean value from one series of measurement to another considerable confidence may be had in the trust worthiness of the procedure but if they do a careful study of the procedure but if they do a careful study of the procedure is necessary to reveal systematic errors.

It should be noted here that is the index of precision. A measurement process with a standard deviation of is said to be more precise than another with a standard deviation of it is smaller than .

Standard and their evaluation

In order to make informality in the measurement through out the would a standard is followed.

Definition of standard

A standard is something that is setup and established by authority as a rule for measurement of quality and value etc.

Throughout the world generally 2 standards are followed for linear measurement is

(i) British/English (yard)

(ii) Metric (metrs) followed by most of the countries due to convenience

Either yard meter are standardized by the following standards:

(i) line standard

(ii) end standard

(iii) wave length standard

1. Line standard

When a length (meter/yard) is measured as the distance between the centers of 2 engraved lined it is called line standard. It is of 2 types.

(a) standard yard (followed by Britishers)

The empirical standard yard is a bronze bar of 1 square inch cross section and 38 long. A round recess 1 away from each end is cut up to central plane of the bar. A gold plug diameter having 3 lines engraved transversely and 2 lines longitudinally is inserted into these holes such that the lines are in the neutral plane.

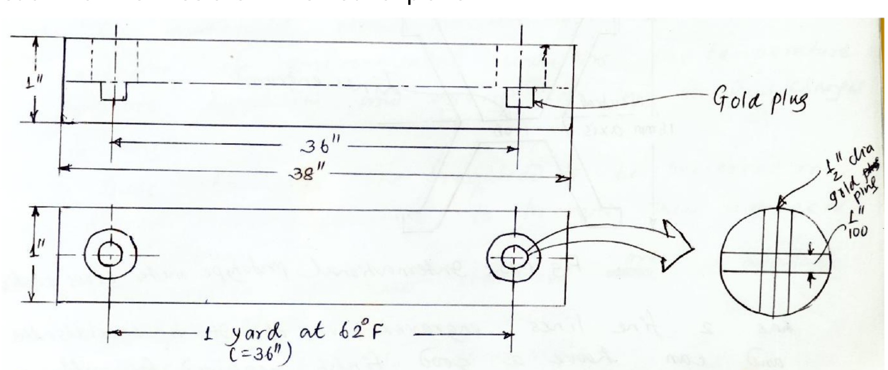
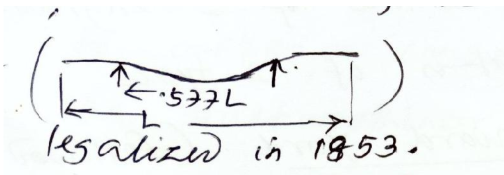


Fig 1.12 : Standard yard

One yard is then defined as the distance between 2 central transverse lines of the gold plug at 62 f. the purpose of keeping the gold plug lines at neutral axis is that due to bending of beam the neutral plane remains unaffected, secondly the plug being in the well is protected from accidental damage. The supports of the yard bar should be at such distance the 2 end faces of the bar are at zero slopes.



This standard was legalized in 1853.

b.Standard meter (followed by most of the countries)

This standard was established originally by international bureau of weights & measures in 1875. The prototype meter is made of platinum iridium alloy(90% platinum & 10% iridium) having a cross section as shown in fig 1.13. the upper surface of the web is highly polished and

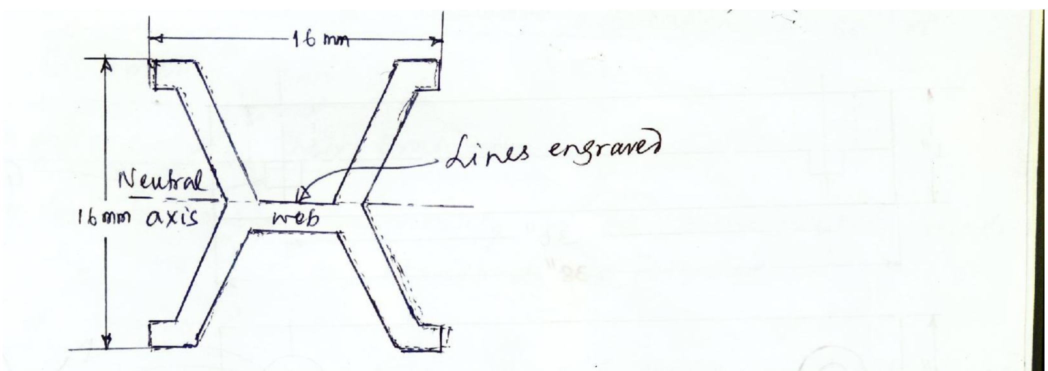


Fig 1.13: International prototype meter cross section.

has 2 fine lines engraved over it. It is in oxidisable and can have a good finish required for ruling good quality lines. The bar is kept at 0 c and under normal atmospheric pressure.

The total length = 102 cm at 0 c & normal atmospheric pressure.

This type of shape has 2 advantages.

i.The graduations being on the neutral plane does not change due to bending effect.

ii.The shape (cross section) gives greater rigidity economy for this costly material.

The bar is supported by 2 rollers of atleast 1cm diameter which are kept 59 mm apart (0.577X1020mm) the distance between the center portions of two lines engaged on the polished surface of this bar of platinum iridium alloy is taken as one meter.

DEFINITION STANDARD METER: According to this standard the length of the meter is defined as the straight line distance at 0 c between the center portion of pure platinum iridium alloy (90% platinum & 10% iridium) of 102 cm total length and having a web cross section as shown in fig 1.13.

Disadvantages of material standard

1.The material standard is influenced by effect of variation of environmental conditions like temperature pressure humidity and ageing etc and it thus changes in length.

2.These standards are required to be preserved or stored under security to prevent their damage or destruction.

3.The replica of these standards are not available somewhere else.

4.These are not easily reproducible.

5.Considerable difficultly is experienced while comparing and verifying the size of gangues.

Wavelength standard

In order to overcome the above draw backs (with the metallic standards meter yard) it became necessary to have a standard of length which will be accurate and invariable.

Jacques cabinet a French philosopher suggested that wave length of monochromatic light can be used as natural and invariable unit of length. in 1907 the international angstrom (A) unit was defined in terms of wave length of red cadmium in dry air at 15 c (6438.4696 A= 1 wave length of red cadmium) seventh general conference of weights and measures approved in 1927 the definition of standard of length (f meter) in terms of wave length of red cadmium as an alternative to international prototype meter.

Orange radiation of krypton isotope was chosen for new definition of length in 1960 by 11^{th} general conference of weights and measures. The committee decided to recommend that krypton 86 was the most suitable element and it should be used in a hot cathode discharge lamp maintained at a temperature of 68 K.

According to this standard a meter was defined as equal to 1650763-73 wavelength of the red orange radiation of kr isotope 86gas.

The accuracy is about 1 part in 10 now the meter and yard can be refined in terms of wave length of kr-86 radiation as

1 meter= 1650763.73 wave-lengths

1 yard= 0.9144m= 0.9144X1650763.73 wave length=1509458.3 wave length

Meter as of today

Although Krypton-86 standard served well technologically increasing demands for more accurate standards. It was thought that a definition based on the speed of light would be technically feasible and practically advantageous 17^{th} general conference for weight and measures agreed to a fundamental change in the definition of meter on 20^{th} Oct 1983.

According a meter is now defined as the length of the path traveled by light in vacuum in 1/29979258 second. This can be realized in practice through the use of an iodine stabilized helium neon laser.

Advantage of wavelength standard

1.Since it is not a material standard it is not influenced by environmental conditions like temp press, humidity & ageing

2.It new not be preserved/ stored under security and no fear of being destroyed.

3.It is not subjected to destruction by wear a scar.

4.It is easily reproducible at any time of requirement.

5.This standard is easily available to all slandering laboratories and industries.

6.There is no problem of transferring this standard to other standard such as meter yard.

7.It can be used for comparative measurement with high accuracy (3 parts in 10)

Classification/subdivision of standards

The accuracy in a vast industrial complex can be maintained only if its standards are traceable to a single source usually the national standard of the country is linked to the international standard.

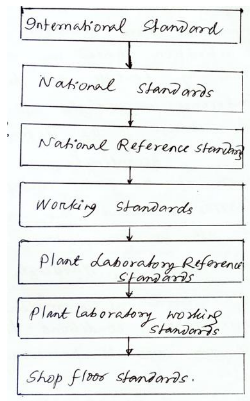


Fig 1.14 explains how the accuracy of measurement 5 transferred from institutional standard to the working shop floor standard.

Since frequent use may impair the accuracy of any standard direct comparison with national standards are less frequently performed. In such a case a slightly lower order of standard known as national reference standards is use. Working standards are ordinarily used in calibration work. These are compared as frequently as necessary with national reference standards.

Clearly there is degradation of accuracy in passing from the defining standard to the standards in use. The accuracy of a particular standard depends on a combination of the number of times it has been compared with a standard in a higher echelon the recentness of such comparison the care with which it was done and the stability of the particular standard itself.

Figuer1.14 Classification of Standard

Depending upon the importance and accuracy required for the work the standard is again subdivided into 4 grades

1.Primary standards

2.secondary standards

3.tertiary standard

4.nor king standard

1. Primary standards

in order that standard unit of length (i.e yard or meter) does not change its value and it is strictly followed and precisely defined there should be one and only one material standard preserved under most careful condition. It is called primary standard. International yard meter are the example of primary standards. Primary standard is used only at rate intervals (say after 10 to 20 years) solely for comparison with secondary standards. It has no direct application to a measuring problem encountered in engineering.

2.Secondary standards

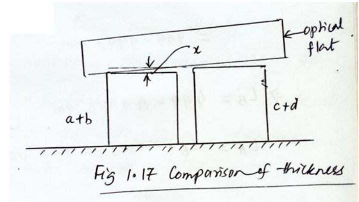
Secondary standards are made as nearly as possible exactly similar to primary standards as regards to design material and length. They are compared with primary standards after long intervals and the deviation are recorded. These standards are kept at number of places for safe custody. They are used for occasional comparison with tertiary standards whenever required.

3.Tertiary standards

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

4.Working standards

Working standards are used more frequently in laboratories and workshops. They are usually made of low grade of material as compared to primary secondary and tertiary standard for the sake of economy.



They are derived from fundamental standards. Both line and end working standard (to be discussed later) are used. Line standards are made from H cross sectional form as shown in fig 1.15.

Most of the precision measurement involves the distance between 2 surfaces (i.e end standard) and not with the length both 2 lines. End standards are suitable for this purpose. For shorter length up to 125 mm ship images are used and for longer length bars of circular c.s are used. The distance between the end faces of slip gausses or end bars is controlled to ensure a high degree of accuracy.

Note: Some time the standards are also classified as:

(a)Reference standards- used for reference purpose

(b) Calibration standards- used for calibration of inspection and working standard.

(c)Inspection standards: used by inspectors

(d) Working standards: used by operators during working.

End standard

When length is expressed as the distance between 2 flat parallel faces it is known as end standard. Examples: measurement by

- Slip gauges
- End bars
- Ends of micrometer anvils
- Venire calipers etc

Comparison between line standard and end standard

Sl.No	Characteristics	Line Standard	End Standard
1	Principle	Length is expressed as the distance between 2 engraved/ marked lines	Length is expressed as the distance between 2 flat parallel faces
2	Accuracy	Limited to 10.2 mm for higher accuracy, the scale is in conjunction with magnifying glass/microscope	Highly accurate upto 1 micron
3	Ease and time of measurement	Measurement is easy and quick	Requires skills and time consuming process
4	Rate of Near	Scale marking are not subjected to wear ho ever significant wear may occur at leading end	Subjected to wear on their measuring surfaces and requires calibration
5	Alignments	Can not easily aligned with the axis of measurement	Can be easily aligned with the axis of measurement

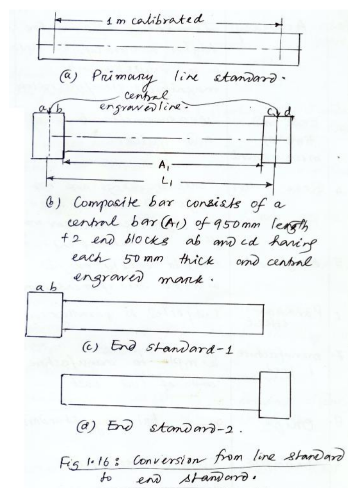
6	Parallax effect	Subjected to parallax error	Not subject to parallax error as the measurement is between 2 flat ii faces
7	Manufacture & Cost	Simple to manufacture and of low cost	manufacturing process is complex and cost is high
8	Origin	It is primary standard	It is derived standard from line standard
9.	Examples	Scale(Meter/Yard)	Slip gauges and bars venire calipers micrometer etc.
10	Use	Loss used for practical purposes	Mostly used for all practical application.

Transfer from line standard to end standard

Primary standards are line standards

Practical workshop standards are end standards.

Therefore the end standards must be calibrated from line standard.



Procedure:

Fig 1.16 (a) is a primary line standard having a basic length of 1m which is accurately known fig 1.16 (b) is a composite bar consist of a central bar of 950mm long and 2 end blocks (a-b & c-d) having a basic length of 50 mm wrung to either end of the central bar. Each end block has a central engraved line.

Now our objective is to obtain the exact dimension of an end standard either © or (d) type. It can be obtained by the following procedure. The end blocks can be wrung with the central bar in various combinations.

Let L = A+b+c (with reference t fig (b))

L= A+b+d (only c.d block wrung in opposite manner)

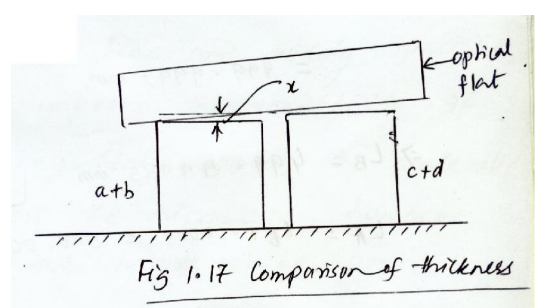
L= A+a+c (only ab block wrung in opposite manner)

L= A+a+d (both blocks wrung in opposite manner)

The exact value of L,L,L and L are known when compared with the primary line standard. Adding 4 measured values i.e

L+L+L+L= 4A+2a+2b+2c+2d

= 4A+2(a+b) + 2(c+d)



now the block ab is unlikely to be exactly the same length as block c+d. the difference (x) can be precisely obtained using an optical flat as shown is fig1.17

hence the sum of 4 measurement becomes:

4A+2(a+b) +2(a+b+x)

= 4A +4(a+b) +2x

dividing by 4 eg (2) becomes

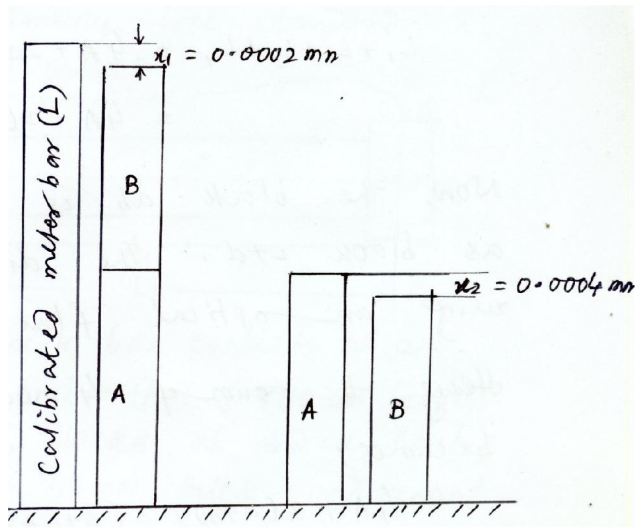
single measurement= A+(a+b)+x/2 which is known from primary line standard.

Also the value of x is known from precise measurement using an optical flat

Now A+b+b can be exactly known by deducting similarly A+c+d= A+(a+b) +x can be known exactly by adding x to A+(a+b) value

Therefore the calibration composite end standards (either A+a+b or A+c+d) can be used to calibrate a solider end standard of the same basic length.

Prob1: A calibrated meter end bar has an actual length of 1000.0003 mm. it is to be used in calibration of 2 bars A and B each having a basic length of 500 mm. when compared with the meter bar L+L was found to be shorter by 0.0002mm. In comparing A with B it was found that A was 0.0004 mm longer than B. find the actual length of A and B.



Soln

With reference to fig 1.18

L-X1= L a+Lb

=Lb+x2+Lb

=2L= L-xl-x2

=1000.0003-0002-004

=999.9997mm

=L= 499.99985mm

L=L +.0004=500.00025mm

Some important terminologies used in measurement

1.Sensitivity it should be noted that sensitivity is a term associated with the measuring equipment whereas accuracy & precision are association with measuring process.

Sensitivity means the ability of a measuring device to detect small differences in a quantity being measured. For instance if a very small change in voltage applied to 2 voltmeters results in a perceptible change in the indication of one instrument and not in the other. Then the former (A0 is send to be more sensitive. Numerically it can be determined in this way for example if on a dial indicator the scale spacing is 1.0 mm and the scale division value is 0.01 mm then sensitivity =100. it is also called amplification factor or gearing ratio.

It is possible that the more sensitive instrument may be subjected to drifts due to thermal and other effects so that its indications may be less repeatable than these of the instrument of lower sensitivity.

2.Readability

Readability refers to the case with which the readings of a measuring instrument can be read. It is the susceptibility of a measuring device to have its indication converted into more meaningful number. Fine and widely spaced graduation lines ordinarily improve the readability. If the graduation lines are very finely spaced the scale will be more readable by using the microscope however with naked eye the readability will be poor.

In order to make micrometer more readable they are provided with vernier scale. It can also be improve by using magnifying devices.

3.**Repeatability**

It is the ability of the measuring instrument to repeat the same results when measurement are carried out

- By same observer
- With the same instrument
- Under the same conditions
- Without any change in location
- Without change in the method of measurement
- And the measurement is carried out in short interval of time.

It may be expressed quantitatively in terms of dispersion of the results.

4.Reproducibility

Reproducibility is the consistency of pattern of variation in measurement i.e closeness of the agreement between the results of measurement of the same quantity when individual measurement are carried out

- By different observer
- By different methods
- Using different instruments
- Under different condition, location and times.

It may also be expressed quantitatively in terms of dispersion of the results.

5.Calibration

The calibration of any measuring instrument is necessary for the sake of accruing of measurement process. It is the process of framing the scale of the instrument by applying some standard (known) signals calibration is a pre-measurement process generally carried out by manufactures.

It is carried out by making adjustment such that the read out device produces zero output for zero measured input similarly it should display output equipment to the known measured input near the full scale input value.

If accuracy is to be maintained the instrument must be checked and recalibration if necessary. As far as possible the calibration should be performed under similar environmental condition with the environment of actual measurement

6.Magnification

Magnification means increasing the magnitude of output signal of measuring instrument many times to make it more readable. The degree of magnification should bear some relation to the accuracy of measurement desired and should not be larger than necessary. Generally the greater the magnification the smaller is the range of measurement.

CHAPTER -2: SIMPLE MEASUREMENT TOOLS

Introduction

Measuring tool and instruments (a) Direct group

(b) Indirect Measuring group

Direct Measuring Tools are applied directly to the W/P as in the case of micrometer or a caliper

Indirect Measuring Tools are optical electronics and pneumatic methods to arrive at the final dimensions of a piece

The Direct measuring instruments are either graduated manual or non-graduated manual type. The manual means that hand operated instrument. The graduated type has their linear or angular graduations. The non graduated types consist of fixed gauges or adjustable tools which compare measurement.

GRADUATED MANUAL MEASURING TOOLS

- Rules
- Calipers
- Height gauge
- Micrometer
- Depth gauges
- Dial indicators

C. RULES

It is also steel rules/scales . The Basic graduated measuring instruments is the rule. It is a graduated measuring instruments in the rule. It is a graduated length of steel, used for approximately determining linear dimension. Fig 2.1 shows a steel rule where all the fine graduations are not shown.

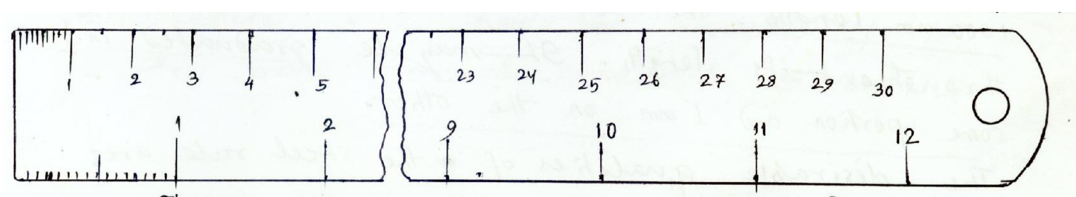


Fig 2-1 : most widely used steel Rule (or Steel scale)

Rules are graduated on one side in eights and on the other is tenths or multiple thereof. Rules are manufactured of carbon steel or stainless steel & spring Steel and many are chrome plated with enameled graduations.

Shrink rules are commonly employed in the pattern making shop where casting of metals is involved. These rules automatically take into consideration the shrink allowances of the materials being cost. The most common allowance are ¼” and 3/16” foot.

Hook rules are frequently used to assure the user that the end of the w/p flush with the end of the rule.

Tapered rules find many applications in me measuring inside of small holes narrow slots and grooves.

Rule are still the most generally used measuring instruments in the industrial metrology today.

Component of limited accuracy: The degree of accuracy 02.mm the quickness and ease with which it can be used and its low cost, makes it a popular and widely used measuring device.

The Steel rules are manufactured in different sizes and styles,. These are available in 150,300, 600 or 1000 mm lengths. The scale need not be graduated uniformly throughout its length. It may be graduated in ½ mm in some position and 1mn on the other.

The desirable qualities of the steel rule are.

1.It should be mode of good quality spring steel.

2 .It should be machine ground on its faces and clearly engraved line.

3. It should have graduations on both edges.

4. It should be chrome plated to present corrosion and protection against staining.

Precautions while using a Steel Rule.

1. The end of the rules should be prevented form wear as it generally forms the basis for one end for dimension.
2. The rule should never be used for cleaning between parts or as s substitute for screw driver for scraping T slots and machine table, otherwise its edges and ends will be damaged.
3. Rusting of the role should avoid by oiling it during weekends and when it is not is used.
4. In order to maintain the sharpness of the graduations for easy and accurate reading scale should be cleaned with grease dissolving fluids.
5. In order to have correct reading of the dimension to be measured, scale should never be laid flat on the part to the measured.
6. When taking measurement with rule, it should be so held that the graduation lines are as closed as possible (Preferably touching) to the faces being measure.
7. In order to avoid the parallax error, while making measurement eye should be directly opposite and 90^0 to the mark on the part to be measured.

C. Calipers

Non graduated manual measuring tool

Graduated manual measuring tool

a.Non graduated manual measurement tool

In order to measure the diameter of a circular part it is essential that the measurement is made along the largest distance or true diameter. The steel rule alone is not convenient method of measuring directly the size of the circular part. A caliper is used to transfer the distance between the faces of a component to a scale or micrometer. It thus converts an end measurement situation to the line system of the rule.

The caliper consists of 2 legs higher at top and the ends of the legs span the part to be measured. The legs of the caliper are made from carbon and alloy steel they are exactly identical in shape with contact points equidistance from the fulcrum. The working ends are suitably hardened and tempered to a hardness of 400 to 500 and

Types →
- Inside Calipers
  - Firm joint calipers
  - Spring calipers
- Divider
- Outside Calipers
  - Firm joint calipers.
  - Spring Calipers
- Transfer caliper
- Odd leg caliper.

The figures are presented in the following.

The divider has 2 straight legs & sharp edges. The adjusting nut is used for proper adjustment of the distance betn the legs. Fig 2.2 shows the figure of a divider

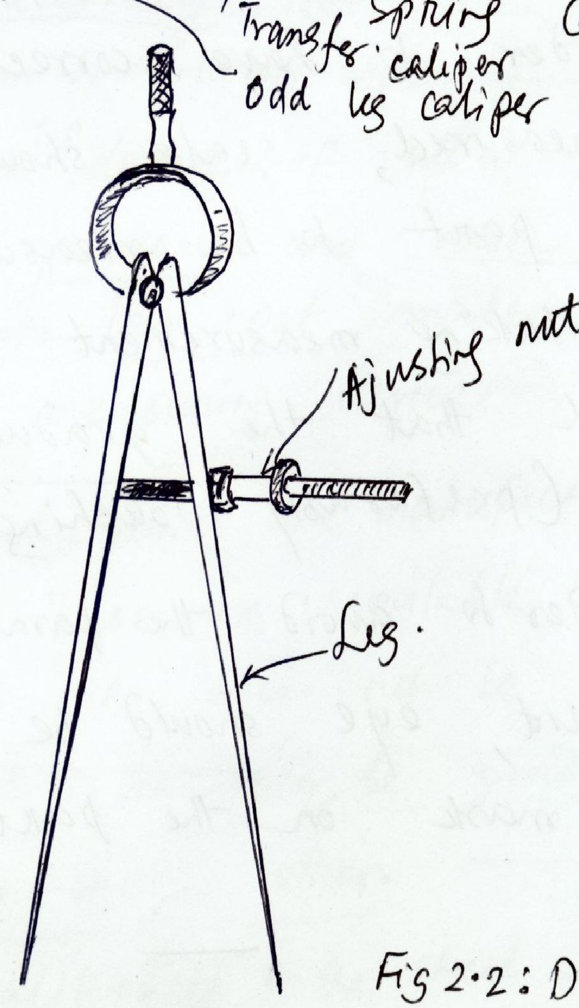


Fig 2.2: Divider

the measuring faces to a hardness of 650 + 50Hv.

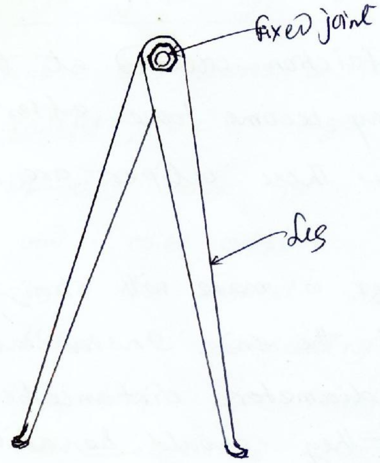


Fig 2.3: ~~Outside~~ Firm joint type inside caliper

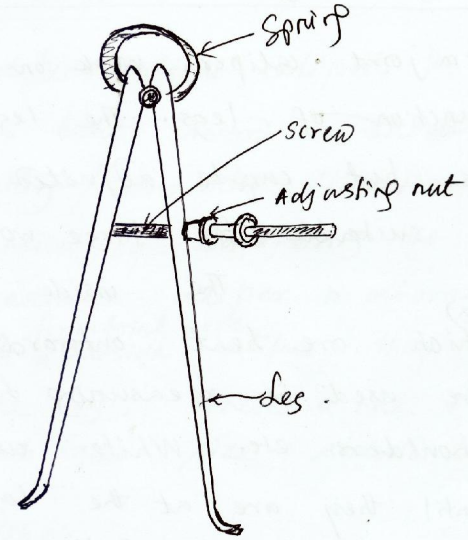


Fig 2.4: ~~Outside~~ Spring type ~~caliper~~. inside caliper.

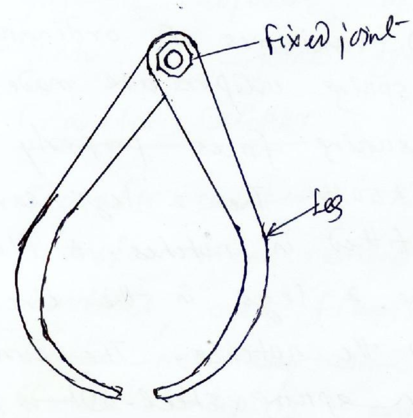


Fig 2.5: Firm joint type. outside caliper.

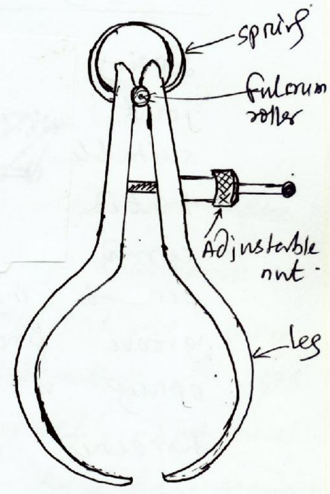


Fig 2.6: Spring type outside caliper.

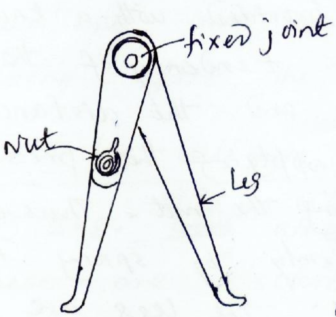


fig 2.7: Transfer Calipers

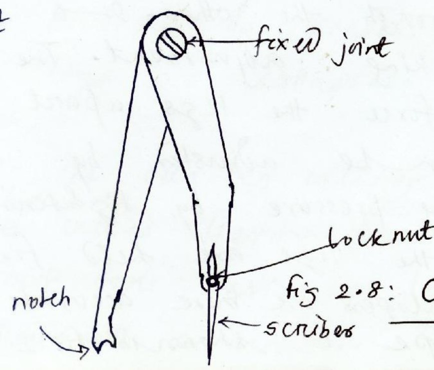


fig 2.8: Odd leg ~~odd~~ caliper

FIRM JOINT TYPE INSIDE CALIPER

Firm joint calipers work on the friction created at the junction of legs. The legs may become loose after certain use but can be adjusted easily. These calipers are particularly suitable for large work.

The inside calipers is made with straight legs which are bent outwards at the ends. Inside calipers are used for measuring hole diameter, distance between shoulders etc. while using they should be adjusted until they are at the largest size at which their legs can just be felt contacting the extremities of a diameters of the hole.

Spring type inside caliper

Spring calipers are improved varieties of ordinary richer joint calipers. The legs of spring calipers are made from suitable along steel the measuring faces properly heat treated to a hardness of 650 +50 Hv. The 2 legs carry a cured spring at the tap, fitted in noteches. The curved spring is made from carbon spring steel, it is properly hardness and tempered to a hardness of 470 to 520 Hv.

A screen is fixed in one leg and made to pass through the other. It is provided with a nut is to force the legs a part and the distance between them can be adjusted by applying the pressure against the spring pressure by heightening the nut. Thus in spring caliper the legs are held firmly by spring tension spring calipers are more accurate. The legs are straight and shape is shown in fig 2.4.

Firm joint type outside caliper

Figure 2.5 shows a firm joint type outside caliper. In outside caliper the 2 legs are bent inword as shown in fig 2.5. it is now for measuring /comparing diameter thickness and other outside dimension by frame firing the reading to the steel rule venirer caliper or micrometer. When measuring with form joint type outside caliper they should be adjusted by taping one leg. When a nice feel has been obtained on the job the size should be read on rule.

Spring type outside caliper

The spring type outside caliper is shown in fig 2.6 when measuring with spring type outside caliper the gap is adjusted by adjusting screen. It is more accurate then firm joint type outside caliper.

Transfer caliper

Transfer caliper is shown in fig 2.7. it is used to make transfer measurement from the inside of chambered cavities over flanges and similar applications where the legs of the calipers can't be removed directly but must be collapsed after the dimension has been measured. In these calipers an auxiliary arm is provided to pressure the original setting after the legs are collapsed.

Odd leg calipers:

The odd leg caliper is shown in fig 2.8 odd leg calipers are also called hermaphrodite calipers. These are scribing tools having one legs bent and the other leg equipped with a scriber. Distances from the edge of a work piece may be scribed or measured with these calipers. They may have either friction joint or spring arrangement. Odd leg caliper are specifically used for finely centers of a circular job marking a line parallel to a three edge and many other types of marking operations.

Graduated manual measuring tool (slide caliper/vernier caliper)

According to IS= 3651-1974 there are 3 types of vernier caliper to meet the various needs of external and internal measurement up to 2 m with vernier least count a accuracy of 0.02, 0.05 and 0.10mm. these are available in sizes 0-125,0-200,0-

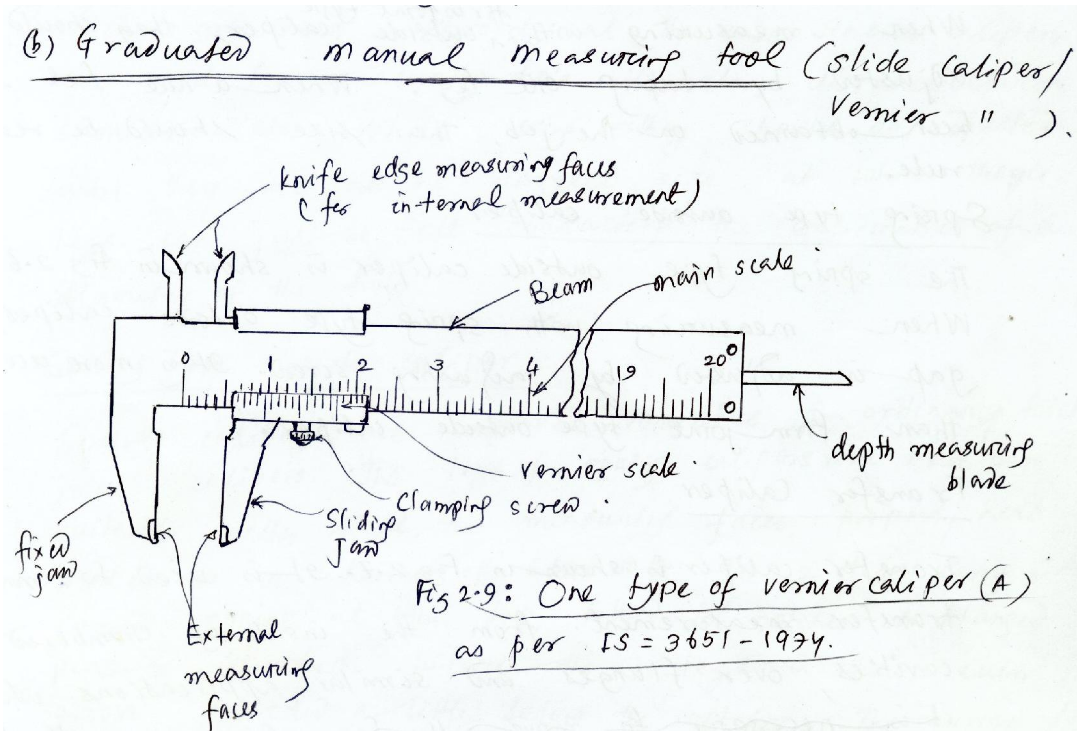


Fig 2.9: One type of vernier caliper (A) as per IS = 3651-1974.

300,0-500,0-750,0-1000,750-1500 and 1500-2000mm. out of 3 types (A,B,C) only A type is shown in fig 2.9.

Type A (shown in fig 2.9) has jaws on both sides for external and internal measurement and also has blade for depth measurement. The vernier calipers are made of suitable good quality steel of hardness 650+ 50Hv. The beam should be flat thought its length to within the tolerance of 0.05mm for nominal sizes up to 300mm and 0.08mm from 900 to 1000mm and 0.15mm for 1500 and 2000mm sizes.

The measuring faces should have ground finish the portion of the jaw between the beam and measuring faces are relieved. The fixed jaw is the integral part of the beam and the sliding jaw in required to have good sliding fit along with the beam and should have seizure free movement along the beam. A suitable locking arrangement should provided on the sliding jaw in order to clamp it on the main beam.

All graduations should be clearly engraved so that they are legible.

Possible errors in vernier instruments

The various causes of errors are given in the following.

(i) Error due to play between sliding jaw on the scale.

(ii) If the sliding jaw frame becomes worm or warped it will not slide squarely on the main scale and will cause error in measurement.

(iii) Due to wear and warping of the jaws the zero line on main scale may not conclude with that on the vernier scale. This is called as zero error.

(iv) Errors are also caused by incorrect reading of vernier scale as the scales are difficult to read even with the aid of magnifying glass.

(v) Error is also introduced if the line of measurement does not coincide with the line of the scale.

(vi) Since it to difficult to obtain correct feel due to its size and weight an error may be introduced due to incorrect feel.

Precautions in the use of vernier caliper

In order to minimum the error the following precautions should be taken while using the instrument.

(i) The line of measurement must coincide with line of scale.

(ii) While measuring the outside diameter with vernier caliper the plane of the measuring tips of the calipers must be perpendicular to the center line of the work piece. The caliper should not be fitted/twisted.

(iii) The instrument is gripped near to the jaws.

(iv) The caliper jaws are moved on the work with light touch under pressure should not be applied.

(v) The accuracy of measurement depends on sense of sight & sense of feel.

(vi) The measuring instrument must be properly balanced in hand and held lightly in such a way that only fingers handle the moving and adjustable screws.

C. Height gauge

it is basically at 2 types
- Vernier height gauge
- Electronic digital read out height gauge

(a)Vernier height gauge

vernier height gauge is similar to vernier caliper but in this instrument the graduated bar is held in a vertical position and it is used in conjunction with a surface plate

Construction

A vernier height gauge consists of

(i) a finely grow and lapped base. The base is massive and robust in construction to ensure rigidity and stability.

(ii) A vertical graduated beam or column supported on a massive base

(iii) Attached to the beam is a sliding vernier head carrying the vernier scale and a clamping screw.

(iv) An auxiliary head which is also attached to the beam above sliding vernier head. It has fine adjusting and clamping screw.

(v) A measuring jaw or a scriber attached to the front of sliding vernier.

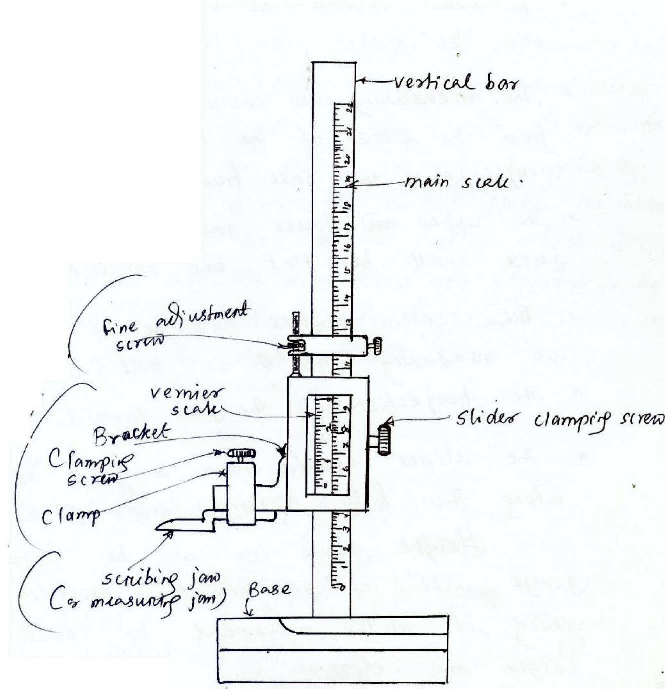


Fig. 2.10: Vernier Height Gauge

Use: The vernier height gauge is designed for accurate measurement and marking of vertical height above a surface plate datum. It can also be used to measure differences in heights by taking the vernier scale reading t each height and determining the difference by substraction. It can be used for number of applications in tool room and inspection department.

The important features of vernier height gauge are :

- all the parts are made of good quality steel or stainless steel.
- The beam should be sufficiently rigid and square with the base.
- The measuring jaw should have a clear protection from the edge of the beam at least equal to the projection of the base from the beam.
- The upper and lower ganging surfaces of the measuring jaw shall be flat and parallel to the base.
- The scriber should also be of same nominal depth as measuring jaw so that it may be reversed.
- The projection of the jaw should be at least 25mm.
- The slider should have a good sliding fit for all along the full worship length of the beam.

Height gauge can also be provided with dial gauge instead of vernier. This provides easy and exact reading of slider movement by dial gauge which is larger and clear.

Precaution

When not in use vernier height gauge should be kept in its case. It should be tested for straightness squareness and parallelism of the working faces of the beam measuring jaw scrubber. The springing of the measuring jaw should always be avoided.

Electronic digital read out height gauge

The digital height gauge provides an immediate digital read out of the measured value without any ambiguity. It is possible to store this value in memory and used as a datum for further reading or for comparing with given tolerances. It is also possible to provide a binary coded digit outputs to enable the results for further statistical analysis and for providing print out.

These are provided with heavier steel or granite bases with air bearing flotation system. Thus these provide a cushion of air between base of the stand and the surface plate which reduces both the effort required to move the gauge and possibility of damage of surface plate. The instrument can be zeroed at any position after which it will display positive and negative dimensions with reference to the datum. There is very fine adjustment facility and the slide can be securely clamped for marking out.

C.Micrometer

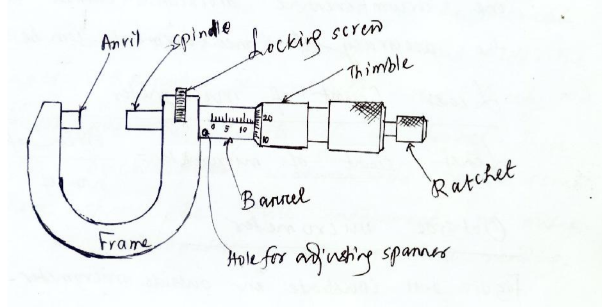


Fig. 2.11: Outside micrometer

the accuracy of vernier caliper is 0.02mm. most engineering precision works have to be measured to a much greater accuracy than this value in order to achieve the interchangeability of component parts.

In order to achieve this greater precision measuring equipment of a greater accuracy and sensitivity must be used. Micrometer is one of the most common and most popular forms of measuring instrument for precise measurement with 0.01 mm accuracy. However micrometer with 0.001 mm accuracy are also available.

Micrometer may be classified as

(a) Outside micrometer
(b) Inside micrometer
(c) Screw thread micrometer
(d) Depth gauge micrometer

Principle of micrometer

Micrometers work on the principle of screw and nut. We know that when a screw is turned through nut by one revolution it advances by one pitch distance if the circumference of the screw is divided into equal parts its rotation through one division will cause the screw to advance through length . thus the minimum length that can by measured by such arrangement will be . so either by reducing the pitch of the screw thread or by increasing the number of division on the circumference of screw, the length value corresponding to one circumfertial division can be reduced and consequently the accuracy of measurement can be increased.

Least count of micrometer

$$\text{Least count of micrometer} = \frac{\text{pitch of the spindle screw}}{\text{no of division in the spindle}}$$

Outside micrometer

Figure 2.11 illustrate an outside micrometer. It is used to measure the outside diameter and length of small parts to accuracy of 0.01mm. The main parts of an outside caliper are:

1. U shaped steel frame
2. anvil & spindle
3. lock nut
4. sleeve or barrel
5. thimble
6. ratchet

1.U shaped steel frame

The outside micrometer has U shaped or C shaped frame. It holds all the micrometer parts together. The gap of the frame permits the maximum diameter or length of the job to be measured. The frame is generally made of steel, cast iron, maleable cast iron or light alloy. It is desirable that the frame of the micrometer be provided with conveniently placed finger grips of heat insulting materials.

2.Anvil & spindle

The micrometer has a fixed anvil protruding 3mm from the left hand side frame. The diameter of the anvil is the same as the diameter of spindle. Another movable anvil is provided on the front of the spindle. The anvils are accuracy ground and lapped with its measuring faces flat and parallel to the spindle. These are also available with WC faces. The spindle is the movable measuring face with the anvil on the front side. The spindle engages with the nut. It should run freely and smoothly through out the length of its travel. There should be no backlash between the spindle screw and nut. There should be full engagement of nut& screw when the micrometer is at its full reading.

3.Lock nut

A lock nut is provided on the micrometer spindle as shown in fig 2.11, to lock it when the micrometer is at its correct reading. The design of the locknut is such that it effectively locks the spindle without altering the distance between the measuring faces. It thus retains the spindle in perfect alignment.

4.Sleeve or Barrel:

The sleeve is accurately divided and clearly marked in 0.5mm division along its length which serves as a main scale. It is chrome plated and adjustable for zero setting.

5.Thimble: The thimble can be moved over the barrel, it has 50 equal divisions around its circumference.

6.Ratchet:

The ratchet is provided at the end of the thimble. It is used to assure accurate measurement and to prevent too much pressure being applied to the micrometer. When the spindle ratches near the work surface to be measured the operator uses the ratchet screw to tighter the thimble. The ratchet automatically slips when the correct (uniform) pressure is applied and prevents the application of too much pressure.

The micrometer usually has a maximum opening of 25mm. They are available in measuring ranges of 0 to 25mm, 25 to 50mm, 125 to 150mm upto 575 to 600mm.

Procedure to take micrometer reading

The following procedure is followed while measuring the dimension with the help of micrometer.

1. Micrometer is selected with a desired range suitable for w/p
2. checking of zero error.

In case of 0.25mm micrometer the zero error is checked by contacting the faces of the fixed anvil and the spindle. While using micrometer of 25-50mm or 125mm to 150mm size the zero error is checked by placing a master of 25mm or 125mm respectively between the anvil & spindle.

Checking of zero error means the zero error means the zero of the thimble should coincide with zero on main scale. If it does not happen then zero error is present in the micrometer. A special spanner is usually provided with the micrometer for eliminating the zero error.

3. For measuring the particular dimension the w/p is first held between the faces of anvil and spindle. Then the spindle is moved rotating the thimble until the anvil and spindle touches the work surface. Fine adjustment is made with the ratchet. Now the reading on the main scale is noted. Let it be 11.00mm.
4. subsequently the thimble reading which coincide with the reference line is taken let it be 34.
5. now total reading= main scale reading+ L.Cx reading on the thimble is 11.00 + 0.01x34=11.34mm

PRECLUSIONS TO BE TAKEN WHILE USING A MICROMETER

1. First clean the micrometer by wiping of oil, dirt, dust and grit etc.
2. Clean the measuring faces of the anvil a spindle with a clean piece of paper or cloth.
3. Set the zero reading of the instrument before measuring.
4. Hold the part (whose dimension is to be measured) and micrometer properly. Then turn the thimble with the forefinger and thumb till the measuring tip just touches the part and fine adjustment should be made by ratchet so that uniform measuring pressure is applied.
5. While measuring dimensions of circular parts the micrometer must be moved carefully over representative are so as to note maximum dimension only.

POSSIBLE SOURCES OF ERRORS IN MICROMETER

Some possible sources of errors are :

1. lack of flatness of anvil & spindle surfaces.
2. lack of parallelism of the anvil at some or all parts of the scale.
3. inaccurate setting of zero reading (zero error)
4. inaccurate reading shown by the fractional divisions on the thimble.
5. applying too much pressure on the thimble or not using the ratchet.
6. wear of the anvil surface threads on the spindle due to constant or incorrect use.
7. wear of ratchet stop mechanism locking arrangement etc.

C. Depth gauge

figure 2.12 shows a vernier depth gauge when it is in use the vernier scale is fixed to the main body of the depth gauge. The reading in taken in the same way as the vernier caliper.

Running through the depth gauge body is the main scale the end of which provides the datum surface from which measurement in taken. The depth gauge is carefully made so that the beam is so the base.

The end of the beam of is square and flat like the end of steel rule and the base is flat and true free from works or wariness.

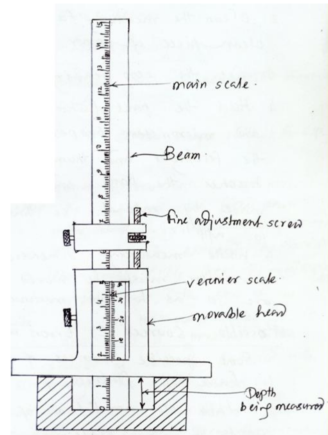


Fig 2.12: Vernier Depth Gauge

Because of the construction a depth gauge will give true measurement when it is used properly while using the instrument first of all it must be assured that the reference surface on which the base of depth gauge is rested is satisfactorily true flat and square. The most common error is shown below (in fig 2.13)

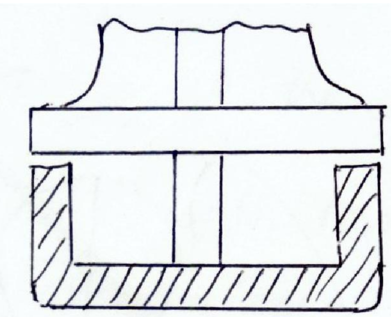


Fig 2.13: A common error while measuring the depth

C. Dial indicator

Dial indicator are basically used for making and checking linear measurement. It is based on mechanical means such as gears for magnification.

Classification

1.Plunger type

2.Lever type

The plunger type is most commonly used

Fig 2.14 shows the main features of a plunger type dial gauge indicator. The main scale is graduated into equal divisions corresponding to 0.01mm movement of the plunger. A second smaller dial is set in the main dial face to indicate the number of complete revolution turned through one revolution is equivalent to 1mm movement of plunger movement. In order to enable the instrument to zero for any convenient position, the main scale can be rotated and locked into place using the scale locking screw indicated in fig 2.14 aside.

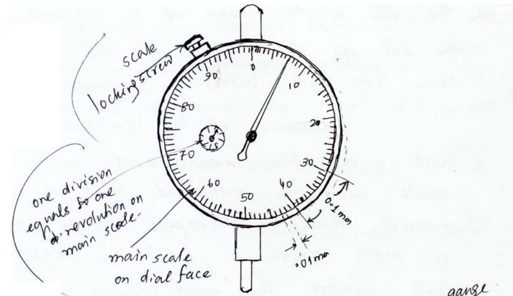


Fig 2.14: Plunger type dial gauge indicator

The principle of operation is shown in fig 2.15. the plunger is attached to a rack. The rack is again mesh with a pinion & gear set for magnification of the pointer rotation as shown in fig 2.15 aside.

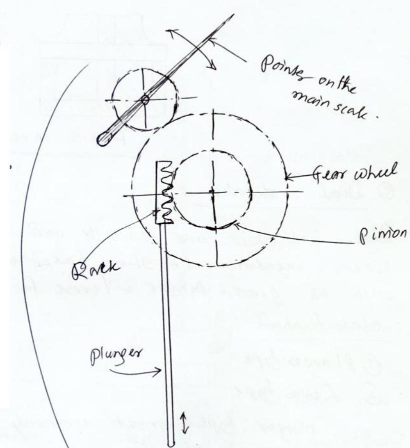


Fig 2.15: Principle of operation of a plunger-type dial gauge indicator.

Slip gauges (= gauge stocks)

= Johnson gauges

Introduction

Slip gauges are rectangular block of high grade steel with exceptionally close tolerance. These blocks are suitably hardened up to 800 Hr through out to ensure maximum resistance to wear. These are then stabilized by heating and cooling successively in stages so that hardening stresses are removed. After being hardened they are carefully finished by high grade lapping to a high degree of finish flatness and accuracy. For successful use of slip gauges their working faces are made truly flat parallel. A slip gauge looks as shown in fig 2.16.

The cross section of the gauges are

(i)9mmx30mm for sizes up to 10mm

(ii)9mmx35mm for larger sizes.

Any 2 slip gauges when perfectly clean may be wrung together. The dimensions are permanently marked on one of the measuring faces of gauges block.

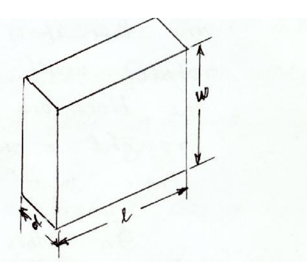


Fig 2.16: Dimension of a slip gauge.

Uses of gauge blocks

(1) Direct precise measurement where accuracy is required.
(2) For checking the accuracy of vernier calipers, micrometer etc
(3) Setting up a comparator to a specific dimension.
(4) It is used for angle measurement with sine bar.
(5) The distance of plugs spigot etc on fixture are measured
(6) To check gap between parallel locations such as in gap gauges or between 2 mating parts

Wringing of slip gauges

The accuracy of measurement depends on the phenomenon of wringing. The slip gauges are wrung together by hand through a combined sliding and rising motion. The various steps will be explained in the following. The gap between 2 wrung slip gauges is only of the order of 0.00635 micro which is negligible.

Procedure for wringing(fig 2.17)

(i) Before using the slip gauges are cleaned by using a lint free cloth a chamois leather or a cleaning tissue.
(ii) One slip gauges is then oscillated slightly over the other gauges with a light pressure.
(iii) One gauge is then placed at 90 to other by using light pressure and then it is rotated until the block one brought in one line.

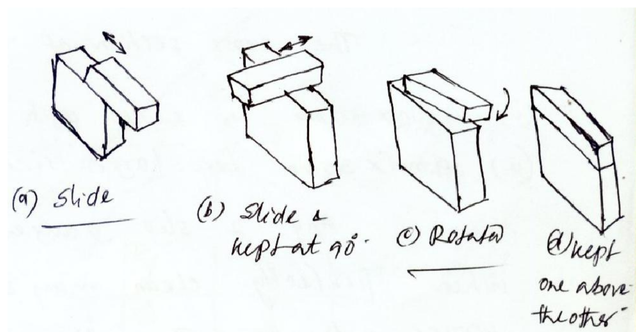


Fig 2.17 : Wringing of slip gauges.

In this way air is expelled out from between the gauges faces causing the gauges blocks to where. The adhesion is caused partly by molecular attraction and party by atmospheric pressure. When the 2 gauges are wrung in this manner the total dimension will be exactly the sum of their individual dimension. The wrung gauge can be handled as a unit without the need for clamping all the pieces together.

Indian standard on slip gauges

According to Is 2984-1966 the size of slip gauges is defined as the distance ‘l’ between 2 plane measuring faces. Slip gauges are available in several grades or qualities.

There are 5 grades available as follows:

GradeII: Grade II gauge blocks are workshop grade and used for rough check. They are used for setting up machine tools, positioning milling cutters etc where the tolerance values are relatively wide.

Grade-I These are used for more precise work such as setting up sine bars checking gap gauges and setting dial test indicators to zero.

Grade 0 (zero) This is more commonly known as inspection grade and its use is confined to tool room or machine shop inspection.

Grade 00(zero zero): This grade gauges are placed in the standard room and used for highest precision work such as checking grade I &Grade II slip gauges.

Calibration grade

This is a special grade with the actual size of the slip calibration on a special chart supplied with a set. The chart must be referred while making up dimension.

The following 2 grades of slip gauges are in general use.

Range (MM)	**Step (MM)**	**Pieces**
1.001 to 1.009	.001	9
1.01 to 1.09	.01	9
1.1 to 1.9	0.1	9
1 to 9	1	9
10 to 20	10	9
	Total	45 nos

Special Set (M-87)

Range (MM)	**Step (MM)**	**Piecs**
1.001 to 1.009	.001	9
1.01 to 1.49	0.01	49
0.5 to 0.95	0.5	19
10 to 90	10	9
1.005	-	1
	Total	87 nos.

Selection of slip gauges for required dimension.

The following standard procedure should be followed while selecting the slip gauges to build up the required dimension

Always start with last decimal place and deduct this from the required dimension. Select the next smallest figure in the same way find the remainder and continue this until the required dimension is completed. Minimum number of slip gauges necessary to build up the given dimension should be selected.

Ex- Let us suppose that the dimension to be build up is 29.758mm.

For the last decimal place of 0.008 select 1.008 mm slip gauge

Now dimension left =29.758-1.008=28.75

For second decimal place of 0.05 select 1.25mm slip gauges

Now the remainder is 28.75-1.25= 27.5mm

Now select 7.5mm & 20mm slip gauges.

Thus we have 20+7.5+1.25+1.008=29.758mm

The above 4 slip gauges are required to build 29.758mm dimension

Care of slip gauges

General care

1. protect all the surfaces against climatic condition by applying suitable anticorrosive such as petroleum jelly.
2. keep the slip gauges in a suitable case in which there is a separate compartment for each gauges and keep the case closed when not in use.
3. protect the gauges and their case from dust &dirt.
4. gauges should not be magnetized otherwise they will attract the metallic dust.

Preparation before use

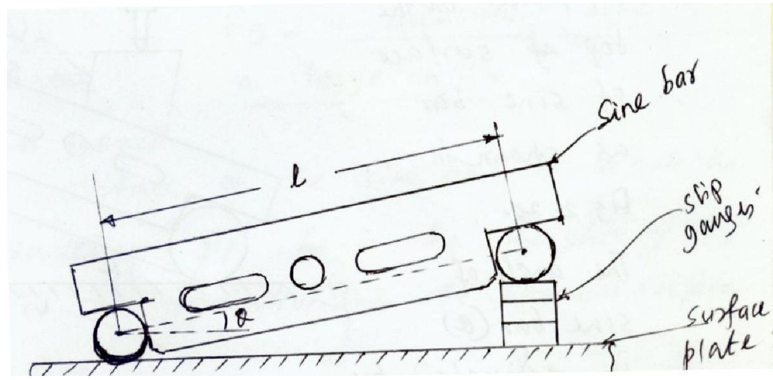
1. Remove protective wafting applied to it with petrol.
2. clean gauges to be used with chemos leather or soft linen cloth even they are temporarily returned to the case uncoated.

Care in use

1. during the actual use the fingering of lapped faces should be avoided,
2. handling should be as minimum as possible to avoid transfer of heat from hand to gauges.
3. if the gauges have to be handled for some time they should be allowed to settle down to the prevailing room temperature.
4. a temp of 20 c is necessary for highest accuracy of measurement.
5. both w/p gauges should be allowed to settled down to room temp before doing any measurement.
6. gauges should not be held over the open case. The required gauges should be selected and the case is closed.
7. placing gauges with their working surfaces on the surface plate should be avoided.
8. while wringing the gauges standard procedure must be followed to remove air gap.
9. if during the process of wringing any sign of roughens or scattering is felt immensely the wringing process should be stopped and the faces are examined for burns & other unwanted foreign materials.

Care after use

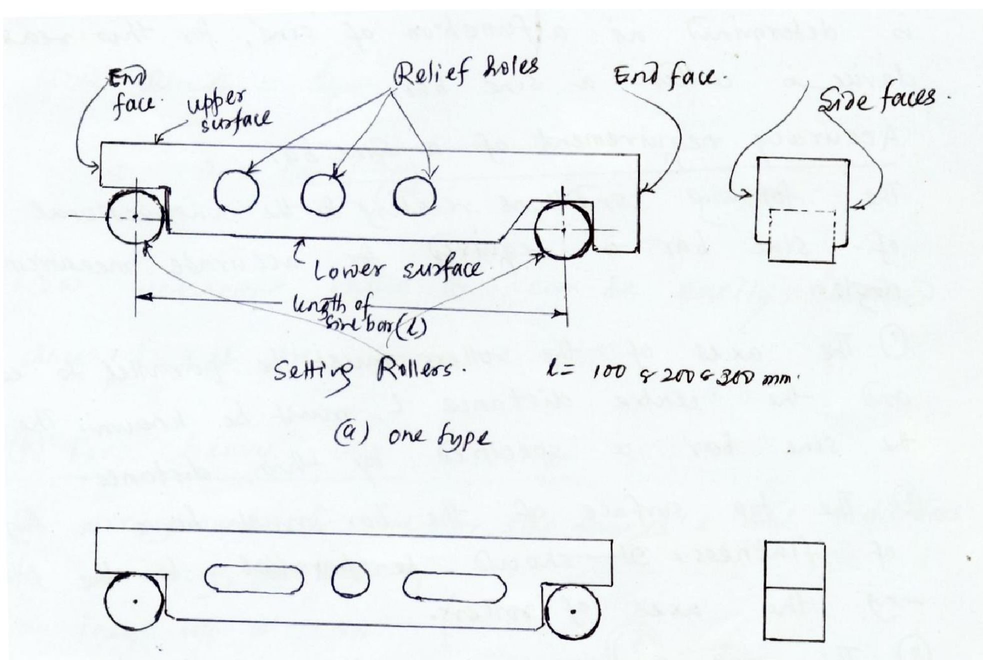
1. Gauges should not be left wrung together for an unnecessary length of time.
2. immediately after use the gauges should be slid a part cleaned and the measuring faces are coated with suitable protective layer of jelly grease etc with a clean piece of soft linen.
3. calibration



due to handling in the laboratory or inspection room, for a considerable long period slip gauges are liable to wear and therefore they should be checked or recalibrated at regular interval.

SINE BAR

Sine bar is an instrument used along with slip gauges for the measurement of angles most accurately in the shop floor. It is also used to locate the work to a given angle within very close limits.



It consists of a steel bar and rollers. The sine bars are available in several designs for different applications. Two most common types are shown in fig 2.18.

It should be noted here that the holes are drilled in the body of sine bar to

(i) make it lighter

(ii) facilitate handling

WORKING PRINCIPLE

the top surface of sine bar can be set to an angle as shown in fig 2.19.

in this configuration sin=

since length of sine bar l is constant h is adjusted to obtained a particular angle

thus the angle to be measured (or to be set) is determined as a function of sine for this reason the device is called a sin bar.

Accuracy requirement of a sine bar

The following conditions relating to the constructional features of sine bar is required for accurate measurement of angle.

1.The axes of the rollers must be parallel to each other and the center distance L must be known. The size of the sine bar is specified by this distance.

2.the top surface of the bar must have a high degree of flatness. It should be parallel to the plane connecting the axes of rollers.

3.the rollers must have identical diameters and round within a close tolerance,

checking or measuring unknown angle of w/p

a.When the work piece car components is small one

The part component to be checked is placed on the top surface of sine bar as shown in fig 2.20. the angle of sine bar is adjusted by placing ship gauges such that the top surface of the part remains parallel to surface plate. It is checked by scanning the dial indicator on the top surface of the part as shown by arrow,

Now sin θ= $\frac{h}{l}$

& θ= Sin $(\frac{^{-1}H}{L})$

Now unknown value θ can be easily obtained since h & l are known

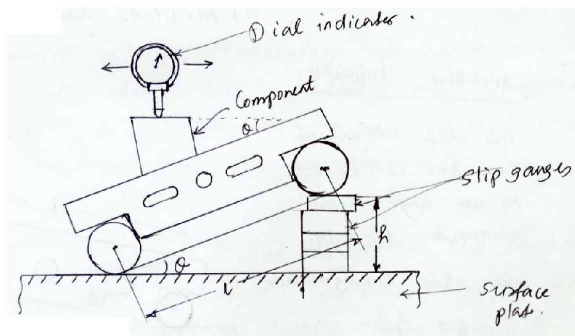


Fig 2.20: measurement of angle of small component

b.For heavy w/p

The arrangement for sine bar slip gauges e dial indicates for measuring the angle of a large w/p is shown in fig 2.21. the component is placed over a surface plate and the sine bar is set up at approximate angle on the component so that its top surface is nearly parallel to the surface plate. A dial gauge is moved along the top surface of the sine bar to note the variation in parallelism . if h is the height of slip gauge and dh is the variation is the parallelism over the distance (L) then

θ= Sin- 1 $(\frac{H \pm Dh}{L})$

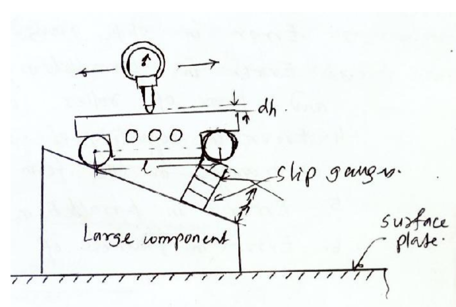


Fig 2.21: measuring angle of a large w/p.

Limitation of sine bar

(i)

sin bar is fairly reliable for angle less than 15 and becomes increasingly inaccurate as the angle increases. It is impractical to use sine bar for angle above 45.

(iii) It is physically clumsy to hold in position

(iv) Slight error of the sine bar cause larger angular error.

(v) A difference of deformation occurs at the point of roller contact with the surface plate and to the gange blocks.

(vi) The size of the part which can be inspected by sine bar is limited.

Sources of errors in sine bar

The different sources of errors are :

1. Error is distance between roller centers
2. error is slip gauge combination used for angle setting
3. error in parallelism between the ganging surface and plane of roller axes.
4. error is equality of size of rollers and cylindrical accuracy in the form of rollers.
5. error in parallelism os roller axes with each other.
6. error in flatness of the upper surface of the bar.

MODULE-II CHAPTER-3

LIMIT, FITS, TOLERANCES AND GAUGE DESIGN

1.C.Basic concept of limit fits and tolerances

Whatever may be the advancement in the field of machine soul technology it is not possible to make any part precisely to a given dimension due to

- Tool wear
- Deflection
- Vibration of m/c tool
- Change of temperature
- Human error etc

Secondly if by chance the part is made exactly to a given dimension it is impossible to measure it accurately enough to prove it.

Thirdly if attempts are made to achieve perfect size the cost of production will increase tremendously as shown in fig 3.1

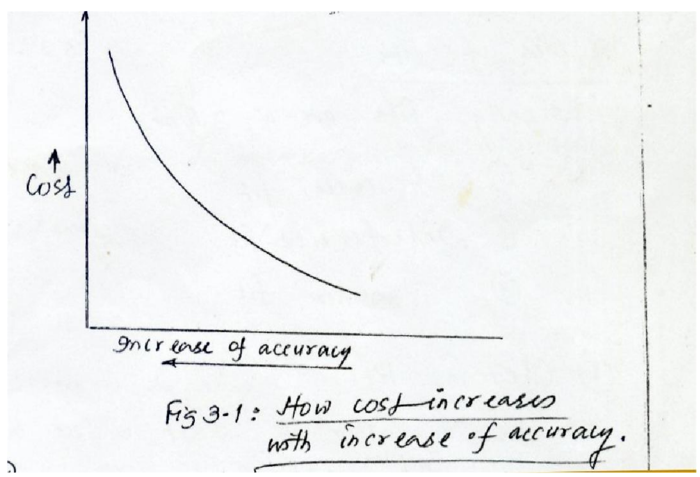
A .Limit

The limits of size of a part are two extreme permissible sizes between which the actual size may lie. Since it is not possible to make all parts exactly alike and to exact dimension (due to variability in man machine tool) and material some permissible variations in dimensions are allowed.

Ex: it a 20mm nominal dia is to be produced the limits may be 19.9 to 20.1 mm.

B. Fits

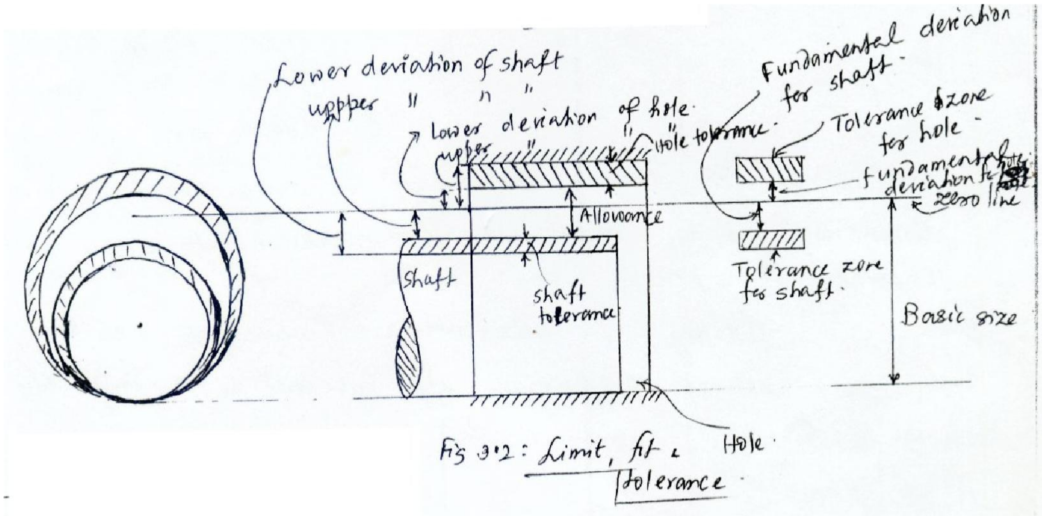
Fit is defined as the degree of tightness or looseness between two making parts to perform a definite function when they are assembled together. Ex shaft in a bearing.



C. TOLERANCE

Tolerance is the permissible variation in the dimension of a part as it is not possible to produce a part to exact specified dimension. It is the differences between higher and lower limits of dimension of a part. It may be unilateral and bilateral

Fig 3.2 shows a conventional diagram for limit fit tolerance



TYPES OF FITS

Basically fits are of 3 types

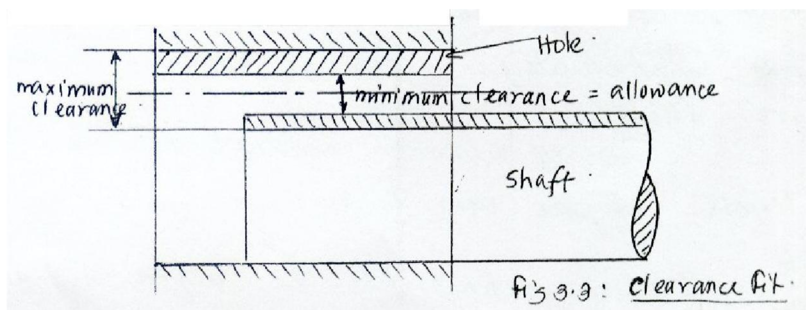
(1) clearance fit

(2) interference fit

(3) transition fit

1.Clearance fit

If the dimension of shaft is less than the dimension of hole even in the case of maximum material condition of hole & shaft, it is called clearance fit as shown in fig 3.3



The clearance fit is again subdivided into the following types depending on the type nature of use.

a. Slide fit

1. It has very small clearance value.
2. The minimum clearance=0
3. It is employed when the moving parts move very slowly.

Ex- (i) Tail stock spindle of lathe.

(ii) Feed movement of spindle quill in drilling m/c.

(iii)Sliding change gears in quick change gear box of lathe.

(b)Easy slide fit

- it has small guaranteed clearness
- Applicable for slow and non regular motion

Ex- (i) spindle of lathe

(ii) Piston & cylinder

© Running fit

- It has appreciable clearance value to make space for lubrication
- Applicable for moderate speed

Ex- (i) Gear box bearing

(iii) shaft pulleys

(iv) crank shaft in their main bearing

(d) Slack running fit

- It has considerable clearance
- Required for compensation of mounting errors.

Ex- (i) Arm shaft of I.C Engine

(i) Shaft of centrifugal pump

(e) Loose running fit

It has largest clearance

Employed for rotation at a very high speed.

Ex- (i) Steam turbine shaft nearing in the bearing at 3000

(ii)idle pulley on their shaft (used in quick return mechanism of planner)

2.interference fit

in this type of fit, the minimum permissible diameter of shaft is greater than max. allowable diameter of hole.

In other words interference exists even in the case of minimum material condition of material parts. The shaft and hole members are intended to be attached permanently and used a solid component. Elastic strain is developed on the making surfaces during the process of assembly and prevents relative movement of the making parts. The interference fit is also subdivided into the following types.

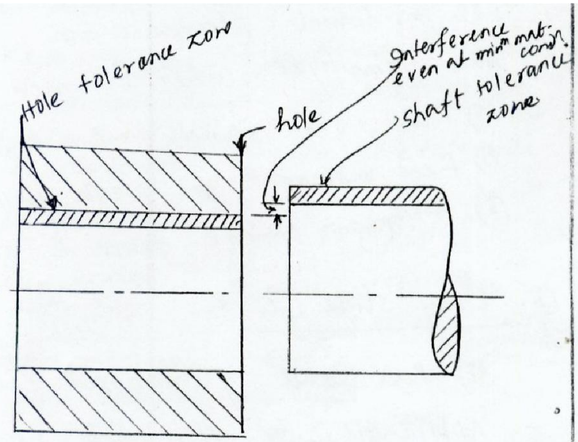


Fig 3.4: Interference fit

a.Tight fit

- Small interference
- Employed for mating parts that may be replaced while over handling of machine.

Ex- (i) stepped pulley on the drive shaft of conveyor

(ii) Cylindrical grinding machine

b.Force fit

- More interference than fight fit (or appreciable inference)
- Employed when the mating parts are not required to be disassembled during their total service life.

Ex- (i) Gears on the shaft of concrete mixer

(ii) die fitted to die holder in forging m/c

© Heavy force and shrink fit

- large interference
- used for permanent assembly

Ex- (i) fitting the iron frame in the rim of wheel used in bullock cart (it is done by heading them rapidly cooling)

3.Transition fit

If there is clearance between shaft hole at minimum material condition and interference at maximum material condition

Transition fit

It is of 2 types

(a)Wringing fit

- Either zero interference or a clearance
- these are used where parts can be replaced without difficulty during minor repair

Ex- coupling rings spigot of mating holes

b.push fit

- This provides small interference
- It is employed to parts that must be dis assembled during operation of a machine
- Ex- change gear slip bushing etc.

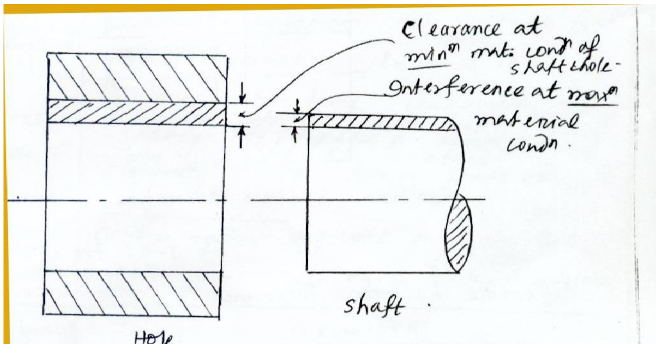


Fig 3.5: Interference fit

D. Allowance

Allowance is the prescribed difference between the dimension of 2 mating parts for any type of fit.

The allowance may be +ve or-ve

The +ve allowance is called clearance and –ve allowance is called interference

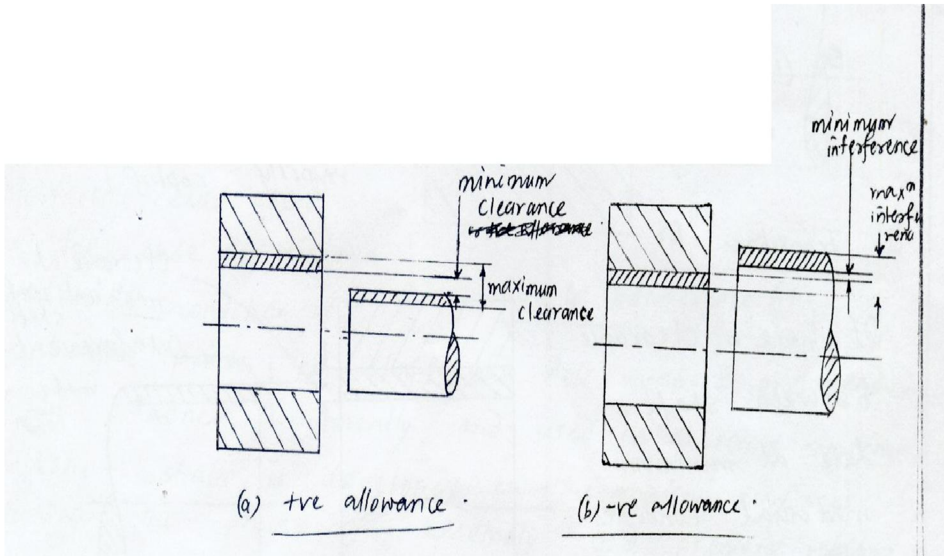


Fig 3.6: +ve & -ve allowances

DIFFERENCE BETWEEN TOLERANCE & ALLOWANCE

Tolerance	**Allowance**
1. It is the permissible variation in dimension of a part either a hole or a shaft)	1.it is the prescribed difference between the dimensions of two mating parts (hole and shaft)
2. it is the difference between higher and lower limits of dimension of a part	2.it is the difference between the maximum shaft and minimum hole size.
3. tolerance is provided or a dimension of a part as it is not possible to make a art to exact specified dimension	3.allowance is provided on the dimension of mating parts to obtain desired type of fit.

Basis of fit system

There are 2 systems for obtaining clearance interference or transition fit these are

1. Hole basis system shaft basis system.

Difference between hole basis & shaft basis system.

Hole basis system	**Shaft system**
1. Size of hole whose lower deviation is zero (H.hole) is assumed as the basic size.	1. Size of shaft whose upper deviation is zero (h-shaft) assumed as basic size.
2. Limits on the hole are kept constant and those of shafts are varied to obtain desired type of fit.	2. Limits on the shaft are kept constant and those of holes are varied to have necessary fit.
3. Hole basis system is preferred in mass production because it is convenient and less costly to make a hole of correct size due to availability of standard drills reamers.	3. This system is not suitable for mass production because it is inconvenient time consuming and costly to make a hole of any size w.r to field shaft size so as to obtain required fit.
4. It is much more easy to vary the shaft sizes according to the fit required.	4. It is rather difficult to vary the hole sizes according to the fit required.
5. It required less amount of capital and storage space for roofs needed to produce shaft of different sizes.	5. It needs large amount of capital and storage space for large numbers of tools required to produce holes of different sizes.
6. Changing of shafts can be easily and conveniently done with suitable gap Gauges	6. Being internal measurement gauging of holes can’t be easily and conveniently done.

Standard limit system

Every country has its own standard for engineering limits and fits. But in order to have universal interchange ability it is essential to followed an uniform standard throughout the world.

Usual standards are

(a) British standard Bs- 4500- 1969

(b) The international standard ISO 286- 1988

(c) Indian standard IS-919

All these 3 standards basically make use of the following

(i) standard tolerance

(j) fundamental deviation

C.ISO SYSTEM OF TOLERANCE

The Indian standards are in line with the ISD (international organization for standards)

It consists of 18 grades of fundamental tolerances (or grades of accuracy for manufacture) and 25 types of fundamental deviation.

The 18 grades of fundamental tolerances are

IT01,IT0,ITI,IT2……. IT16

The 25 fundamental deviations are

A,B,C,D,E,F,G,H,J,J,K,M,N,P,R,S,T,U,V,X,Y,Z,Z,Z,Z

(i.e all alphbet except I,Q,L,O,W, & I – JS +ZA,ZB &,ZC

(26-5) +1+3=25 nos.

The above capital letter symbols are used for hole and corresponding small letter symbols are used for shaft (i.e for shaft a,b,….. ZA,ZB &,ZC

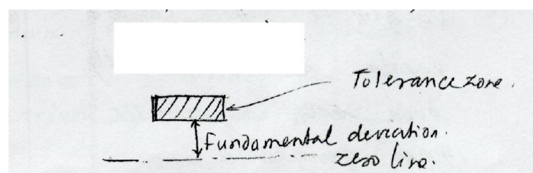


Fig 3-7 : Fundamental deviation & tolerance

Pictorially the tolerance & fundamental deviations are shown aside

the fundamental deviation is nothing but the nearest distance from the zero line to the tolerance zone. The positions of different fundamental deviations for hole and shaft are shown below. (fig 3.8)

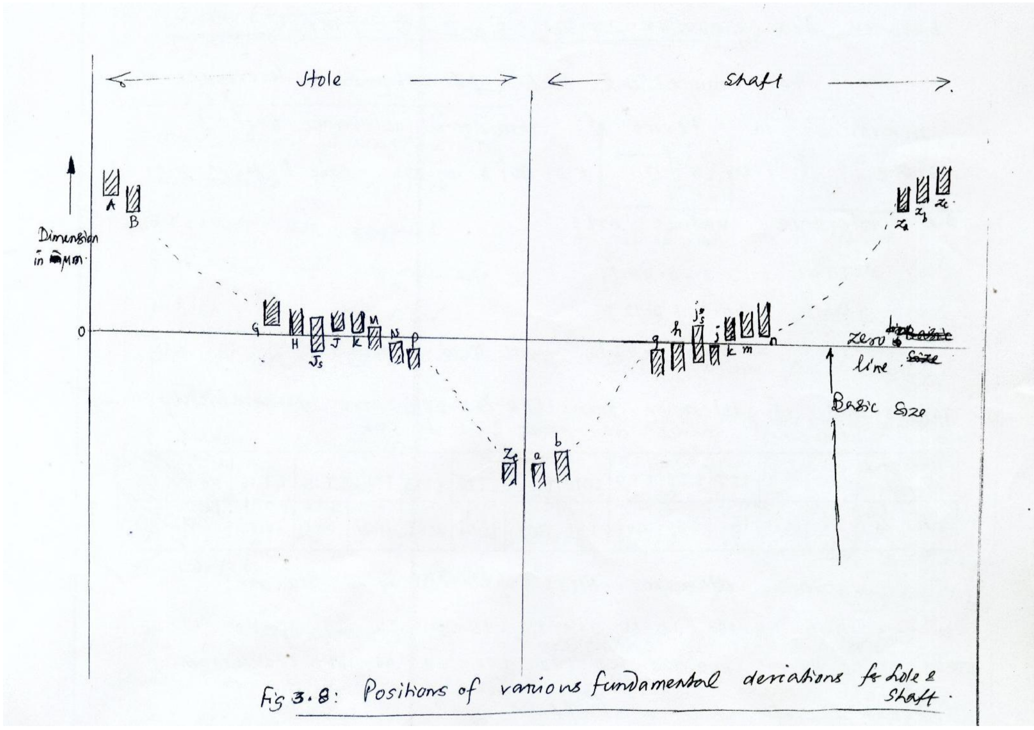


fig 3.8 positions of various fundamental deviations for hole & shaft

for any basic size there are 25 different holes and shafts. A particular hole when combines with a particular shaft (both being at common basic size say 20mm) a definite fit is obtained. For each fundamental deviation there are different grades of tolerances. The tolerance grade decides the accuracy of manufacture. The 7 finest grade (IT01 to IT05) covers size upto 500mm and the rest covers the size upto 3150 mm.

The numerical value of fundamental deviation is determined by using the appropriate formula for specific fundamental deviation.

For ex for ‘f’ shaft   -5.5D 0.41 micron .

Where D= geometric mean of lower and upper diameter of a particular diameter step in which the basic size falls (f8 example if basic size = 20mm falls between dia step 18-24 mm then D= 18x24

The numerical value of standard tolerance are determined in terms of standard tolerance unit ‘i’ where I= 0.45 D +0.00iD micron where D is in mm.

The tolerance values are :

IT01= 0.3+0.08D

IT0=0.5+0.12D

IT1=0.8+0.02D where D is in mm.

The values of tolerance from IT2 to IT4 are geometrically scaled between values of IT1 to IT5

The values of tolerance from IT2 to IT4 are geometrically scaled between values of ~~IT0~~ IT1 to IT5

Tolerance Grade	IT5	IT6	IT7	IT8	IT9	IT10	IT11	IT12	IT13	IT14	IT15	IT16
values	7i	10i	16i	25i	40i	64i	100i	160i	250i	400i	640i	1000i

The various diameter steps specified by IS919 are :

1-3,3-6,6-10,10-14,14-18,18-24,24-30,30-40,40-50,50-65,65-80,80-100,100-120,120-140,140-160,160-180,180-200mm.

design of hole & shaft

A hole or a shaft or assembly is completely described by its basic size followed by appropriate letter and number of tolerance grades.

Ex- 50 H f

-Basic size= 50 mm

Fundamental deviation for hole is 'H' with tolerance grade IT7

Fundamental deviation for shaft is 'f' with tolerance grade IT8

From the above notation the type of fit can be determined since the position of shaft & hole w.r.r zero line is represented by letters of fundamental deviations. It is a hole basic system since H is capital letter.

C. NTERCHANGEABILITY & SELECTIVE ASSEMBLY

what is interchangeability?

Manufacture of machine tools, automobiles, IC engines air craft etc require thousands of components which are identical. In such large scale production (or mass production) each male component should fit with corresponding female component without interchanging the parts present in a lot of identical items (i.e called random assembly) as shown in fig 3.9. if this condition exist it is called interchangeability in manufacturing or simply interchangeability.

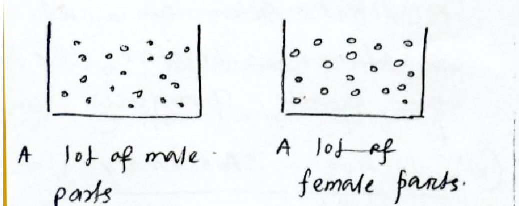


Fig 3.9. male & female Component for assembly

Interchangeability is essential in mass production. Interchangeability is possible only when certain standards are strictly followed. Required fit in an assembly can be **obtained by either**

i.Full interchangeability (if international standard is followed)

Partial interchangeability (if local standard is followed)

(i) **Full interchangeabilit**y(or universal interchangeability) full interchangeability means any component will match with corresponding mating components without classifying manufactured components into subgroups or without going for minor modification for the mating purpose. For full/universal interchangeability international standard must be followed by various manufacturing units. It requires machines capable of maintaining high process capability and very high accuracy.

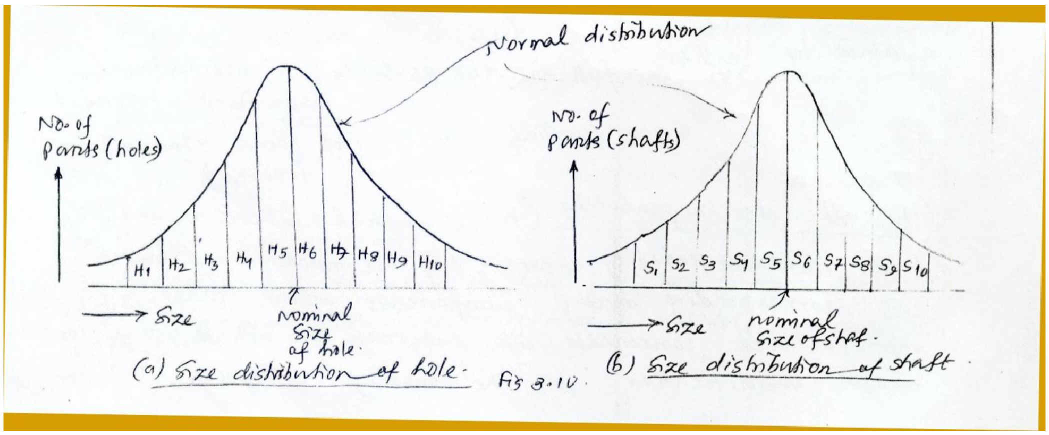
ii.partial interchangeability

When local standard is used the part produced may not be used for replacing similar part in other countries or localities. It does not require high process capability machine. Therefore the parts are less costly than the parts produced under full interchangeability.

iii.Selective assembly (or group assembly)

In selective or group assembly the components produced by machine are classified into several groups according to size. This is done both for hole and shaft. A group of shafts having a particular range of size will match properly with the corresponding group of holes. Because of wider tolerance the manufacturing lost is also reduced.

As an example if some parts (shafts holes) to be assembled are manufactured to normal tolerance of 0.01mm. and the size distribution of shaft holes follow normal distribution pattern as shown below fig 3.10



An automatic gauge can segregate them into 10 different groups (with 0.01mm limit) for selective assembly of a group of shaft with corresponding group of hole (say with HG) thus parts with tolerance of 0.001mm are obtained due to grouping and both the condition.

(i) high quality (narrow tolerance)

(ii) low cost (.01mm man tolerance) are possible . However it is very important that the 2 component parts to be filled together must be kept with normal distribution.

In conclusion the full interchangeability requires high precision costly machine skilled workers and ultimately the parts are costly whereas selective assembly requires less precision and less costly machine with less skilled workers operator and therefore the parts are cheaper although quality can be maintained by grouping.

e.Taylors principle of gauge design

Limit gauges are designed based on taylor's principle

It states that

(i) Go gauges should be designed to check the maximum materials limit while the No go gauges should be designed to check the minimum material limit of shaft/hole

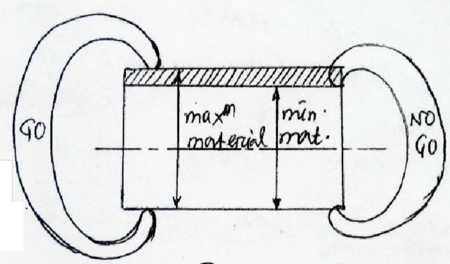


Fig 3.11: GO & NOGO gauges checking max^m & min^m mat. conditions respectively.

(iii) Go gauges should check all the related dimensions simultaneously whereas NOGO gauge should check only one element of dimension.

According to this rule go plus gauge should have full circular section and be of full length of hole it has to check as shown in fig 3.12

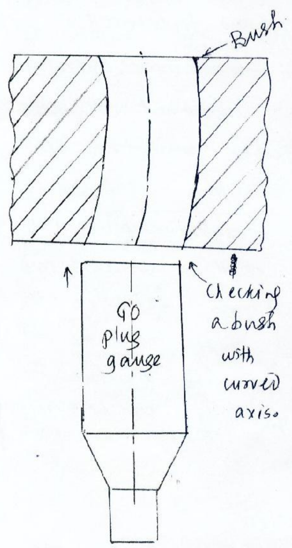


Fig 3.12: Checking the circularity straightness by a GO gauge.

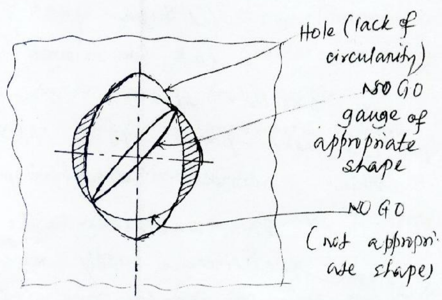


Fig 3.13: NO GO gauge checking the ovality of hole.

This ensures that any lack of straightness/roundness of hole will prevent the entry of full length of GO plug gauge.

Similarly a NOGO gauge with circular section can't check the availability of the hole as shown in fig 3.13. here a pin type shape is appropriate which can check both circularity and size of hole.

C.Gauge design – Basic design rules for plus and ring gauges

Appropriate materials and dimensions are two important aspects of gauge design.

(i) Gauge material

A good quality high carbon steel (cheaper) with suitable heat treatment.

Cr/Wc plated steel for wear and conversion resistant

(ii) Determination of dimension

The following problem will give a guide line for the determination of dimension.

Q-: Design a general type Go and No-Go workshop gauges for component 20 H F fit given

I (micron)= 0.45D + 0.001D

Fundamental deviation for F shaft= -5.5 D

20mm falls in the diameter step 18-24

IT7= 16i, IT8=25i, wear allowance = 10% of gauges tolerance.

Soln

D= 18x24=20.785mm

I= 0.45(20.785) + .00x20.785= 1.258

IT7=16i=16x1.258= 20.128=.020mm

IT8=25i=25x1.258= 31.45 = .031mm

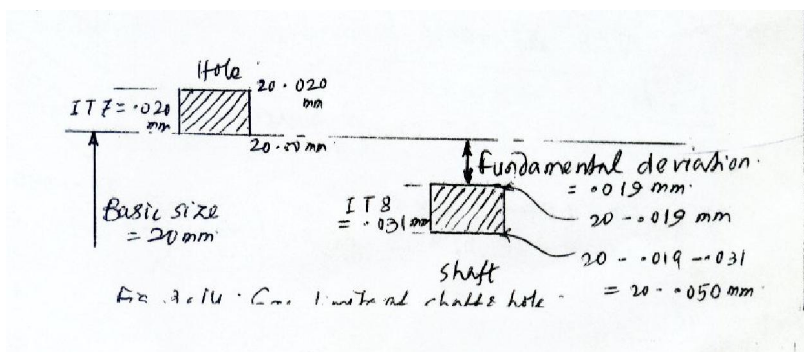
Fundamental deviation for f shaft= -5.5xD=-5.5x(20.758)

=-19.07

=-.019mm

fundamental deviation for H hole =o

now the size limits for shaft e hole is shown in fig 3.14 aside



(a) Design for plus gauges (for hole)

The value of gauges tolerance= 10% of work tolerance

=.10x .020= .0020mm

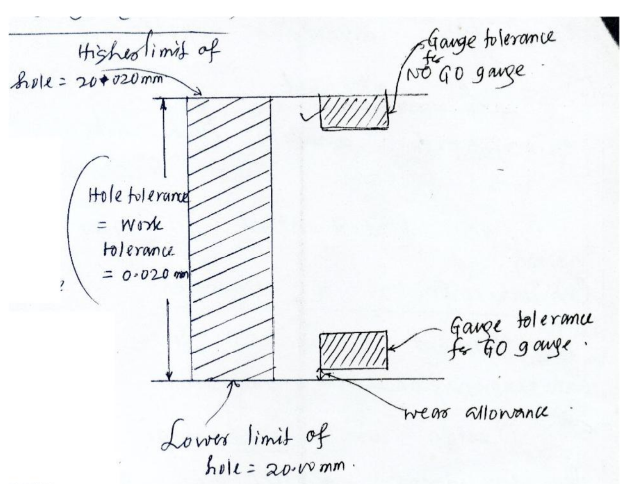
wear allowance=

10% of gauge tolerance

=.10x.0020=.00020mm

with reference to fig3.15

(i)Size of Go plug gauges =20.0002mm lower limit and



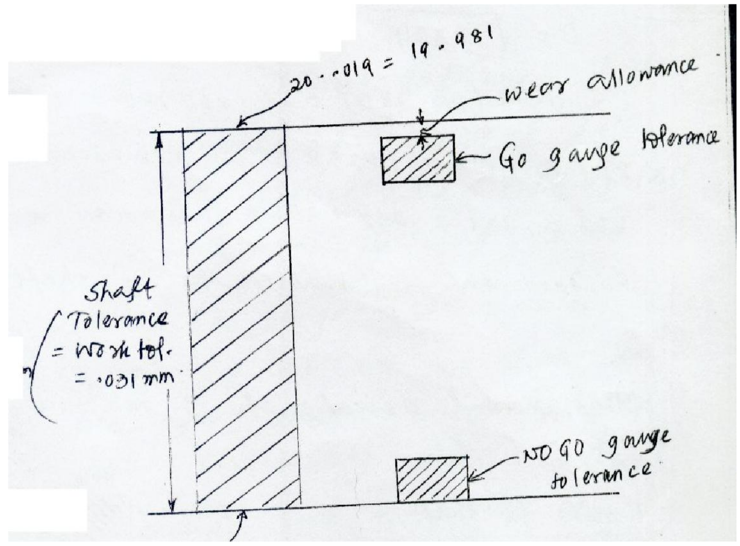
20.0002+.002=20.0022mm-higher limit

(ii)Size of NOGO plug gauges

20.020-

20,020-.002= 20.018 lower limit

b.Design of snap (ring) gauges for shaft



The value of gauges tolerance

= 10% of work tolerance

=.10x.031=.0031mm

wear allowance= 10.1 of

gauge tolerance

=10x.0031mm= .00031mm

with reference to

fig3.16

(i)size of Go snap gauges

=19.9810-.00031

=19.9807mm- higher limit

and 19.9807-.0031=19.9876mm- lowest limit

(iii) Size of NOGO snap gauges

19.95mm--- lower limit

19.95+.0031= 19.9531 higher limit

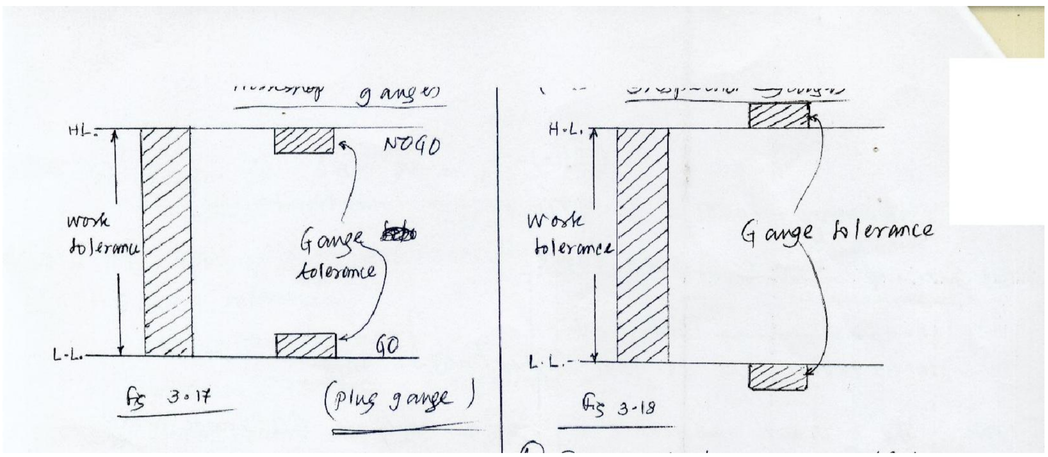
[Note: The wear allowance is provided only to Go Gauge because the Go Gauges are rubbed constantly against the surface of w/p during checkup. The size of go gauges are reduced due to wear. Hence a wear allowance is provided to the Gauges in the direction opposite to that of wear. In case of Go plus gauges wear allowance is added while in ring or shape gauges it is subtracted. The difference between the sizes of these 2 Gauges (Go No Go) is equal to the tolerance on the w/p]

DIFFERENCE BETWEEN WORKSHOP & INSPECTION GANGES

workshop gauges Inspection of gauges

(i)Workshop gauges are used by the operator during manufacture of parts in the shop.	Inspection gauges are used by inspectors for final inspection of the manufactured part.
	These gauges are mode slightly larger

(ii) These gauges usually have limits within those of the components being inspected.	tolerance than the workshop gauges. This is ensure that the work which passes the workshop gauges will be accepted by inspection gauges
iii. The tolerance on the workshop gauges is arranged to fall inside the work tolerance as shown in the next page	The tolerance on the inspection gauges is arranged to fall outside the work tolerance zone as shown in the
iv. Some of the components which are in work tolerance limits may be rejected under workshop gauges	Some components which are not in work tolerance may be accepted when tested by inspection gauges



DIFFERENCE BETWEEN GAUGES MEASURING INSTRUMENTS

Gauges	Measuring instrument
1. Check the dimension a part whether is within a range or not	It measures the actual dimension of a part
2 No adjustment is required while is use	2. Adjustment is required
3 Quick method	3 Time taking Method
4. These are specially meant	4. These are general purpose instruments
5. Less skill is required during use Ex. Limit Gauges	5. Skill is required during use Ex. Micrometer, Varied calipers etc

Various types of plug Gauges

1. Solid type plug gauge for size upto 10mm

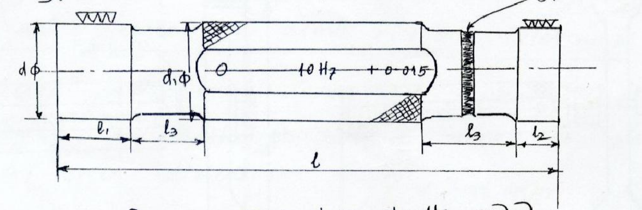
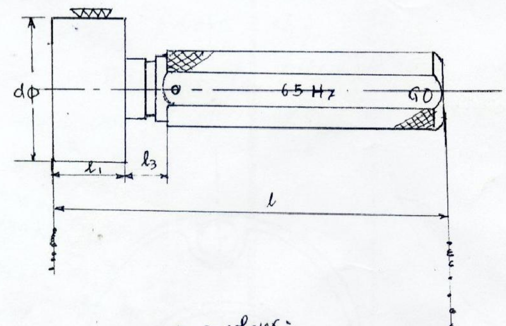


Fig 3.19 · Solid type double ended plain plug gauge Ref from IS-3484.

(Note! Double ended can so upto size 63 mm.)

2. Single ended for size over 63 mm and below 100mm.



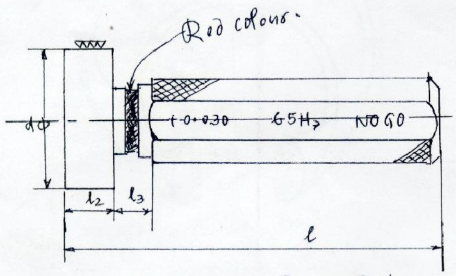


Fig 3. 20 Fastened type GO and NOGO single ended gauges.

3. Flat Type (for sizes over 100mm & upto 250mm)

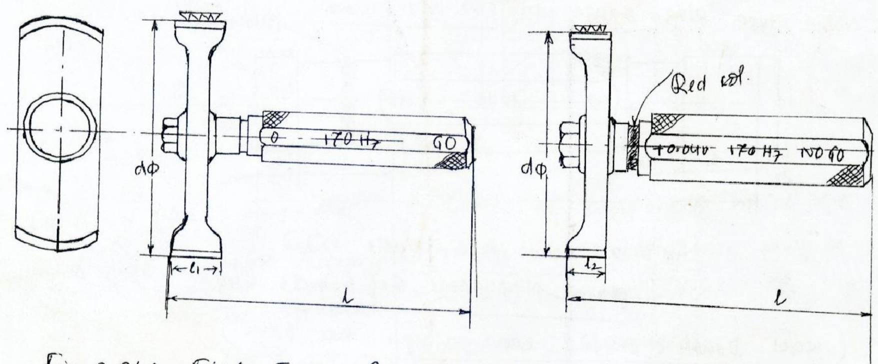


Fig 3.21: Flat Type GO and NO GO plug single ended gauges (from IS 3484)

Snap Gauges

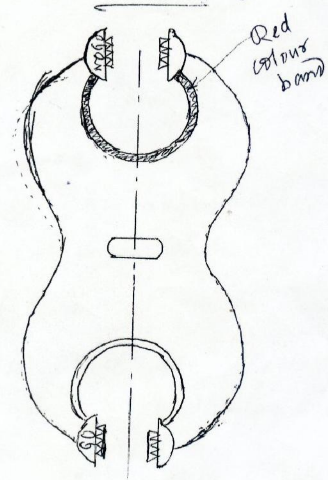


Fig 3.22 Double ended snap gauge for size 3 to 100mm

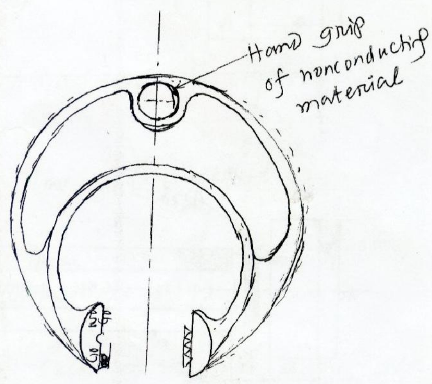


Fig 3.23: Progressive type ring gauge (= snap gauge) for sizes above 100 mm upto 250mm

CHAPTER-4 INTERFEROMETER

1. Types of light sources and interferometer

(A) Types of light sources

A wide varieties of light sources are available for interferometer. The selection of proper source for an application depends on the result to be obtained by interferometer cost and convenience. For simple appli8cating like testing of surface geometry where the different between the interfering path is of the order of few wavelengths only a tungsten lamp with a filter transmitting only a narrow band of wavelength would be adequate.

However sophisticated application requires the use the light sources such as mercury 198 cadmium krypton thallium helium hydrogen neon sodium potassium zinc laser radiation etc. in these sources the discharge lamp is charged with the particular element and contains means to vaporize them. The atoms of these elements are excited electrically so that they limit radiation at certain discrete wavelength.

(B) Interferometer & types of interferometers

Interferometers are optical instrument used for measuring flatness and determining the length of slip gauges. They are based upon the interference principle and employ wavelength of light as their measuring units. The interferometers make use of some type of beam deliver that splits an incoming ray into 2 parts as shown in fig 4.1. the 2 parts of the ray travel along different parts until they are recombined.

In interferometers the lay of optical system can be controlled and the fringes can be oriented to the best advantage. Secondly an arrangement to view the fringes directly from top and above the fringes is also in corporate.

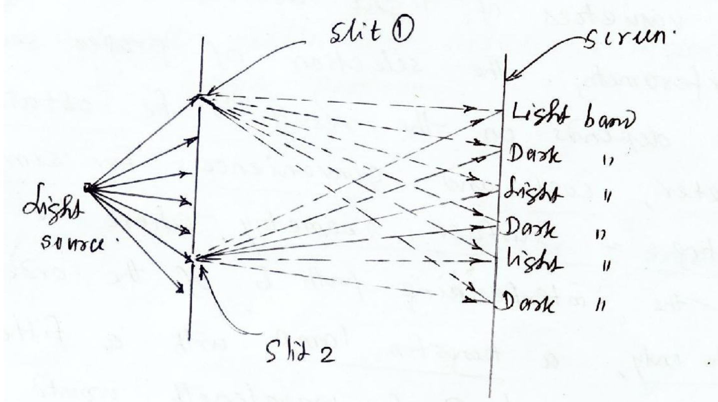


Fig 4.1: Method of producing interference pattern

Types of interferometer

The various types of interferometers are:

(1) Michelson interferometer
(2) Fabre parrot interferometer
(3) Fringe counting interferometer
(4) N.P.L flatness interferometer
(5) Pitter NPL gauge interferometer

(6) Zeiss gauge block interferometer
(7) Multiple beam interferometer
(8) Laser interferometer

1. Michel son interferometer

This is the oldest type of interferometer. It which is monochromatic light from an extend source. The monochromatic light falls on a beam splitter as shown in fig 4.2. the beam splitter is a lain parallel plate having a semi transparent layer of silver at its back. It has 50% reflectance. It splits the light into two rays of equal intensity at right angles. One is transmitted through compensating plate to the mirror and the other reflected through beam splitter to mirror m. from both these mirror the rays are reflected back and these reunite at the semi reflecting surface from where they are transmitted to the eye as shown in fig 4.2. as a result of which the fringes can be observed. The mirror m is fixed whereas the mirror m is movable i.e it is attached to the object whose dimension is to be measured.

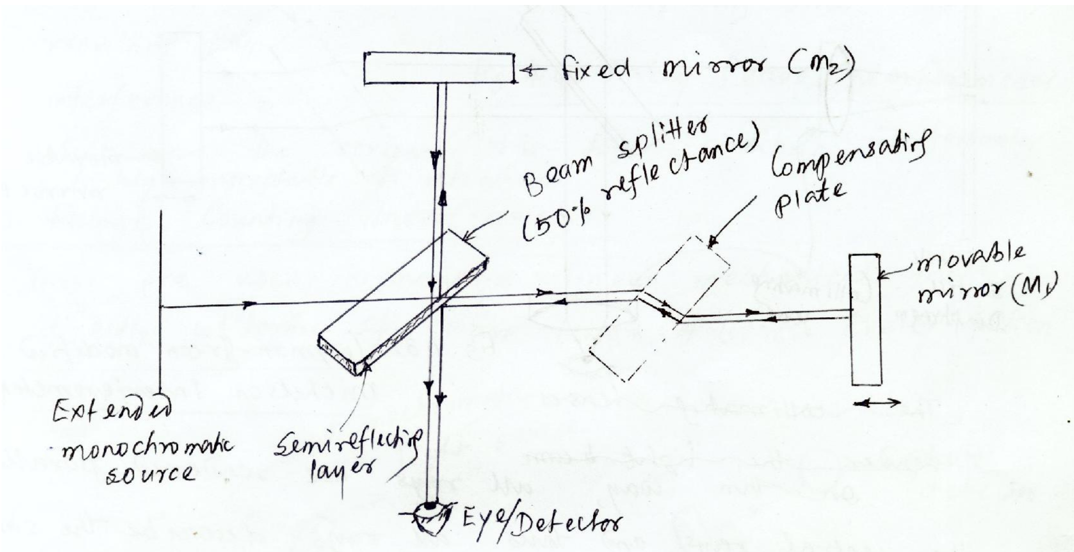


Fig 4.2 : Michelson Interferometer.

Each half wavelength of mirror travel produces a change in the measured optical path of one wavelength and the reflected beam from the moving mirror shifts through 360 phase change. When the reference beam reflected from fixed mirror and the beam reflected from moving mirror rejoin at the beam splitter, they alternately rein force and cancel each other as the mirror moves. Thus each cycle of intensity at the eye represents distance of mirror travel.

1(b) Twyman green specialization of Michel son interferometer.

In the Michelson interferometer the rays actually describe a cone giving rise to various types of fringe patterns which may be different to intercept.
Twyman green modified Michelson interferometer utilizes a pinhole source diaphragm and collimating lenses as shown in fig 4.3

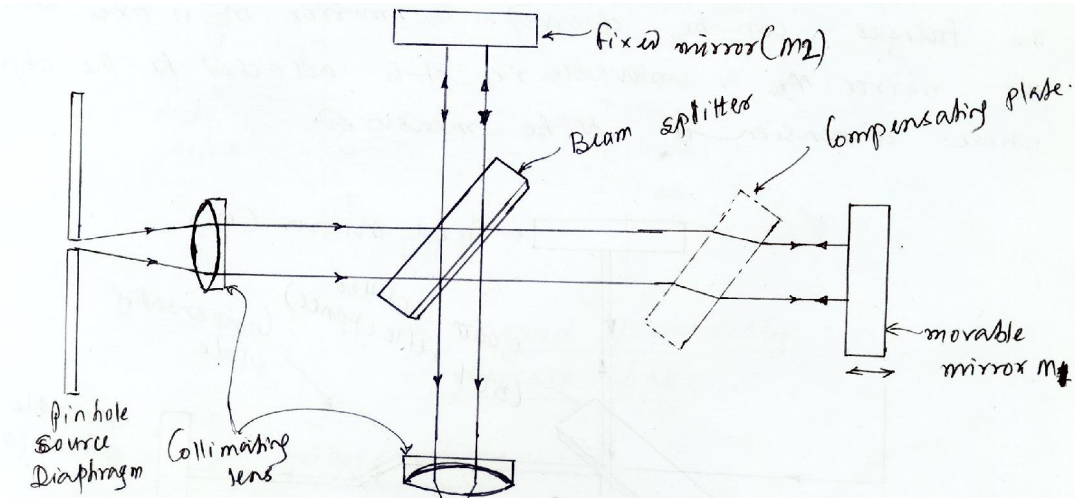


Fig 4.3: Twyman-Green modified Michelson Interferometer

In this way all rays are reared parallel to the central rays and thus all rays describe the same path. All modern two beam interferometer are based on the arrangement. The mirror m,m are arranged to the optical axis. If mirror m is kept fixed and m is moved slowly exactly to itself the observe evil note periodic change in the intensity of the field being viewed from bright to dark for every movement of mirror in fact the intensity variation is found to be sinusoidal.

2.Fabry perot interferometer

This consists of two optical flats counted with high efficiency semi transparent film on the two facing surfaces.

These flats are kept exactly parallel by means of a carefully designed spear when illuminated a series of very sharply defined bright circles resulting from interference is such on the screen. It is high sensitively interferometer & highly susceptible to vibration.

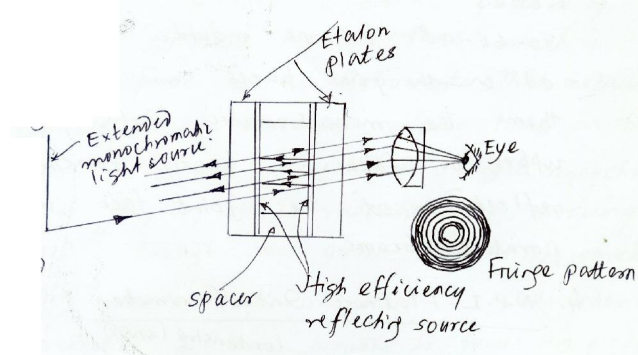


Fig 4.4: Fabry-Perot Interferometer

3.**Fringe counting interferometer**

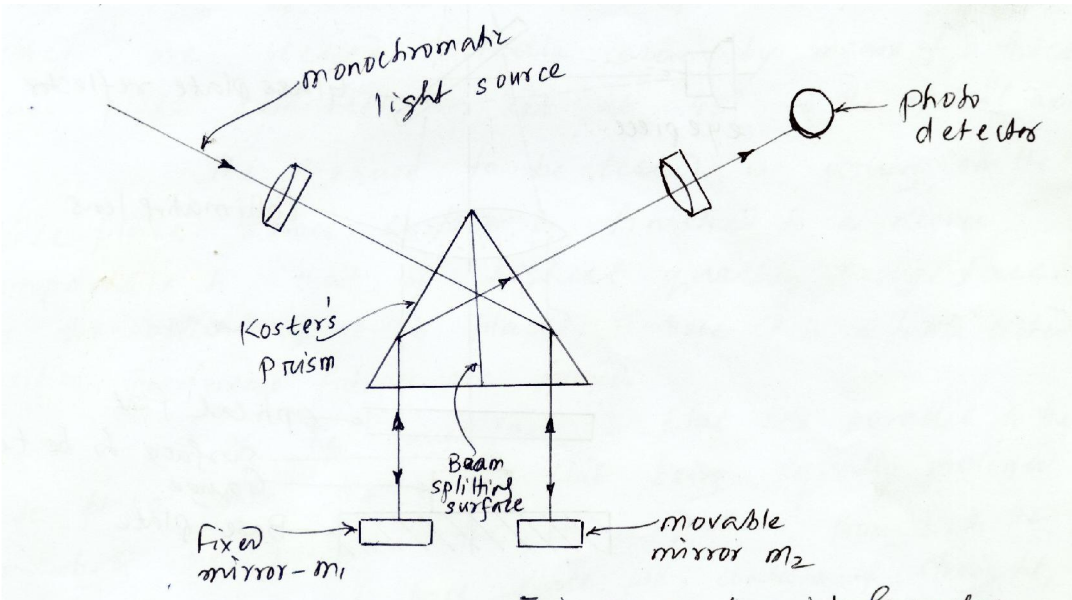


Fig 4.5 : Fringe counting interferometer

These are used to measure linear mechanical motion directly in terms of wave length of light. Every motion of x/2 amount by moving mirror will move the parallel fringes by one fringe. This can be counted by eye or with hole detector.
Kosters prism used in this cosmists of two 30-60-90 prism mounted back to back semi silvered on the joint faces and with an oil film between them. The monochromatic light incident normally on the upper 60 face is party transmitted and party reflected at the joint face and then comes as parallel beams.
4. N.P.L. Flatness's Interferometers

4. N.P.L Flatness Interferometer

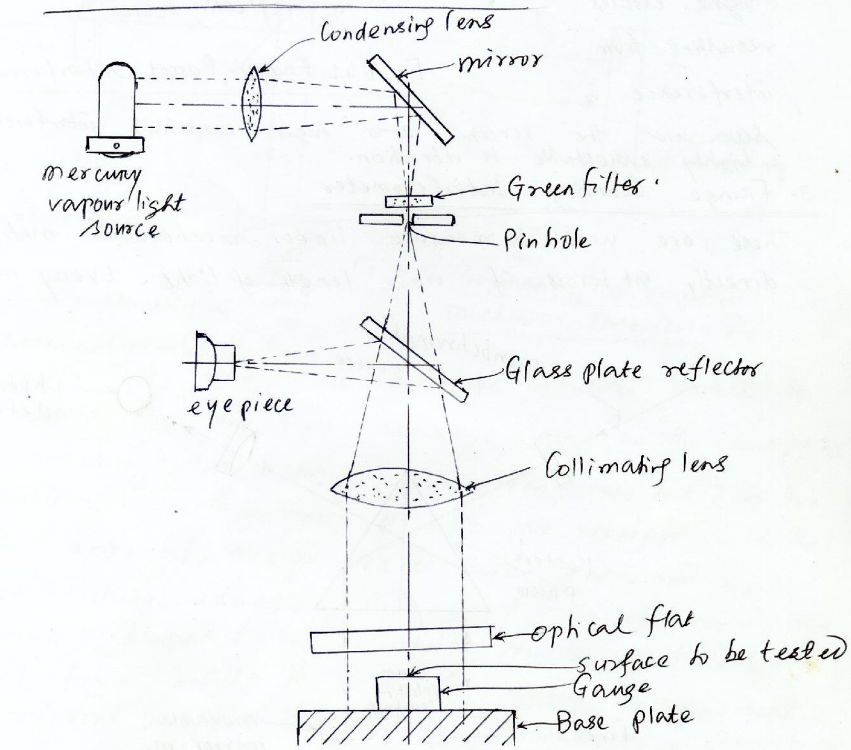


Fig 4.6: NPL Flatness Interferometer

This instrument is mainly used for checking the flatness of flat surface. This interferometer was designed by national physical laboratory and is commercially manufactured by Higher and Wats Ltd.

The flatness of any surface is judged by comparing with an optically flat surface which is generally the base plate of the instrument. This instrument essentially consists of a mercury vapour lamp as shown in fig 4.6. as we are interested in single monochromatic source of light the radiation of mercury lamp is passed through a green filter. The wave length of the resulting monochromatic radiation is of the order of 0.0005mm. this radiation is then brought to focus on pinhole in order to obtain an intense source of light. A mirror is used in order to deflect the light beam through 90. the pinhole is placed in the focal plane of collimating lens thus the radiation out of the lens will be parallel beam of light. This beam is directed on the gangues to be tested via an optical flat. The fringes formed are viewed directly above by means of a thick glass plate semi reflector set at 45 to the optical axis.

The gauge to be tested is wrung on the base plate whose surface is finished to a degree comparable to that of highest quality gauge face. As the optical flat is placed above it in a little tilted position interference fringes are formed.

If the gauge face is flat and parallel to the base plate then the optical flat being equally inclined on both the surfaces the fringe pattern from both the gauge face and the base plate will consist of straight parallel and equally spaced fringes as shown in fig 4.7.

When the gauge is flat but not parallel to the base plate then straight and parallel fringes of different pitch will be seen as shown in fig 4.8.

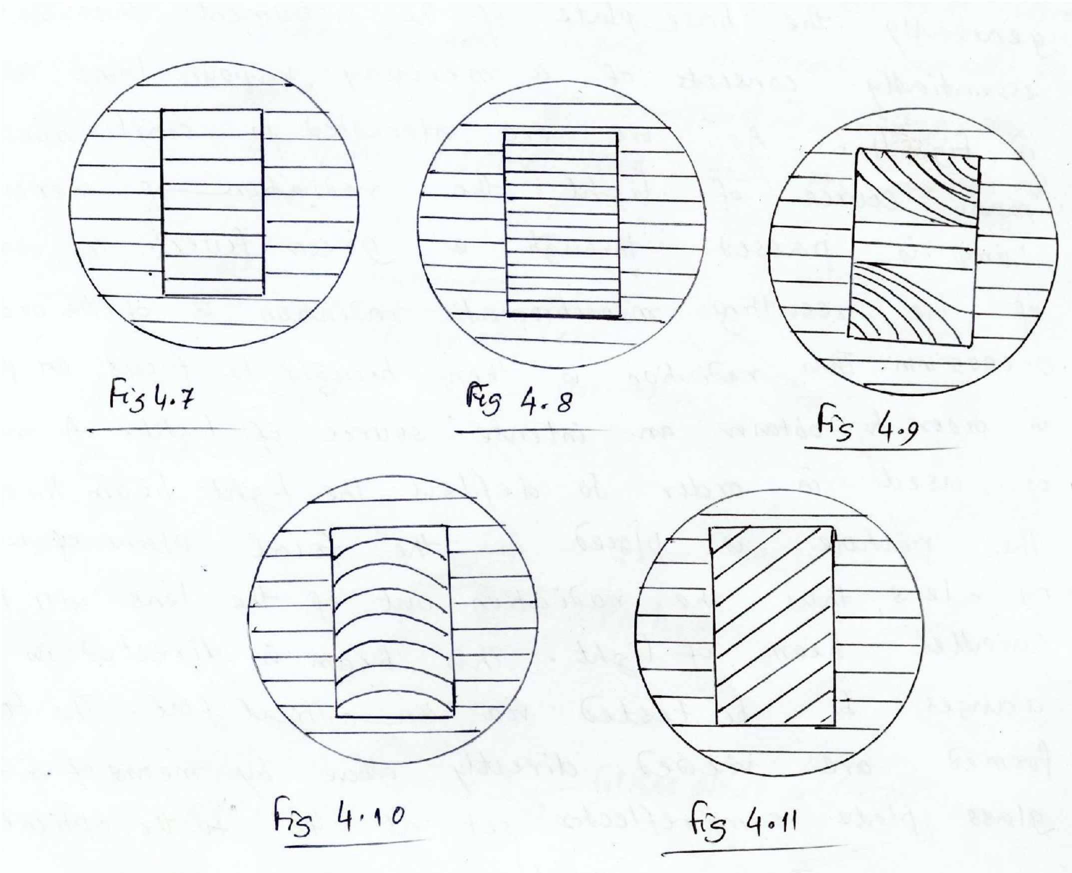


Fig 4.7 Fig 4.8 Fig 4.9 Fig 4.10 Fig 4.11

In case taper is present in some other direction i.e surface of the gauge is inclined to the base plate at some other angle then the fringe pattern will be as shown in fig 4.9.

When the gauge surface is convert or concave then fringe pattern will be as shown in fig 4.10.

Slight rounding of at the corners of an otherwise generally flat and parallel surface will give a fringe pattern as shown in fig 4.11.

5.The pitter –N.P.L Gangue interferometer

This is also called the gauge length interferometer.

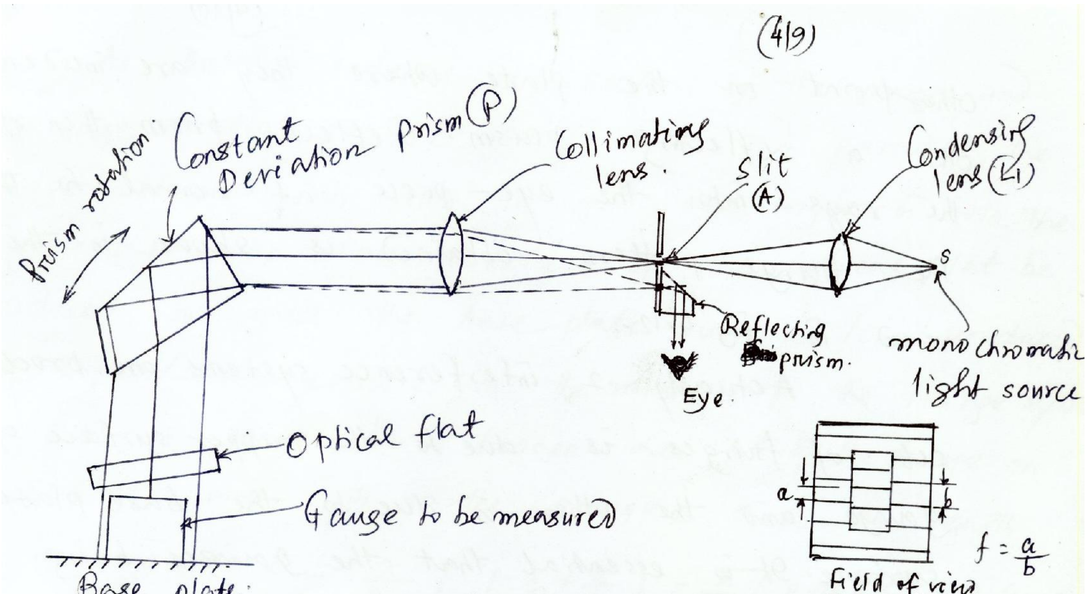


Fig 4.12: Pitter - N.P.L. Gauge Interferometer

It is used for determining the actual dimension or absolute length of the gauge. Fig 4.12 shows the schematic arrangement of N.P.L Gague interferometer. The height from the source falls on the slit A thought condensing lens (L). after collimation by lens l it goes through constant deviation prism P. The constant deviation prism disperses the light into constituent colours. The beams of different colours are reflected downwards by the prism is slightly different directions. In case of cadmium source of light the various colours of beam are red, green, blue & violet. Any one of these colored beam can be directed vertically downward on the gauges & base plate through the optical flat by slightly rotating the constant deviation prism about a certain axis, the rays reflected at the face of the base plate return along the same path approximately as the incident rays. But their axis is tilted slightly due to inclination of optical flat and thus brought to focus at some other point on the plate where they are incident on a reflections prism .Reflections prism then reflects the rays into the eye-piece at normal to these rays. The fringe pattern obtained is shown in the field of view in fig 4.12

Actually 2 interference systems are produce. One set of fringes is due the upper surface of the gauges am he other in due to the base plates reflecting surface. It is essential that the gauges being calibration by this method possess a very high degree of flatness and parallelisms. Only then the fringes pattern from the gauge and base plate will consist of straight parallel and equall spaced fringes of same frequency. Generally two fringe patterns can’t be in phase and will be displayed as shown in fig.4.13. the amount of this displacement varies for each colour and therefore wavelength of light is used. The displacement observed is a and expressed as a fraction of the fringe spacing b ie F= a/b

In order to determine the length of the gauge an estimation of F is made for each of the four radiations from the cadmium lamp.

As the 2 surfaces (i.e surface of the gauge and the base plate) are perfectly flat and parallel the wedge shaped air film is of same angle in both the cases. Let the lower surface of the optional flat be produced to meet the base plate surface line produced at 0. let anywhere in the middle of the fringe system a pair of fringe be choosen. Let P be the fringe on base plate and q on the gauge, then the length of the gauge l= where F= fraction a/b and N= difference of fringes P Q. obviously the value of N will be very large and also complete number as P Q are full integers.

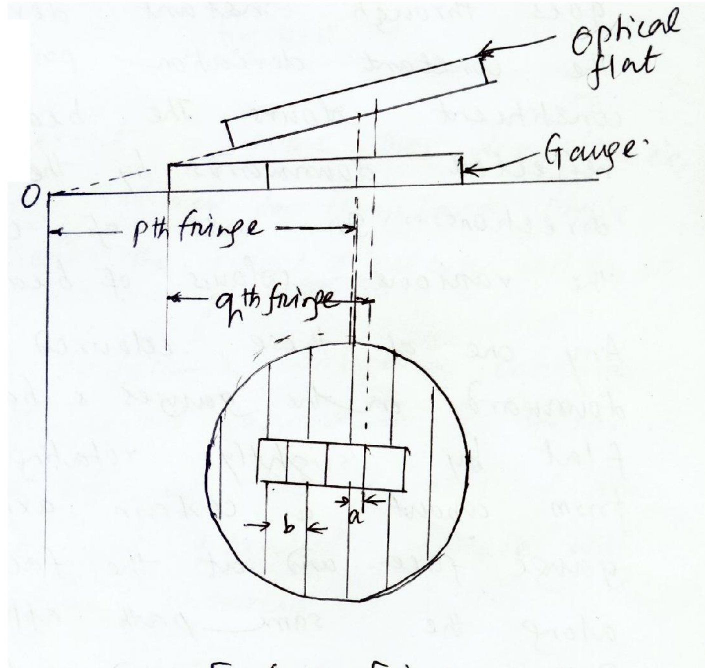


Fig 4.13 : Fringe pattern.

6. Zeiss gauge block interferometer

The working principle of this interferometer is explained with the help of fig 4.14.

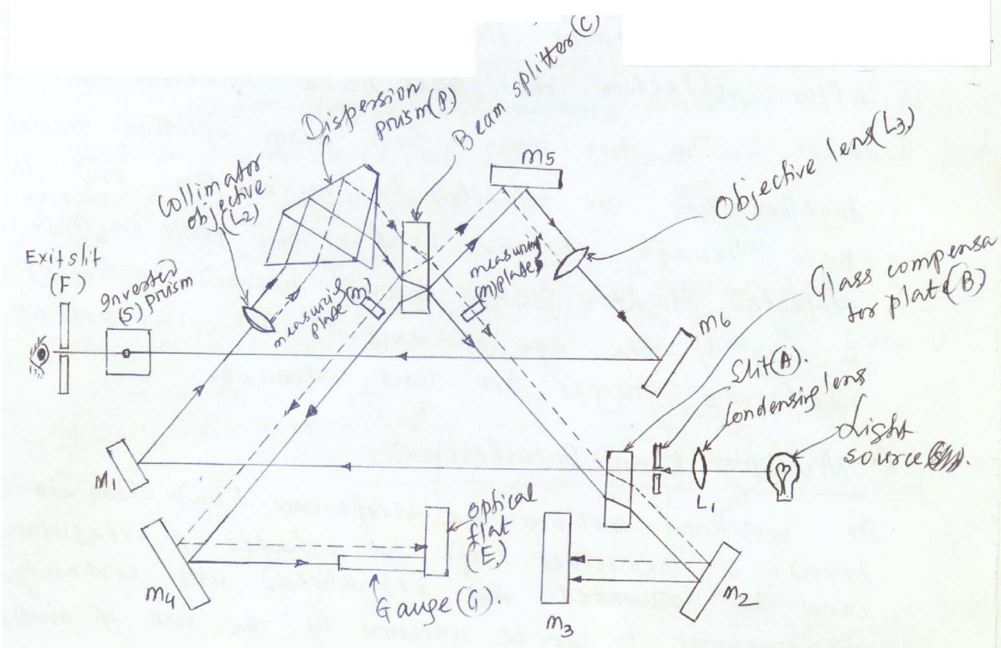


Fig 4.14 : Zeiss Gauge block interferometer.

The light source falls on slit a through condensing lens (L). after that it passes through glass compensator plate (B) and then reflected by mirror M. the reflected ray passes through collimator objective (L). the light rays emerging from this lens are parallel and pass through the dispersion prism (P) and then beam splitter (C). the beam splitter divides the light rays into 2 paths. One side of the beam falls on mirror M after passing through measuring plate (m) and glass compensator plate (B) and then on reference mirror (m). from here it is reflected back and goes back to beam splitter c.

The other portion of the ray is reflected from the beam splitter c and falls on mirror (m) through measuring plate (m). the rays reflected from mirror (m) falls on the gauge block (G) wrung to optical flat. After reflection it goes back to beam splitter c.

The two rays from beam spiller travel together and are reflected by mirror m and then pass through objective lens (L) and falls on mirror m. the reflected light passes through inverted prism(s) and is seen by the eye at exit slit (f). two sets of interference fringes are thus obtained.

7.Multiple beam interferometer

In ordinary methods the in interference bunds obtained are broad in themselves and the shapes of irregularities cannot be established with certainly. This disadvantages can be overcome by the use of multiple beam interferometer. In this type the beam are forced to pass through the interference space a great number of times so that the final image is built up from a large number of partial beams with decreasing intensity in a series. The fringes are sharp. Such a system is shown aside in fig 4.15.

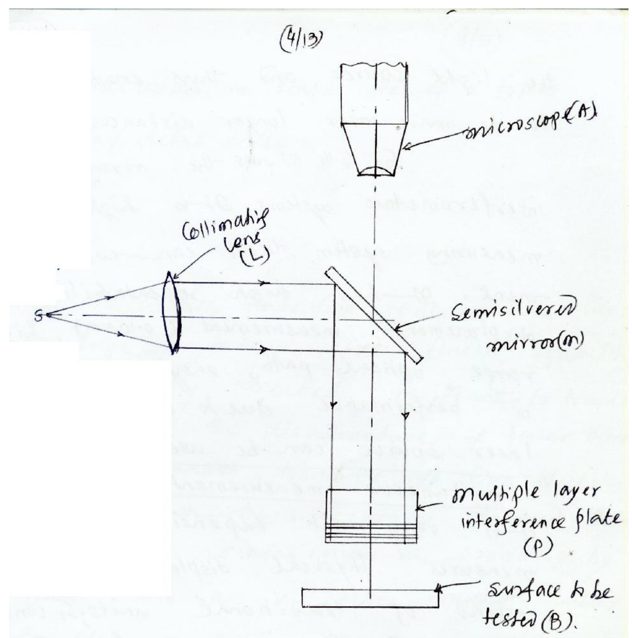


Fig 4.15: Multiple Beam Interferometer

In this system the light from source 'S' falls on semi silvered mirror (m) through the collimating lens(l) and reflected through a multiple layer interference plate (p) and on the surface B to be tested. The fringes are observed through the microscope (A).

8.Laser interferometer

Laser interferometer utilizes the principle of both optical techniques and digital electro rigs. It uses A.C laser as the light source and thus enables the measurement to be move over longer distances.

Fig 4.16 shows the arrangement of a laser interferometer system. It is highly accurate and versatile measuring system that can be with industrial environment. It has high repeatability and resolution of displacement measurement (0.10m) high accuracy long range optical path easy installation and no change in performance due to ageing or wear & fear. A single laser source can be used for as many as six simultaneous measurement in different axes. However it is very much expensive since the basic instrument measures physical displacement in terms of wave length instead of traditional units so conversion instrumentation is required for conventional readout.

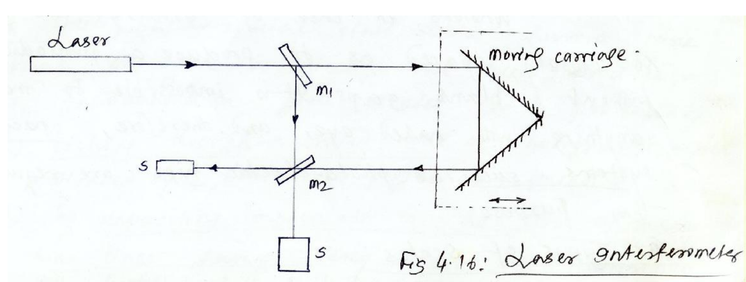


Fig 4.16: Laser Interferometer

C.Types of scale and grating

(a) Difference between scale & grating

Scales are usually made of steel with lines (=rulings) marked on them and spaced relatively far apart so that some sort of interpolating device like vernier device is required to make accurate settings.
Where as in case of grating the rules are so closely spaced as to produce a periodic pattern without blank gaps. It is impossible to make out anything with naked eye and therefore special readout systems such as photo electric type are required for this purpose.

D.Types of scales

Based on the materials the scales are of 2 types
(a) Steel scale /metal scale
(b) Glass scale

(a) Metal scales

Metal scales are usually made from stainless steel which has the advantage of taking good finish stable with time if properly treated resistant to transiting. However it has the disadvantage of lower thermal efficient of expansion than the w/p like steel cast iron. Responding on the accuracy desired the graduations on metallic scales may be produced by

(i) Cutting lines with a v section milling utter on milling M/c or
(ii) Etching through a ruled resist or a photo etch resist copied from a glass master or
(iii) Engaging directly into a polished surface with a sharp diamond

(b) glass scales

glass scales are also commonly used which can be easily polished are stable and are able to work in both transmitted and reflected light. Through ordinary glass has 15-30% less thermal coefficient of expansion than steel but special glass scales having same thermal expansion as steel have been produced. The graduations on glass scales can be produced by

(i) etching through ruled wax or photographic resist activated by contact or projection printing or
(ii) depositing materials in the form of very thin lines having very high edge definition and highly resistant to wear or
(iii) depositing photographic emulsion on glass

most of the scales are produced by duplicating from a master scale on ruling engine. Thre master scale and the scale to be engraved are placed side by side, the master scale being on a fixed table and the other on a carriage . the carriage is successively positioned until master graduations are exactly in the with a reference in the form of a photoelectric microscope and line marked on the scale.

The master scales are produced on ruling engines having an accurate lead screw for successive indexing of the required interval.

The scales may be read by:
(i) naked eye utilizing vernier

(ii) aided by eyepiece or microscope
(iii) projection system which are finding more and more applications as these reduce fatigue.

c.Types of grating

There are 3 types of grating commonly used in moiré fringe system of measurement. These are
(i) Phase transmission grating which are normally produced on selected glass blanks.
(ii) Metal reflecting grating which are used for travel length greater than 1800mm.
(iii) Line and space transmission grating. It includes the widely used 40 lines/mm variety which are reproduced photographically on glass.

The optical system used also differ depending on the type of grating used.
C.Optical flats

Optical flat works on the principle of light interference
It is made of any transparent material usually glass or quartz with 2 highly polished parallel flat surfaces as shown in fig 4.17.

The yellow orange light eradicated by helium gas is most satisfactory for use with optical falat. For greater accuracy of optical flat it must be used in areas where the temperature is constant. The optical flat must be extremely clean when measurements are being made. It is advisable to use lint free paper for cleaning the optical flat and the surface of the part to be measured in order to form fringe band of normal contrast with a diffused monochromatic light, the optical flat must be close to the work but it need not actually touch.

Flatness testing

An optical flat is considered to be placed upon a flat metal surface so that a thin wedge film of air is entrapped between them as shown in fig 4.18. this wedge is stable enough for fringe bands reading because of the presence minute dust particle or lint (friendly dirt) after grease and soil have been removed. A suitably illuminated interference fringes are visible. When the deviation from the planarity are of the order of 1mm or less.

Fig 4.17: Optical flat

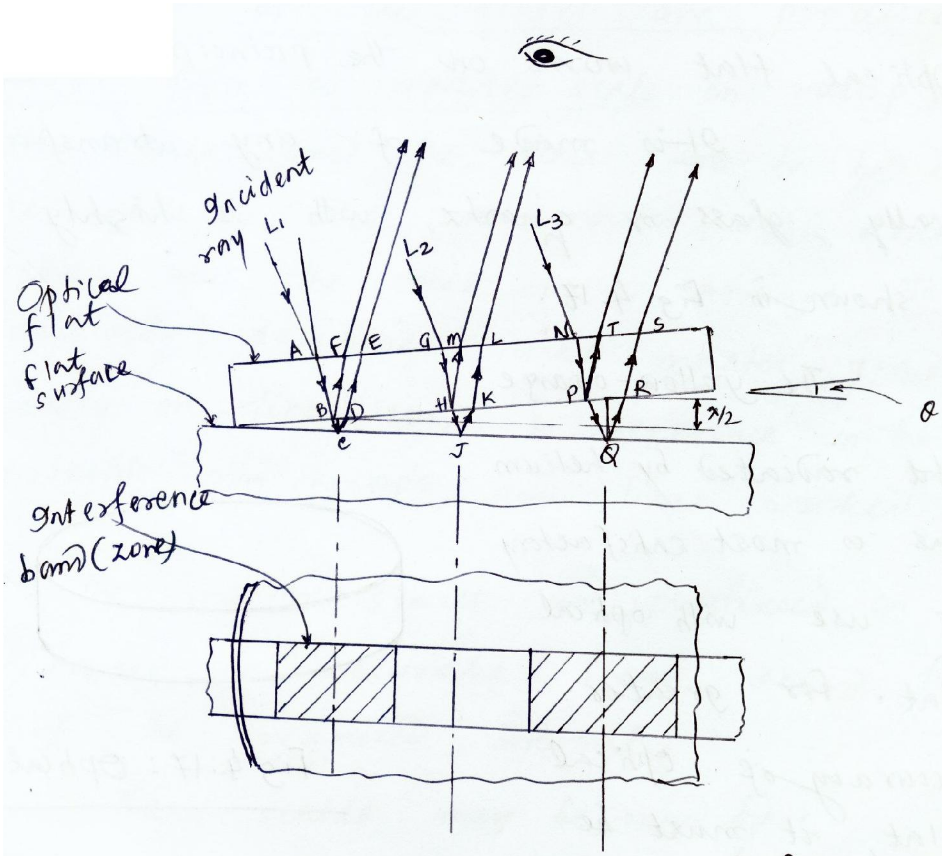


Fig 4.18: Use of optical flat for flatness testing

The behavior of a ray of light as it passes through the optical flat to the surface and thence to the observes eye may be understood as follows

Ray L follows the path AB. At point B a part of the ray if reflected to the follow path BF, while the remainder continues along the both BC and reflected from the mental surface from c and move along paths CD, CDR Both parts of the ray are recombined at the yea, having trussed unequal distances.

If this path difference= old multiple of X/2 dark furnace will be observes

And if this path difference= even multiply of x/2 – a bright fringe will observed at eye.

The rays L2 , L3 follow simple path as describe above

The rate of separation of the lower surface of the flat and the surface under test depends on the angle of the air wedge. If the angle (Q) is too large the rate of separation is correspondingly too great and the fringes will be so close together that they cannot be distinguished one from the another. On the other hand if the angle is too small the fingers will be so for apart as not to appear in sufficient number. Thus the pitch of the fringes varies inversely as the anger Q. therefore it may be necessary to perform a number of the trail placing of optical flat before satisfactory results are obtained.

Since the path difference from one finger the next similar fringe is one whole wave length then PQR-BCD=2 . When the value of Q is very small , the vertical displacement of the surface from the points Q & C are seen to very nearly ½ PQR and ½ BCD Respectively.

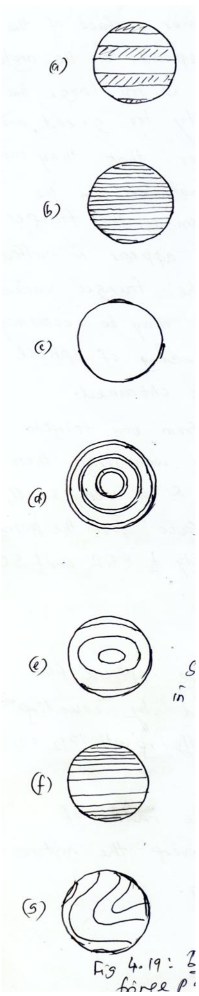
½ PQG –1/2 BCD= 1/2X

The change is elevation between the optical flat and the surface cane be calculated by counting the number of fringes(n) and multiplying with x/2 i.e change in evaluation= n=x/2

Expect the above sue, the nature of surface can also determined by observing the nature of fringes as shown in Fig. 4.19

Surface is flat but inclined.

Small inclination results in wider spacing of finger pattern



Inclined flat surface with large inclination

Inclined flat surface with small inclination

Completely flat surface
No inclination (no fringe)

Spherical surface: To determine whether concave or convex a light finger pressure may be applied at the centre of the fringe. If the fringe bands move towards the centre concave if the fringe bands move away from centre convex.

Surface curved more in one direction than in other direction

Cylindrical Surface

Surface with either ridges & valley

Fig.4.19 : Different fringe pattern

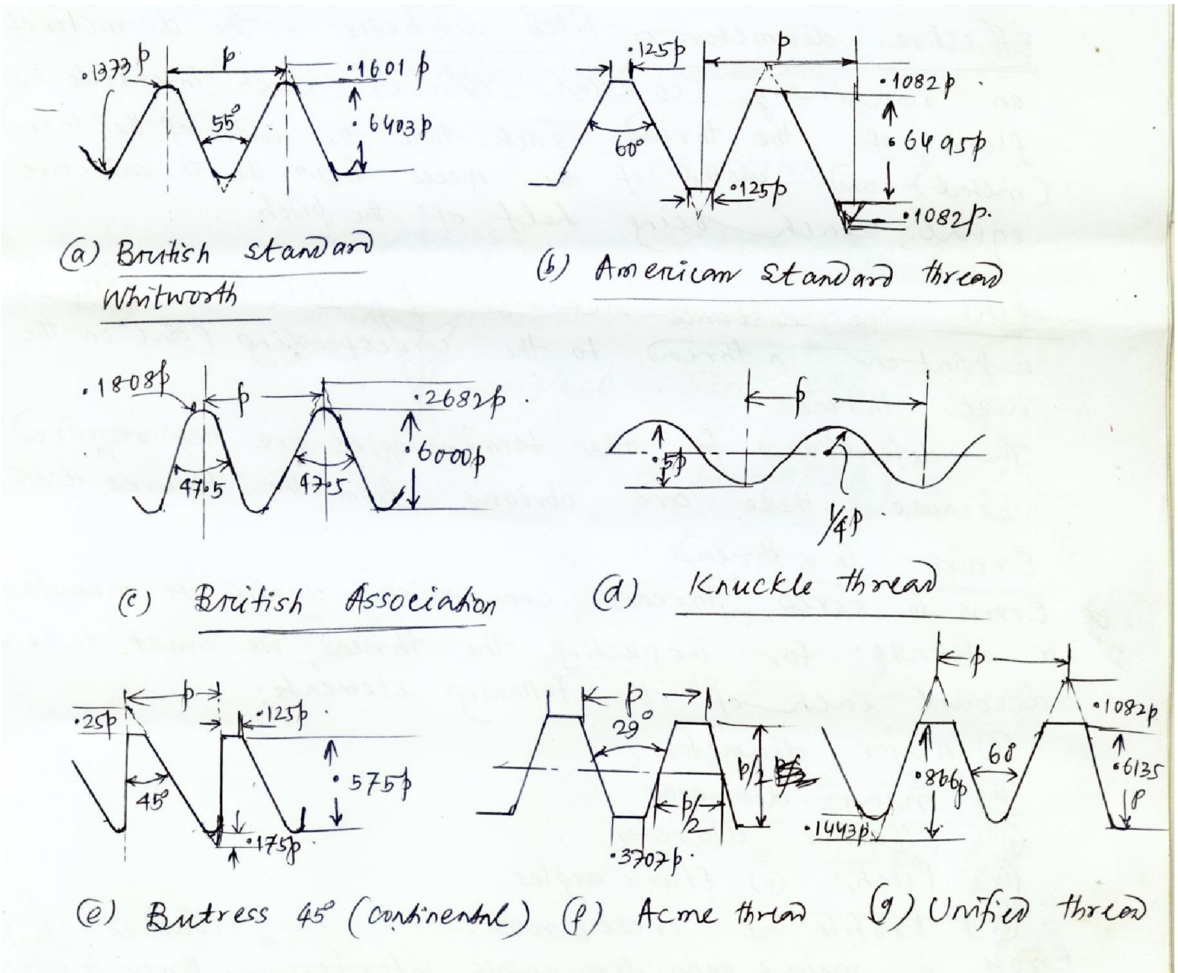
MODULE -III: CHAPTER-5: SCREW THREAD MEASUREMENT

1. Introduction

Screw threads are broadly classified into 2 groups
(a) V threads (used for fastening)
(b) square thread (used for power festering
V threads are more important from metrology point of view.

2. (c) standard thread profiles.

Most commonly used standard thread profiles are shown in fig 5.1.



Fis 5·1: Commonly used thread form.

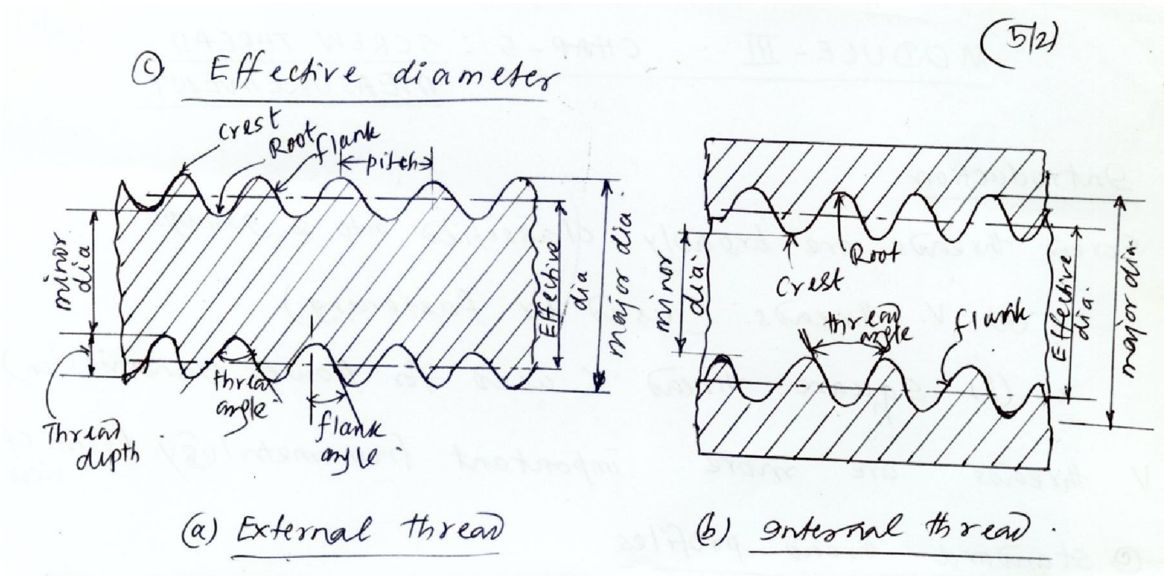


Fig 5.2 Basic nomenclature of external i internal thread.

Effective diameter or pitch diameter is the diameter of an imaginary co axial cylinder which intersects the flank of the threads such that the widths of the threads (metal) and widths of the spaces best the threads are equal, each being halt of the pitch.

Pitch, The distance measured parallel to the axis from a point on a thread to the corresponding point on the next thread.

The definition for their terminologies are not required because there are obvious from the figures itself.

Errors in threads: Errors in screw threads can arise during its manufacture or storage. For inspecting the thread we must take into account each of the following elements.

(i) Major diameter
(ii) Minor diameter
(iii) Effective diameter
(iv) Pitch,
(v) Flank angles
(vi) Profile at crest & roof

Errors in major e minor dia cause interference or reduction in flank contact error in effective diameter determines the amount of slackness or interference between the flanks of metric threads.

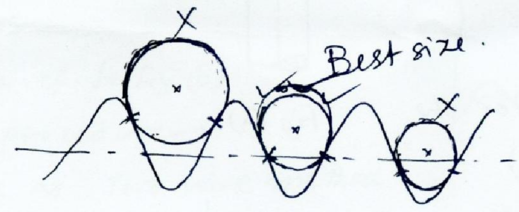
if there is erratic pitch the advance of helix is irregular drunken threaded.

(c) Measurement of effective diameter (= PCD)

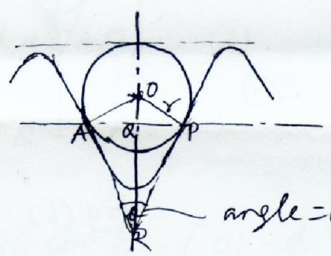
(i) Two wire method/ most popular methods.
(iii) Three wire method

Appropriate size of wire.

The diameter of wire should be such that it should touch at the intersecton points of pitch line with flank as shown below.



<u>Actual size from geometrical calculation</u>



$PQ = \frac{pitch}{4} = \frac{p}{4}$

$\angle POQ = \left(90 - \frac{\theta}{2}\right)$

In $\Delta\ POQ$

$\sin \angle POQ = \frac{PQ}{OP}$

$\Rightarrow \sin\left(90 - \frac{\theta}{2}\right) = \frac{PQ}{OP}$

$\Rightarrow \cos\left(\frac{\theta}{2}\right) = \frac{\frac{p}{4}}{r}$

$\Rightarrow r = \frac{p}{4} \sec\frac{\theta}{2}$

$\Rightarrow 2r = \frac{p}{2} \sec\frac{\theta}{2}$

$$\Rightarrow \boxed{d = \frac{p}{2} \sec\frac{\theta}{2}}$$

for American & metric thread

$d = 0.577p$

for Whitworth $\rightarrow d = 0.564p$

(c) Two wire method

Let d = dia of each wire
p = pitch of thread
θ = angle of thread

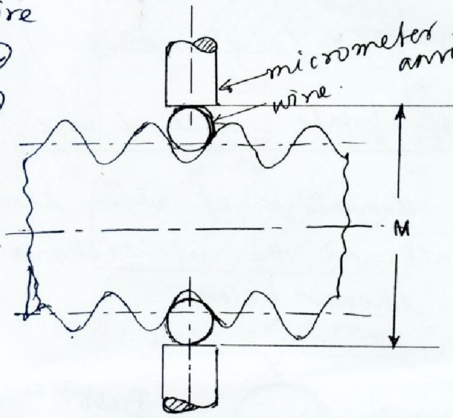


Fig (a)

With reference to Fig (a) shown aside, the dimension bet^n 2 micrometer anvil can be measured. Let it be M.

Let T = dimension under the wire (w.r.t. fig (b))

Now $T = M - 2d$ — (1)

With ref. to fig (b) effective dia → $E = T + 2AQ$

or $E = M - 2d + 2AQ$ — (2)

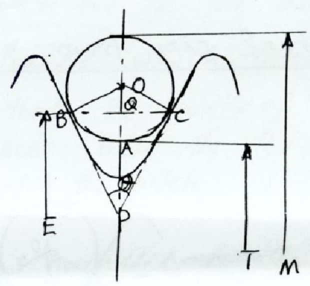


Fig (b)

But $AQ = PQ - PA$

$= QC \cot\frac{\theta}{2} - \left(OP - \frac{d}{2}\right)$

$= \frac{p}{4} \cot\frac{\theta}{2} - \left(\frac{d}{2} \operatorname{cosec}\frac{\theta}{2} - \frac{d}{2}\right)$ $\left(\because \text{In } \Delta POC \quad \frac{OC}{OP} = \sin\frac{\theta}{2} \right.$

$= \frac{p}{4} \cot\frac{\theta}{2} - \frac{d}{2} \operatorname{cosec}\frac{\theta}{2} + \frac{d}{2}$ & $OP = OC \operatorname{cosec}\frac{\theta}{2}$

$2AQ = \frac{p}{2} \cot\frac{\theta}{2} - d \operatorname{cosec}\frac{\theta}{2} + d$ — (3) $\left. = \frac{d}{2} \operatorname{cosec}\frac{\theta}{2} \right)$

Hence Eq^n (2) becomes:

$$E = M - 2d + \frac{p}{2} \cot\frac{\theta}{2} - d \operatorname{cosec}\frac{\theta}{2} + d \quad \text{— (4)}$$

The RHS of eq^n (4) is known because value of M, d, θ are known. So E can be determined

(c) Three wire method

Three wire method is more accurate than 2 wire method because it ensures the alignment of micrometer anvil as shown from the following figure.

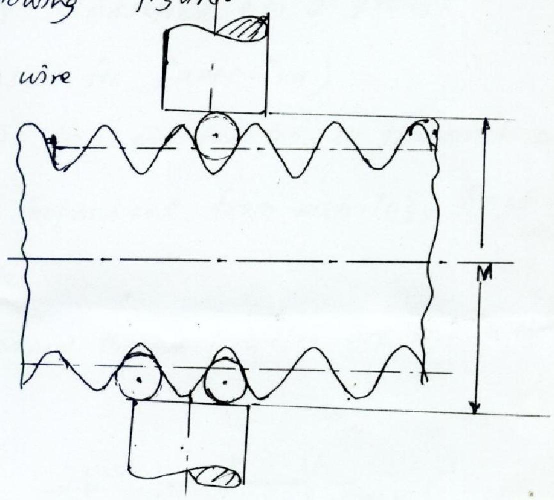


Fig (a)

Let M = distance over the wire

d = dia of each wire

T = distance below the wire.

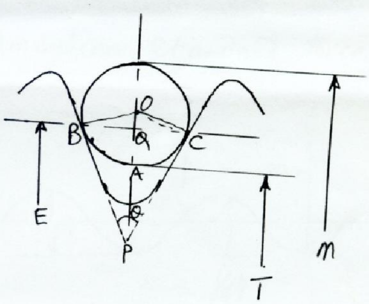
$= M - 2d$ — (1)

With ref. to Fig (b) the procedure is same as Two wire method

i.e. Effective dia →

$$E = T + 2AQ$$

$$= M - 2d + 2AQ \quad \text{--- (2)}$$



But $AQ = PQ - PA$

$$= QC \cot\frac{\theta}{2} - \left(OP - \frac{d}{2}\right)$$

$$= \frac{p}{4}\cot\frac{\theta}{2} - \left(\frac{d}{2}\operatorname{cosec}\frac{\theta}{2} - \frac{d}{2}\right) \quad \text{fig (b).}$$

$\left(\because \text{In } \Delta POC \quad \frac{OC}{OP} = \sin\frac{\theta}{2}\right.$

$\Rightarrow OP = OC \operatorname{cosec}\frac{\theta}{2}$

$\left. = \frac{d}{2}\operatorname{cosec}\frac{\theta}{2}\right)$

$$= \frac{p}{4}\cot\frac{\theta}{2} - \frac{d}{2}\operatorname{cosec}\frac{\theta}{2} + \frac{d}{2}$$

$$\Rightarrow 2AQ = \frac{p}{2}\cot\frac{\theta}{2} - d\operatorname{cosec}\frac{\theta}{2} + d \quad \text{--- (3)}$$

Hence Eqn (2) becomes:

$$E = M - 2d + \frac{p}{2}\cot\frac{\theta}{2} - d\operatorname{cosec}\frac{\theta}{2} + d \quad (4)$$

The R.H.S. of Eq (4) is known so value of E can be determined.

CHAPTER-6: SURFACE ROUGHNESS

1.(c) Source of surface Irregularities in Manufacturing introduction.

Whatever may be the manufacturing process, it is not possible to produce perfectly smooth surface. There must be some imperfection/ irregularities on the surface.

Surface texture.

Surface texture is nothing but repetitive or random deviation from the nominal surface. Surface texture includes roughness, waviness, l ay lines & flaws etc. as shown in Fig 6.1.

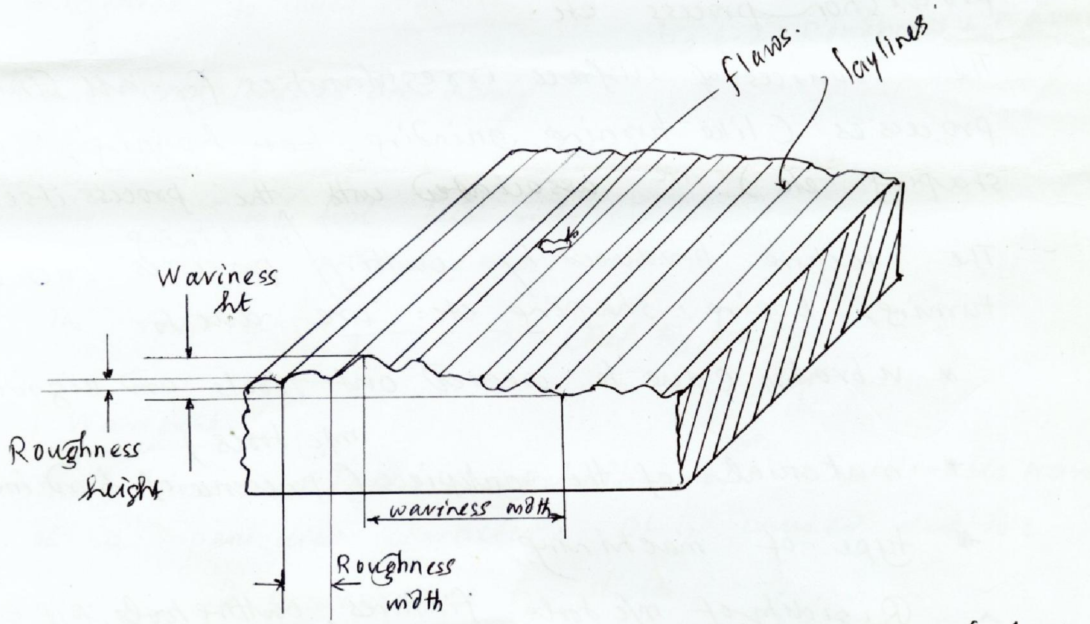


Fig 6.1: Elements of surface texture.

Sources of surface irregularities.

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 component and its suitability for an intended application.

The source of surface irregularities for all performing processes (like casting, hot working, cold working, powder metrology) are associated with manufacture of dies. production process etc.

The sources of surface irregularities for all finishing processes (like turning, grinding, harming, lapping, shaping etc) are associated with the process itself.

The texture produced by writing/machining processes such as turning, boring, shaping etc. are due to

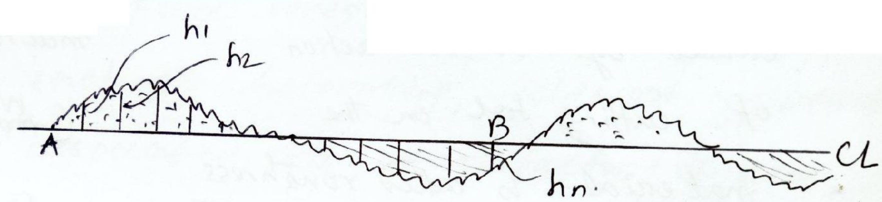


Fig 6.3: CLA value calculation.

* Vibration (due to the weared out tools and rigidity of m/c tools)
* material of the work piece (Presence of land inclusion .
* Type of machining.
* Rigidity of m/c tools, fixtures, cutting tools, w/p etc.
* type, form, materials and sharpness of cutting tools.
* cutting condition (few, sped & depth of unit)
* type of coo/ ant
* Deformation due to weigh of work piece etc.

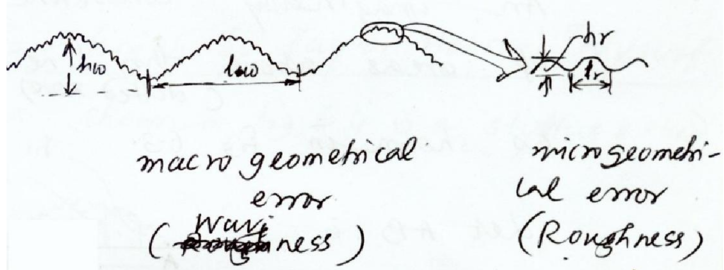


Fig 6-2: Roughness & Waviness

(c) Roughness and waviness

The Irregularities on the surface can be broadly grouped into 2 categories ie.

(i) Primary texture (Roughness)

(ii) Secondary texture (waviness)

1. **Roughness.**

Surface irregularities of small wavelength caused by direct action of cutting tool on the material is called rough tress.

This irregularities are mainly due to

* Shape of cutting tool
*Toll few rate
* Friction /wear/ corrosion

The ration of.Lr/Hr < 50 (ref fig 6-2)

(ii) Waviness

These are surface irregularities of considerable wave length of a periodic character. it is caused due to;

* In accuracies in slides
* wear of guide /guide ways
* Misalignment of centres
* nonlinear feed motion
* information of w/p under the action of writing force
* vibration of any kind.

In this case Lw/Sw >50 (reference fig 6.2)

(c) RMS and CLA values (Re value)

Surface roughness in described by either

* CLA (Centre line average)
* RMS (Root mean square) values

(**a) CLA Value (or arithmetic mean value)**

An imaginary centerline in drawn such that the sum of areas above this line = sum of areas below this line is shown in fig 6.3.

Let AB is the cost of length within which the ra value arithmetic mean value) is to be found out now CLA value = Ra value = $\frac{h_1 + h_2 + ...h_n}{N}$

(b**) Root mean square (RMS) value**

By definition, RMS value= $\frac{h_1 + h_2 + ...h_n}{N}$

It is to be noted that the most common method of specifying/ representing the surface roughness is by CLA value or Ra value.

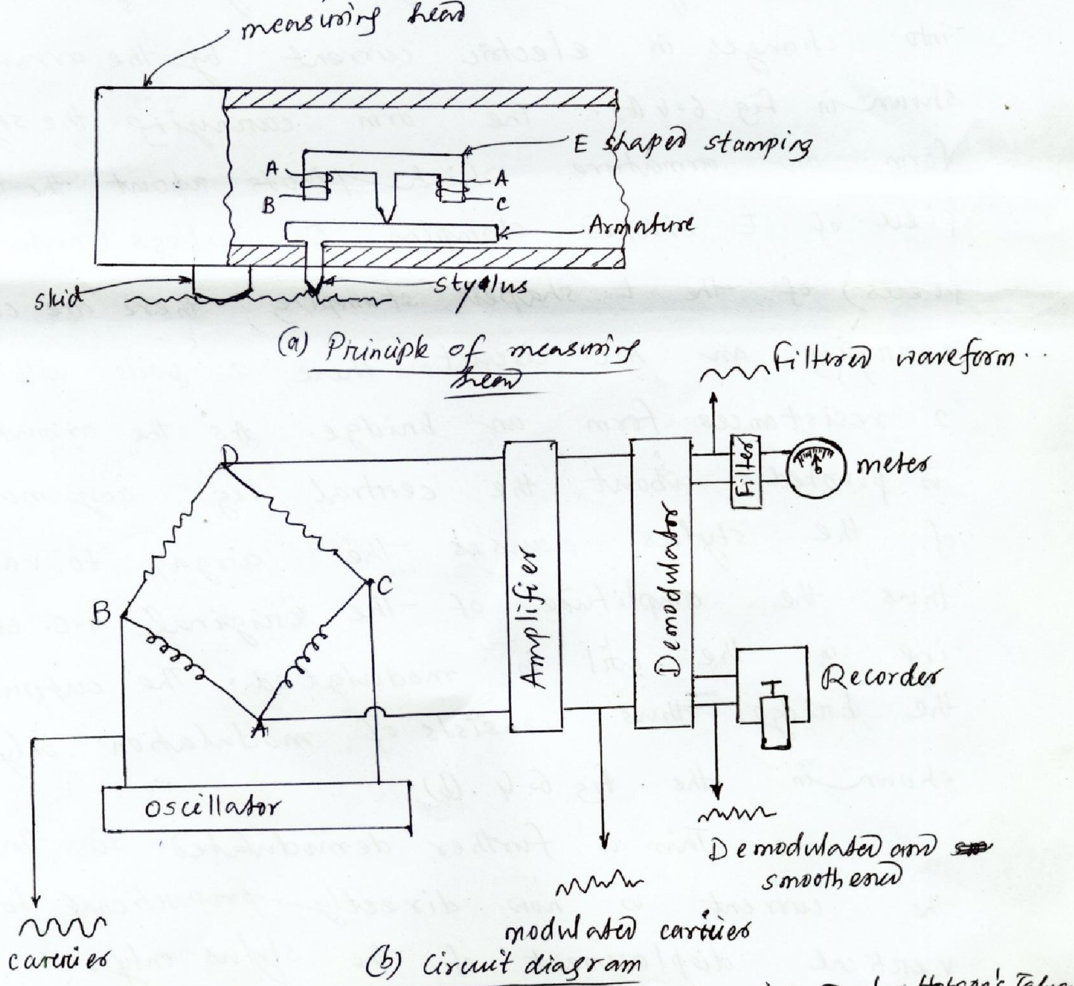
The unit of ra value is micron. The ra values for various manufacturing processes are given in the following

Manf. Process	Ra value in micro metre	
1. Lapping -	0.012	-0.16
2. Super finishing	0.016	-0.32
3. Horning	.025-	.04
4. Polishing	0.04 -	.16
5. Burnishing	0.04-	.8
6. Turning & Milling	.32	25
7. High precision Casting	.32	-2
8. Die casting	0.8-	3.2
9. Permanent Mould Casting	.8	6.3
10. Sand Casting	5-	50

Ra Value in μm	Roughness grade symbol
50	→ ~
12.5 – 25.0	→ ∇
1.6 – 6.3	→ ∇∇
0.2 – 0.8	→ ∇∇∇
0.025 – 0.1	→ ∇∇∇∇

(c) Measurement of surface finish by Taylor Hobson's Talysurf

Taylor Hobson's Talysurf as shown in fig 6.4 is a stylus & skid



(a) Principle of measuring head

(b) Circuit diagram

Fig 6.4 : Principle of measurement using Taylor Hobson's Talysurf type of instrument working on carrier modulating principle. Its response in more rapid and accurate.

The measuring head of this instrument consist of a sharply pointed diamond stylus of about 2 mm tip radius and a skid/ shoe which is drown across the surface by means of a motorized driving unit.

In this instrument the stylus in made to trace on the profile of the surface irregularities and the oscillatory movement of the stylus in converted into changes in electric current by the arrangement shown in fig 6.4. The arm carrying the styles form an armature which pivots about the centre piece of E. shaped stamping. n 2 legs (outer pole pieces) of the E shaped stamping, there are coils carrying an A.C. circuit. These 2 coils with other 2 resistances form and bridge. As the armature is pivoted about the central leg. any movement of the stylus causes the air gap to vary and thus the amplitude of the original a.c.flowing in the coil is modulated. The output of the bridge thus consists of modulation only as shown in the fig 6.4 (b)

This is further demodulated so that the current is now directly proportional to the vertical displacement of the stylus only.

The demodulated output is caused to operate a pen recorder to produce a permanent record and the meter (may be an along type as shown in fig 6.4 (b) or digital type) will give numerical value directly.

The magnification in the vertical direction = 1000 x to 5000 x Whereas the magnification in the horizontal direction -100x

CHAPTER-7 STATISTICAL QUALITY CONTROL

1. **Introduction**

Statistical quality control (sqc) analyze the production output through random sampling from the whole lot of product. It consists of 4 general activities

1. systematic collection of data
2. graphic recording of data
3. analysis of data
4. engineering /management action if there is significant deviation from the standard.

- The ultimate objectives of sqc are
- Exercising quality control
- Improvement of quality
- Creation of consumers confidence
- Entrancement of productivity

The following statistical tools are generally used for the achieving the above objectives

1. frequency distribution
2. control chart
3. acceptance sampling
4. analysis of data

frequency distribution

Graphical representation of data obtained from measurement arranged in ascending descending order according to size. Let 50 pieces of shafts are taken from a lot whose outside dia has been turned. The graphical representation of no of shafts as various dimenson range presented in the following.

Recorded as Follows

Length in mm	freq
9.50 – 9.51	6
952-9.53	2
9.54-9.55	20
9.56-9.57	32
9.58-9.59	22
9/60-9.61	8
9.62-9.63	6
9.64-9.65	4

A. Find arithmetic mean (X) Standard deviation (δ) and variance (δ^2)

B. What Percentage of pins Manufactured has length 9.52-9.63

Length mm	Set Min point (x)	Feq (f)	D = x = k K=9.565	fd	Fd2
9.50-9.57	9.505	6	-.06	-.36	-.216
9.52-9.35	9.525	2	-.04	-.08	.0032
9.54-9.55	9.545	20	-.02	-.40	.008
9.56-9.57	9.565	32	0	0	0
9.58-9.59	9.585	22	+.02	+.44	-0088
9.60-9.61	9.605	8	+.04	+.32	-0128
9.62-9.63	9.625	6	+.06	+.36	-0216
9.64.-9.65	9.645	4	+.08	+.32	-0256

N= $\sum f$ =100, $\sum f$ d=.60 $\sum f^2$ =-1016

(a) Now arithmetic mean (x)= $k + \frac{Efd}{n}$ = 9.565 + 060 = 9.57

Standard deviation $\sqrt{\sum + \frac{Efd^2}{n} - \frac{Efd^2}{n}}$

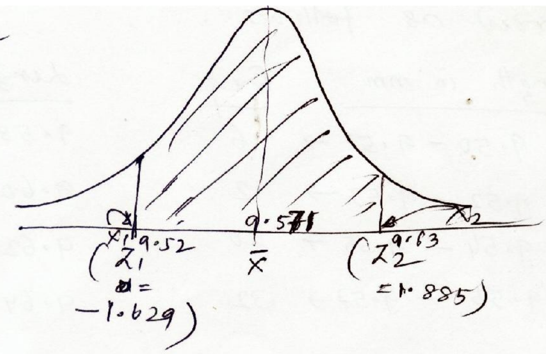
= $\frac{\sqrt{-1016}}{100} - (\frac{60}{100}^2)$

=.0313

Variance= $r^2 = (.0313)^2 = .009796$

(b) % pins lies within length 9.52-9.63

With ref to fig shown aside



$Z_1 = \frac{x_1 - \bar{x}}{\sigma}$

$= \frac{9.52 - 9.571}{.0313}$

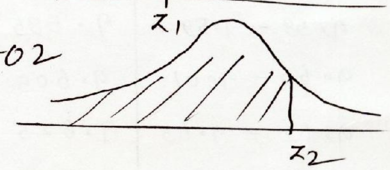
$= -1.629$

Ily $Z_2 = \frac{x_2 - \bar{x}}{\sigma} = \frac{9.63 - 9.571}{.0313} = 1.885$

Referring normal distribution table

Sum of area upto $Z_1 = 0.0516$

Sum of area upto $Z_2 = .9702$



Now area betn Z_1 & Z_2

= .9702 − .0516 = .9186 = 91.86%

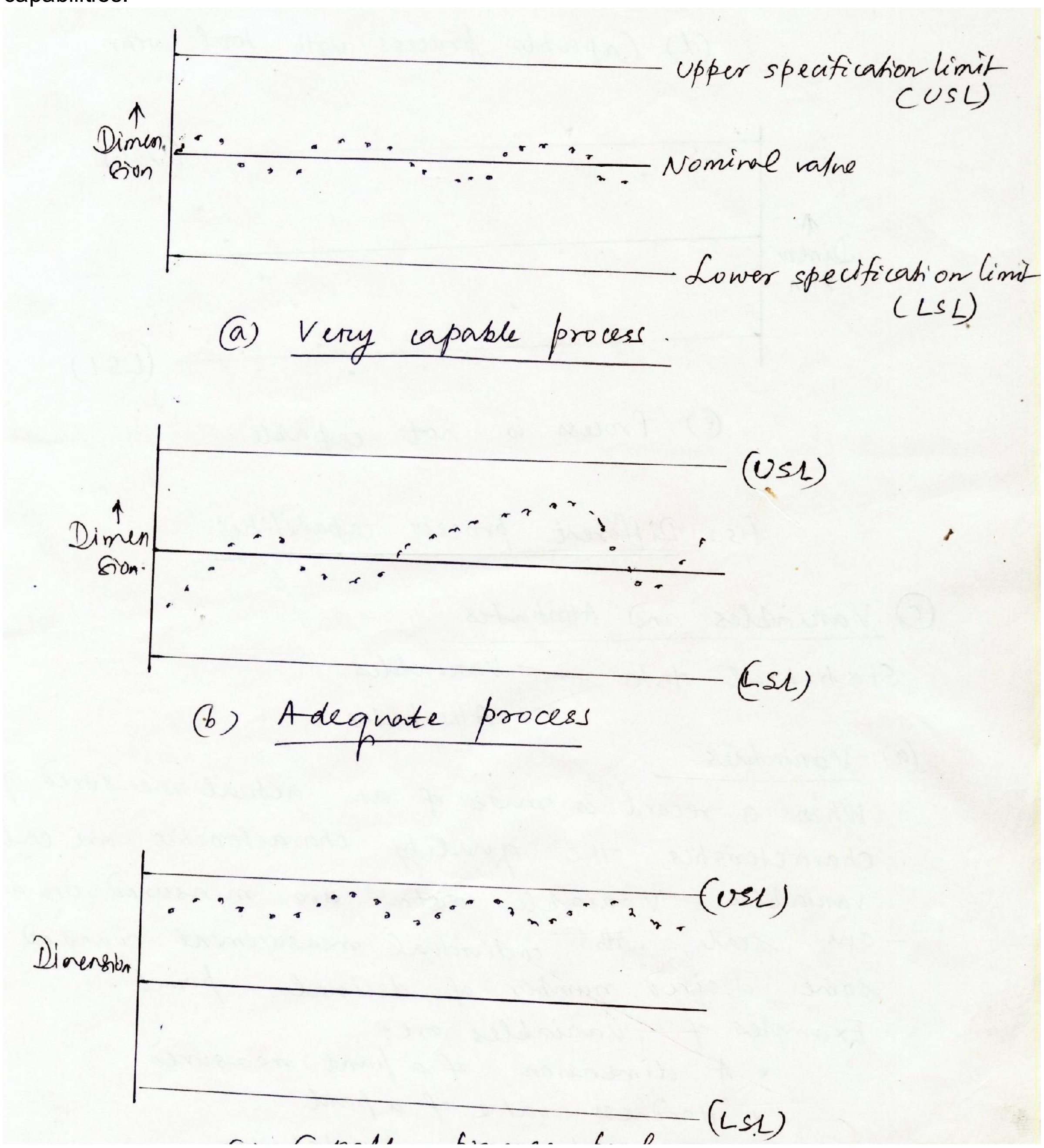
So % pins having length 9.52 to 9.63 = 91.86% Ans

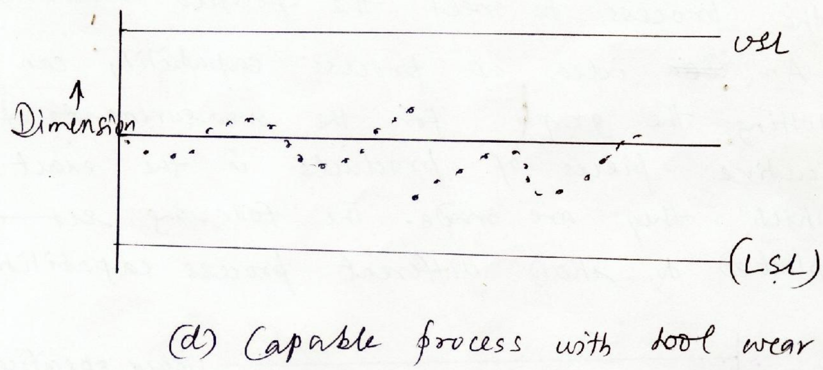
Process capability

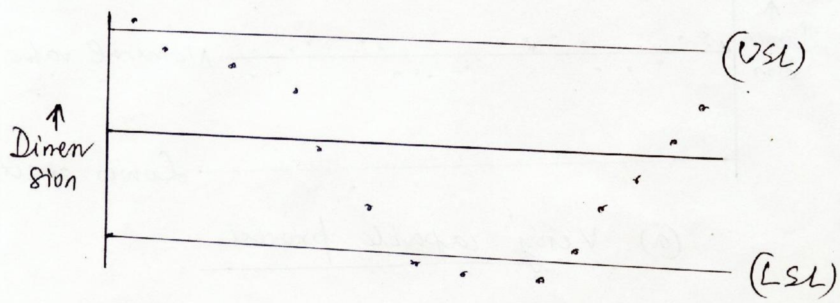
The process capability of a m/c or a manufacturing process is the minimum spread (or minimum tolerance) to which m/c or process is expected to work and produce negligible detective under the specified condition.

In other words process capability = since is taken as a measure of spread of the process. It is also called as natural tolerance. Process capability study carried out to measure the ability of the process to meet the specified tolerance .

An idea of process capability can be obtained by plotting the graph for the measurements of 50 to 100 consecutive pieces of products in the exact order in which they are made. The following set of figures are plotted to show different process capabilities.







PROCESS IS NOT CAPABLE

Fig : Different process capabilities

Variables and attributes
Statistical data Variable
Attributes

A. VARIABLES
When a record is made of an actual measured quality characteristic the quality characteristic are called variables. Variable data are measured on a continuous scale with individual measurement rounded to some desired number of decimal point .
Example of variables are:

- A dimension of a part measured
- Hardness value of a part
- Temperature of a substance
- Tensile strength of some specimen
- Weight of some parts

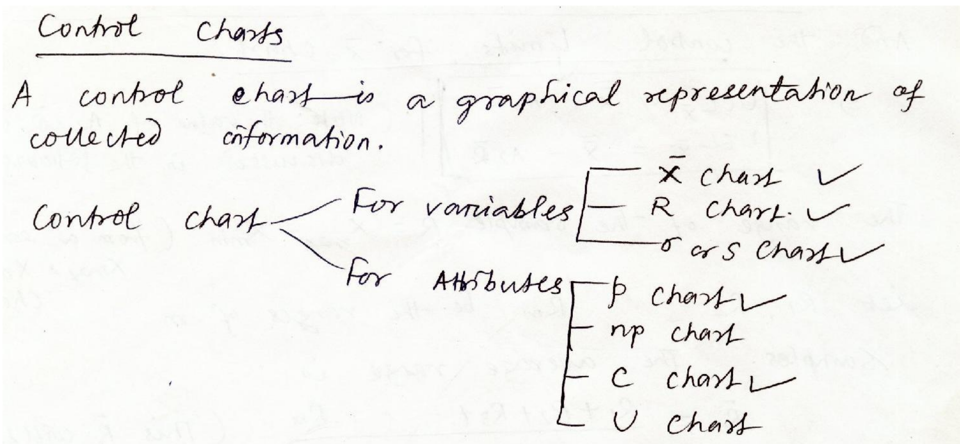
B. Attributes
When a record shows only the number of parts article conforming and number of parts/ articles not conforming to any & specified requirement it is said to be recorded as attributes are discrete data having integer values.

Example:

- Number of detective pieces found in a sample
- Cracks in sheet by spot held etc
- Number of casting defects in a casting

Variable treated as attributes

One can actually note the diameter variable or interested in merely knowing whether the object is good or bad attribute hence at certain times the variable are treated as attributes. Thus the measured quality of objects in dimension is called variable and growing of articles as per the dimension is called attribute (good/bad).



Note: √ marked charts are in syllabus

C.X and R charts

X chart

- It shows changes in process average
- It shows eratic cyclic shift of the process

X chart is always associated with R & (δ /s) charts
R chart: it is chart to measure the spread

plotting of X and R chart

A good number of samples of items /products are collected at random at different intervals of time. Let m samples are taken each containing n observation on the quality characteristic. Typically ‘n’ will be small either 4,5 or 6

If $x_1, x_2 \cdots x_n$ be the quality characteristics of a sample of size n.

Then average value of quality ch. (ex. dimension)

$$= \bar{x} = \frac{x_1 + x_2 + \cdots x_n}{n}$$

Let $\bar{x}_1, \bar{x}_2 \cdots \bar{x}_m$ be the average of each sample, then the best estimator of process average

$$= \bar{\bar{x}} = \frac{\bar{x}_1 + \bar{x}_2 + \cdots \bar{x}_m}{m}$$

Thus $\bar{\bar{x}}$ would be used as centreline of $\bar{x}$ chart.

And the control limits for $\bar{x}$ chart

$$\Rightarrow \quad UCL_{\bar{x}} = \bar{\bar{x}} + A_2\bar{R}$$
$$LCL_{\bar{x}} = \bar{\bar{x}} - A_2\bar{R}$$

(Note: the value of A_2 & $\bar{R}$ will be discussed in the following).

The range of the sample $R = X_{max} - X_{min}$ (from a sample. X_{max} & X_{min} is choosen).

Let $R_1, R_2 \cdots R_m$ be the ranges of m samples. The average range is

$$\bar{R} = \frac{R_1 + R_2 + R_3 + \cdots R_m}{m}$$

(This $\bar{R}$ will be used for $\bar{x}$ & R chart)

Now the control limits & centreline for R chart $\Rightarrow$

$$UCL_R = D_4\bar{R}$$
$$\text{Centreline} = \bar{R}$$
$$LCL_R = D_3\bar{R}$$

T

he values of A,D and D are obtained from table (factors for variable control chart) for different sample size ‘n’
rough drawing of R& X chart

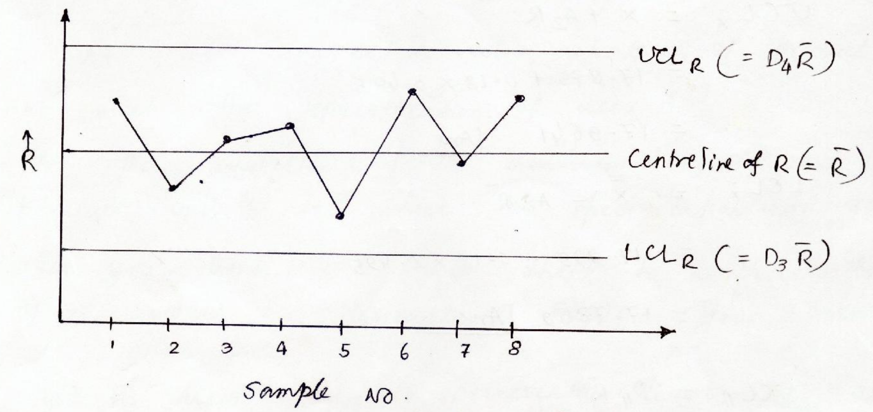


fig (a) → R Chart

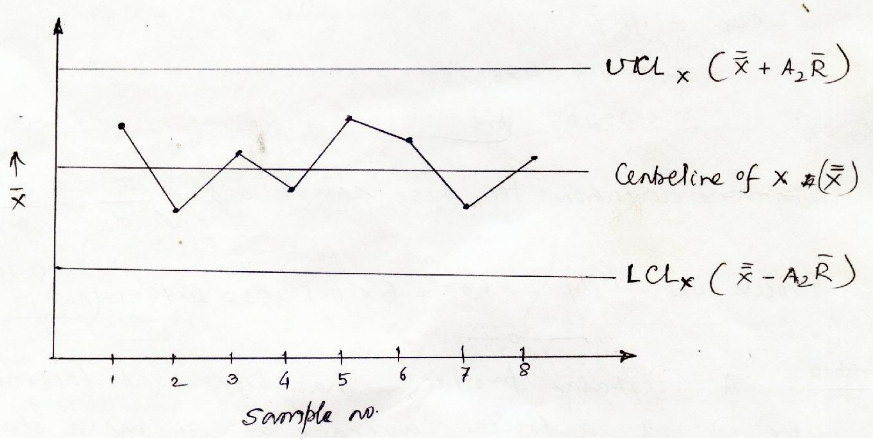


fig (b) X̄ Chart

Prob-1:

Determine the control limits for X and R chart if $\sum$ X=357.50 $\sum$ R=9.90 number of subgroups (=sample) =20 it is given that A_2=0.18 D_3= 0.41, D_4=1.59 and d_2= 3.735. also find the process capability

(6/10)

Soln: $\bar{\bar{x}} = \frac{\Sigma \bar{x}}{m} = \frac{357.50}{20} = 17.875$

$\bar{R} = \frac{\Sigma R}{m} = \frac{9.9}{20} = 0.495$

$UCL_{\bar{x}} = \bar{\bar{x}} + A_2 \bar{R}$

$= 17.875 + 0.18 \times 0.495$

$= 17.9641$ Ans

$LCL_{\bar{x}} = \bar{\bar{x}} - A_2 \bar{R}$

$= 17.875 - 0.18 \times 0.495$

$= 17.7859$ Ans

$UCL_R = D_4 \bar{R}$

$= 1.59 \times 0.495$

$\simeq 0.79$ Ans

$LCL_R = D_3 \bar{R}$

$= 0.41 \times 0.495$

$= 0.20295$ Ans

Standard deviation for these sample $= \hat{\sigma} = \frac{\bar{R}}{d_2} = \frac{0.495}{3.735}$

$= 0.13253$

Process capability $= 6\hat{\sigma} = 6 \times 0.13253 = 0.79518$ Ans

Problem- 2

A certain product has been satisfactorily controlled at a process average of 36 and a standard deviation of 1.00. the product is presently been to two user who have different specifications,

For user A- specification= 38.0±4

For user B- specification – 36±4

Based on the present process setup what % of the product will not meet the specification set up by A

What % of product will not meet the specification of user B?

Assuming that the two users need are equal a suggestion is made to shift the process average to 37.

At this suggested value what % of product will not meet the specification of user A?

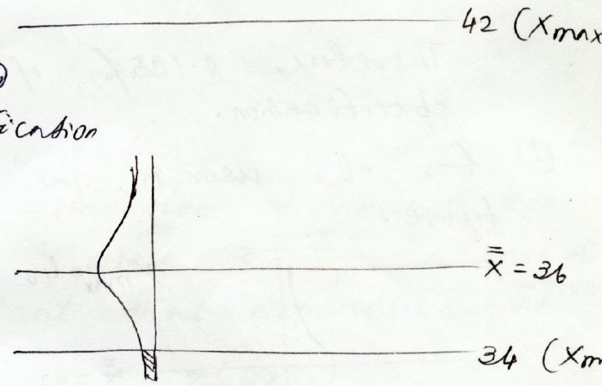
At the suggested process target what % of product will not meet the specification of user B?

Do you think that this shift to a process target of 37 would be desirable ? explain your answer.

Sol^n (a) for user A upper specification limit $= X_{max} = 38+4 = 42$
and lower " " $= X_{min} = 38-4 = 34$

Process capability $= 6\sigma = 6 \times 1 = 6$
Process average $= 36$

The amount of defectives will corresponds to the shaded area below the lower specification limit (X_{min}) of 34.



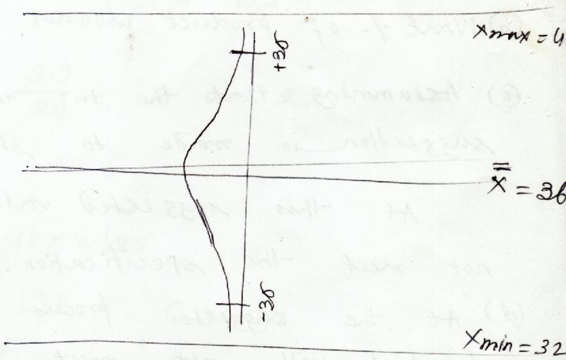
i.e, $z_1 = \frac{34-36}{\sigma} = \frac{-2}{1} = -2$

Corresponding area from normal distribution table $= 0.0228$.
Therefore, 2.28% of the product will not meet the specification setup by A.

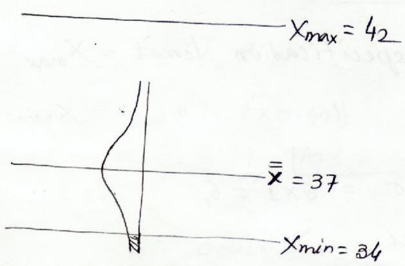
(b) For user B the upper specification limit $= 36+4 = 40$
and lower " " $= 36-4 = 32$

$(X_{max} - X_{min}) > 6\sigma$ and the process is midway, therefore, all the products will meet the specification for the user B.

This fact is represented pictorially as shown aside.



(c) When the process average is shifted to 37. The situation for user A is represented in the following



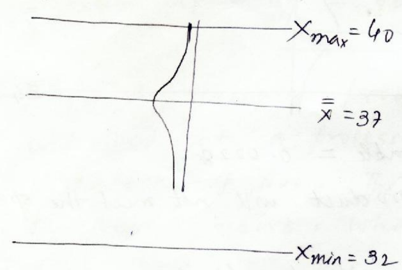
The defective products will corresponds to the area below the lower specification limit 34

i.e. $z = \frac{34-37}{1} = -3$

Referring Normal distribution table area $= 0.00135$

Therefore, 0.135% of the product will not meet the specification.

(d) For the user B, the situation is represented in the following figure.



The defective products will corresponds to the area above the upper specification limit. In this case $z = \frac{40-37}{\sigma} = \frac{3}{1} = 3$

Corresponding area $= 0.00135$

And the % of the product will not meet the specification $= 0.135\%$.

(e) The shift of the process is desirable, since the total % defective $= 0.135 + 0.135 = 0.27\% < 2.28\%$. Ans

—o—

C. X and S chart

While X and R chart are widely used it is occasionally desirable to estimate the process standard deviation directly instead of indirectly through the use of the range R. This leads to the control chart for X and S. where S is the sample standard deviation (same= R/d) another refer the S chart as the chart.

Generally X and S chart are preferable to their more familiar counterpart X and R chart when either
The sample size n is moderately large (say n > 10 or 12) it should be remembered that the range method for estimating loses statically efficiency for modern to large sample

2.The sample size n is variable

<u>Construction of $\bar{x}$ and s Charts</u>

For each sample, the sample average $\bar{x}$ and the sample standard deviation, s are calculated where

$$s^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}$$

The sample standard deviation, s is not an unbiased estimate of σ. If the distribution is normal, then

$\bar{s} = c_4\sigma$ where $\bar{s} = \frac{\Sigma s}{N}$ N = no. of subgroup.

where c_4 is a constant that depends on the sample size i.e.

$$c_4 = \left(\frac{2}{n-1}\right)^{\frac{1}{2}} \frac{\Gamma(n/2)}{\Gamma[(n-1)/2]}$$

~~where~~ (where $\Gamma(r) = \int^{\infty} x^{r-1} e^{-x} dx$, for $r > 0$; If r is a +ve integer, then $\Gamma(r) = (r-1)!$)

The centreline for s chart = $c_4\sigma$

and 3 sigma control limits for s chart ⇒ $UCL_s = c_4\sigma + 3\sigma\sqrt{1-c_4^2}$

$LCL_s = c_4\sigma - 3\sigma\sqrt{1-c_4^2}$

It is customary to define 2 constants

(6/14)

$B_5 = c_4 - 3\sqrt{1 - c_4^2}$

and $B_6 = c_4 + 3\sqrt{1 - c_4^2}$

So the required parameters for s chart ⇒

$UCL_s = B_6 \sigma$

$\text{Centreline} = c_4 \sigma$

$LCL_s = B_5 \sigma$

The values of c_4, B_5 and B_6 are obtained from Table.

The $\bar{X}$ and s chart can be plotted as $\bar{X}$ and R chart.

Control charts for Attributes

- ~~Fraction~~ Nonconforming (defectives)
  - p chart (when subgroup size is ~~constant~~ variable)
  - np chart (when subgroup size is const.)
- Nonconformities (defects)
  - u chart (when subgroup size is variable)
  - c chart (when subgroup size is const.)

Distinguish between defects and detectives

An item is said to be defective if it fails to conform to the specification in any of the characteristics. Each characteristic that does not meet the specification is a defect. An item is defective if it contains at least one severe defect. For example if a casting contains undesirable hard spots blow holes etc, the casting is defecting and the hard spots blow holes etc. which makes the casting defective are defects.

A nonconforming item is a unit of product that does not satisfy one or more of the specification for the product. Each specific point at which a specification is not satisfied results in a defect or nonconforming, consequently a nonconforming item will contain at least one nonconforming. However depending on their nature and severity it is quite possible for a unit to contain several nonconformities and not be classified as nonconforming (defective). As an example, we are manufacturing personal computers. Each unit could have one or more very mirror flaws in the cabinet finish and since these flaws do not seriously affect the units functional operation it could be classified as nonconforming. However if there are too many of these flaws the personal computer should be classified as nonconforming. Since these flaws would be very noticeable to the customer and might affect the sale of the unit. There are many practical situation in which we prefer to work directly with the number of defects or nonconforming rather than the fraction nonconforming. These include the no of defective welds in 100m of oil pipe line the number of broken rivels in an aircraft wing, the number of functional defects in an electronic logic device and so forth.

... and so forth.

(c) P chart

Suppose that the true fraction nonconforming p in the production process is known or is a standard value specified by the management. Then the central line and control limits are:

When standard value p is given:

$$UCL = p + 3\sqrt{\frac{p(1-p)}{n}}$$

$$\text{Centreline} = p$$

$$LCL = p - 3\sqrt{\frac{p(1-p)}{n}}$$

When the process fraction nonconforming P is not known then it must be estimated from observed the usual procedure is to select m preliminary samples (where m= 20 or 25) each of size n. then if there are di non conforming units in sample we can compute the fraction nonconforming in the sample as:

as:

$$\hat{p}_i = \frac{D_i}{n}, \quad i = 1, 2, 3 \ldots m.$$

and the average of these individual sample fraction nonconforming is

$$\bar{p} = \frac{\sum_{i=1}^{m} \hat{p}_i}{m}$$

The centreline and control limits are:

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

$$\text{Centreline} = \bar{p}$$

$$LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$$

Problem

The following table represents the inspection results of magnets for 19 observations . calculate the average fraction defective and 3 sigma control limits construct the control chart and state wheat her the process is in statically control.

Week No	No of magnet Inspected	No of Defective magnets'	Fraction Defective
1	724	48	0.066
2.	736	83	0.109
3.	748	70	0.094
4.	748	85	0.114
5.	724`	45	0.062
6.	727	56	0.077
7.	726	48	0.066

8.	719	67	0.093
9	759	37	0.049
.10.	745	52	0.070
11.	736	47	0.064
12.	739	50	0.068
13.	723	47	0.065
14.	748	57	0.076
15.	770	51	0.066
16.	756	71	0.094
17.	719	53	0.074
18	757	34	0.045
19.	760	29	0.038
Total	14091	1030	-

Soln

The average sample size $= \frac{14091}{19} = 741.63 \simeq 742$ (say)

The average fraction defective $(\bar{p}) = \frac{\text{Total defectives in all samples}}{\text{Total no. inspected}}$

$= \frac{1030}{14091} = 0.0731$

Now $UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$

$= .0731 + 3\sqrt{\frac{.0731(1-.0731)}{742}}$

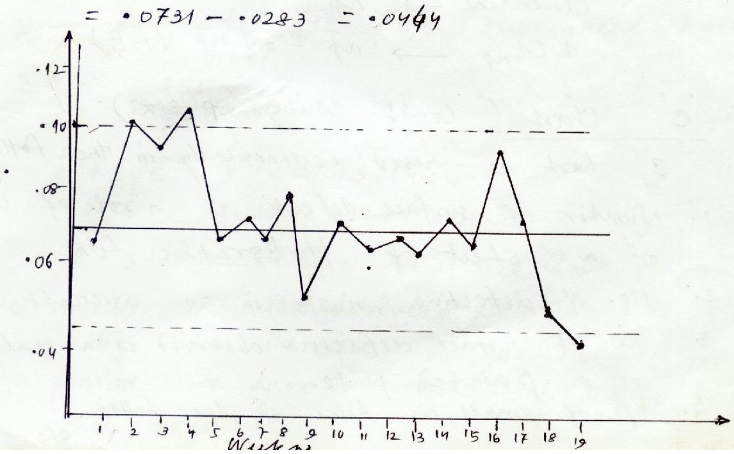
$= 0.1018$

Centreline $\bar{p} = 0.0731$

$LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$

$= .0731 - .0283 = .0444$

A control chart is plotted as shown aside.



It is seen that sample no 2 and ,4th and 19th goes out of control limits. Therefore the process does not exhibit statistical control.

[N.B although up chart is not mentioned in the syllabus for the knowledge sake it is briefly described in the following]

np chart

when the subgroup size is variable p chart is used however if the subgroup size is constant np chart is used. The reasons are

1.np chart saves are calculation for each subgroup (ie division of no of defective by subgroup size to get fraction defective)
2.some people may understand the np chart more readily however to avoid confusion it would be better to use p chart even for constant subgroup.

Control limits for np chart

The average fraction defective p is used as the best available estimate of p i.e

$$\bar{p} = \frac{\Sigma np}{\Sigma n}$$

$$UCL_{np} \longrightarrow n\bar{p} + 3\sqrt{n\bar{p}\,(1-\bar{p})}$$

$$\text{Centreline} \longrightarrow n\bar{p}$$

$$LCL_{np} \longrightarrow n\bar{p} - 3\sqrt{n\bar{p}\,(1-\bar{p})}$$

'C' chart (const subgroup size)

C chart is used economically in the following causes.
1.number of surface defect in a role of coated paper or a sheet of photographic film.
2.no of defective rivets in an aircraft wing
3.no of surface defects observed in a galvanized sheet or a painted plate.
4.no of small air holes in glass bottles etc.

Control limits for C chart

Control limits for c chart

(i) When standard value of c is given

$UCL = c + 3\sqrt{c}$

$\text{Centreline} = c$

$LCL = c - 3\sqrt{c}$

(ii) When standard value of c is not given

$UCL = \bar{c} + 3\sqrt{\bar{c}}$

$\text{Centreline} = \bar{c}$

$LCL = \bar{c} - 3\sqrt{\bar{c}}$

Prob The following table gives the number of missing rivets noted at aircraft final inspection

Airplane no	No. of missing rivet	Airplane no	No. of missing rivets	Airplane no	No. of missing rivets
1	8	10	12	20	9
2	16	11	23	21	10
3	14	12	16	22	22
4	19	13	9	23	7
5	11	14	25	24	28
6	15	15	15	25	9
7	8	16	9		
8	11	17	9		
9	21	18	14		
		19	11		

Compute $\bar{c}$ trial control limits. What value of c' would you suggest for the subsequent period?

Soln

$$\bar{c} = \frac{\Sigma c}{N} = \frac{351}{25} = 14.04$$

$$UCL = \bar{c} + 3\sqrt{\bar{c}} = 14.04 + 3\sqrt{14.04}$$

$$= 14.04 + 11.24 = 25.28$$

$$LCL = \bar{c} - 3\sqrt{\bar{c}} = 14.04 - 11.24 = 2.80$$

Now the number of missing rivets of airplane no 24=28 falls above the UCL. Therefore to suggest e for subsequent period we have to revise the limits by eliminating this reading.

Now $\bar{c} = \frac{351 - 28}{24} = 13.458$

Hence new UCL $= \bar{c} + 3\sqrt{\bar{c}}$

$= 13.458 + 3\sqrt{13.458}$

$= 13.458 + 11.005$

$= 24.463$

LCL $= \bar{c} - 3\sqrt{\bar{c}}$

$= 13.458 - 11.005$

$= 2.453$.

Now it is seen that the reading for airplane no 14 (ie, 25) goes out of control. Therefore, we have to revise the control limit once again. And revised

$\bar{c} = \frac{323 - 25}{23} = 12.956$

UCL $= 12.956 + 3\sqrt{12.956} = 23.754$

LCL $= 12.956 - 3\sqrt{12.956} = 2.158$

Now all other readings are within the control limits. So the suggested value of $c' = 12.956$

(c) Inspection by Sampling

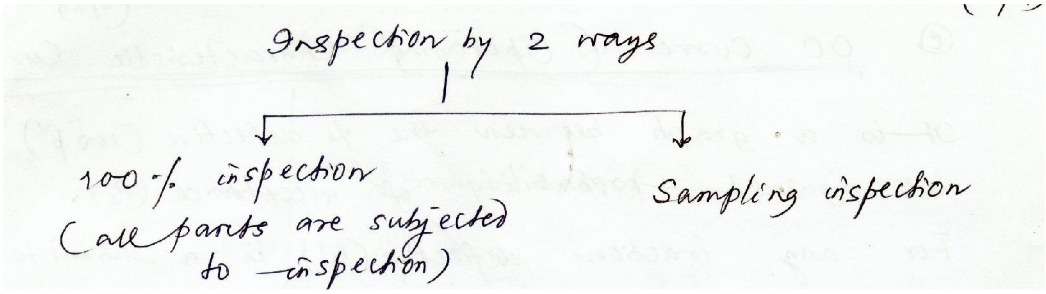
What is inspection?

The act of checking components whether it performs the required function or satisfies required specification

Inspection serves 2 purposes:

- Separate defective components
- Locate defects in
  - raw material
  - process
  - person

Inspection for acceptance purpose is carried out in many stages of manufacturing



sampling inspection

Definition

A technique to determine the acceptance /rejection of a lot /population on the basis of no of defective parts found in a random sample drawn from a lot.

A. Advantage of sampling inspection over 100% inspection

1.items subjected to destructive test must be inspected by sampling inspection only
2.cost and time is less compared to 100% inspection
3.inspection fatigue is elimination
4.less staff for inspection
5;.the problem of monitory and inspection error is eliminated
6;.it chart more effective pressure an quality improvement (because the rejection of entire lot is based on the quality at sample)

B.Limitations

1.Risk of making wrong decision
2.provides less information about the product

The success of sampling plan depends on

- Randomness of sample
- Sample size (sample size= where N- batch size)
- Quality characteristics to be used
- Acceptance criterion
- Let size

Oc curve operating characteristic curve

It is a graph between the % defective (100p) in a lot against probability of acceptance (p_a) for any fraction defective (p_1) in a submitted lot the OC curve shows the probability pa that such a lot will be accepted but the sampling plan

In a single sampling plan 3 parameter are specified

N= lot size from which samples are drawn

n=sample size

C= acceptance number

Using known values of N,n and c i.e

Let $N = 100$, $n = 5$, $c = 2$ } means: If a random sample of 5 items from a lot of 100 contains more than 2 defective → reject the lot otherwise → accept the lot.

An OC curve may be plotted by referring Tables of Poisson's distribution (Table G) of SQC by Mahajan (As shown in next page)

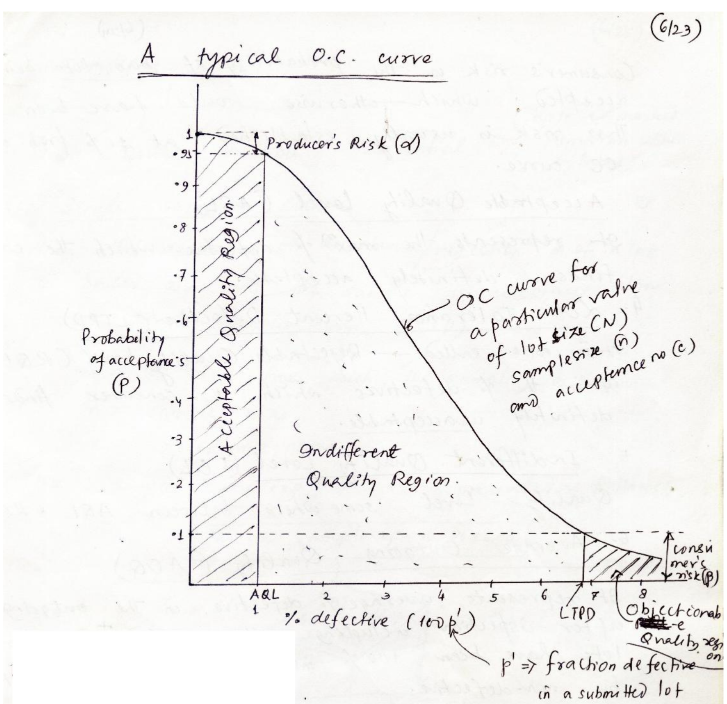
i.e,

c → / ↓ np'	0	1	2
	x	x	x
	x	(x)	x

→ Probability of acceptance × 1000

General characteristics of OC curve

- It shows the ability of sampling plan to distinguish between good and bad lot.
- For different sampling plan (for different values of N and c) Oc curve will be different
- A sampling plan is completely divined by OC curve
- The steeper the curve –the greater the efficiency of plan
- The sloper is mostly effected by sample size (n)



Various terminologies associated with OC curve

1. producer's risk

ideal sampling plan which satisfy both consumer and producer is not possible. Some compromise has to be made and both the parties have to tolerance certain risk.
The producer 's risk is the probability of rejecting a good lot which otherwise would have been accepted. This risk is usually taken as 5%. This means in a long run 1 lot in 20 will be rejected even if the lots are coming from a controlled process at acceptable quality level (AQL)

2. consumer's risk

If the quality is bad still from the sampling plan some lots are to be accepted for which the consumer will suffer consumer's risk is the probability of bad lots being accepted which otherwise would have been reject. This risk is usually established at 10% prob on OC curve.

3. Acceptable quality level(AQL)

It represents the max defective which the consumer finds definitely acceptable.

4. Lot tolerance percent defective (LTPD)

It is also called –reject able quality level (RQL)
It is the % defectives which the consumer finds definitely unacceptable

5. Indifferent quality level (IQL)

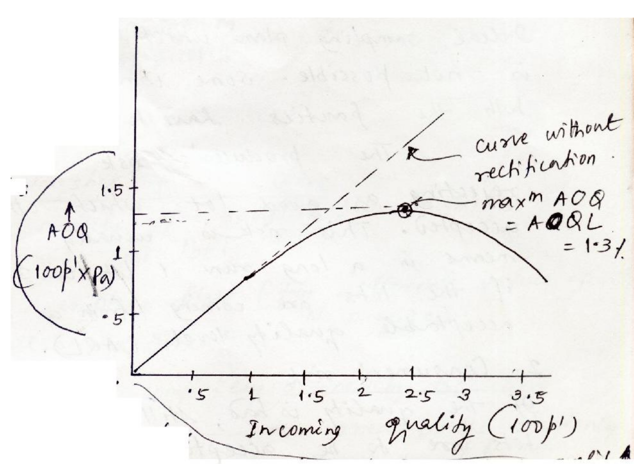
Quality level somewhere between AQL & RQL.

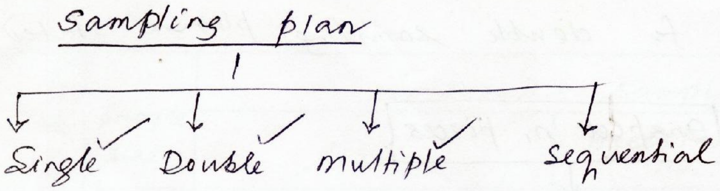
6. Average outgoing quality (AOQ)

It represents average % defective in the outgoing products after inspection including all accepted + all rejected lots have been 100% inspected and defective replaced by non-defective.

7. Average outgoing quality limit (AOQL)

The consumer is very much concerned with AOQL value as it ensures him that the submitted lots may be of any quality but he will not get quality worse than AOQL value. If the incoming quality is very poor then many of the lots will be rejected and defective items are to be replaced- outgoing quality





(Note ✓ marked plans are within syllabus)

ⓒ Single sampling plan

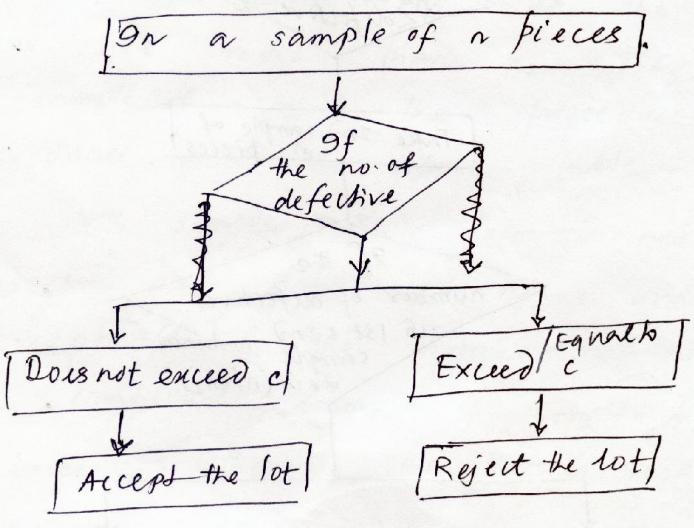
When the decision on acceptance/rejection of a lot is based on only one sample, the acceptance plan ⟶ single sampling Plan (SSP)

If N = lot size from which the sampling is drawn

n = sample size

c = acceptance number

The single sampling plan is represented as follows:



ⓒ Double sampling plan

If n_1 = no. of pieces in the 1st sample

c_1 = acceptance number of 1st sample

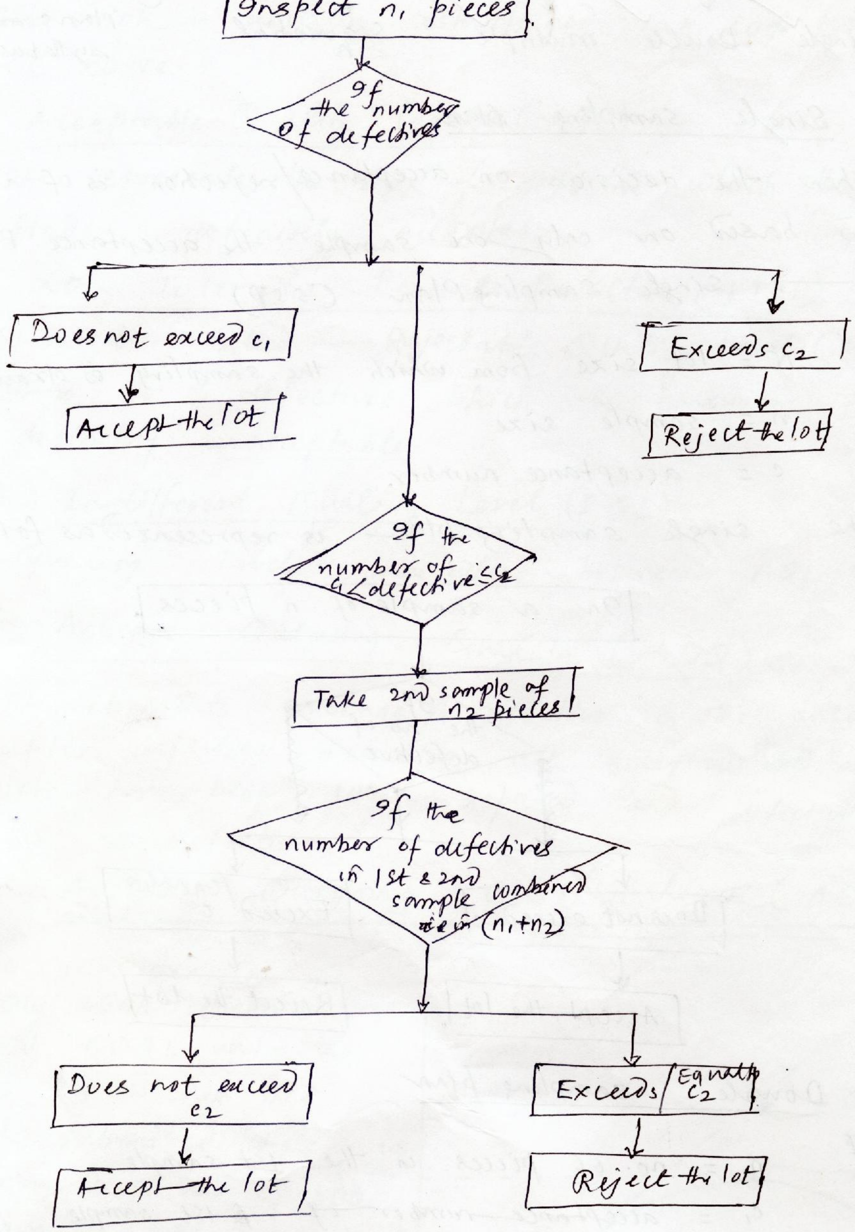
n_2 = no. of pieces in the 2nd sample

n_1+n_2 = no. of pieces in two samples combined

c_2 = acceptance number for the 2 samples combined

i.e, the maximum number of defectives that will permit the acceptance of the lot on the basis of 1st and 2nd sample combined.

The procedure for double sampling plan is stated as fo



(X) (c) multiple sampling plan

A multiple sampling plan is an extension of double sampling plan. A multiple sampling procedure can be represented with the help of a table such as:

Sample	Sample size	Combined sample		
		Size	Acceptance no.	Rejection no.
first	n_1	n_1	c_1	r_1
2nd	n_2	n_1+n_2	c_2	r_2
3rd	n_3	$n_1+n_2+n_3$	c_3	r_3
4th	n_4	$n_1+n_2+n_3+n_4$	c_4	r_4
5th	n_5	$n_1+n_2+n_3+n_4+n_5$	c_5	c_5+1

A first sample of n, is drawn the lot is accepted if there are no more than c, defective a lot is rejected if there are more than r, defectives. Otherwise a 2nd sample of n, is drawn the lot is accepted if there are no more than c defective in the combined sample n,+n. the lot is rejected if there are more than r defective in the combined sample of n,+n. the procedure is continued in accordance with the above table. If by the end of 4th sample the lot is neither accepted nor rejected a sample of n is drawn. The lot is accepted if the number of detectives in the combined sample of n+n+n+n+n does not excess c. otherwise the lot is rejected. Note that c,<c,<….<c and c<r for all.

A multiple sampling plan will generally involve less total inspection than the corresponding single & double sampling plan guaranties the same protection. But they usually requires higher administrative cost and higher caliber inspection personal may be necessary.

CHAPTER-8 RELIABILITY

A typical example of reliability

100 W.Phillips bulb **100 W local make bulb/ ordinary bulb.**

This bulb can last satisfactorily for at least 6 month It rarely lasts for 2 months under similar condition.

So a 100 w phillips bulb is more reliable than its counterpart local make /ordinary bulb.

(c) Definition of Reliability

Reliability is the Probability of a device /product giving satisfactory performance for a specified period under specified operating condition.

This definition states 4 things

(1) Reliability has some numerical value (like probability) (0-1)

(2) A adequate /satisfactory performance by the product

(3) Works for a specified period

(4) works under specified environmental condition.

(c) Relationship of Reliability with maintainability and availability.

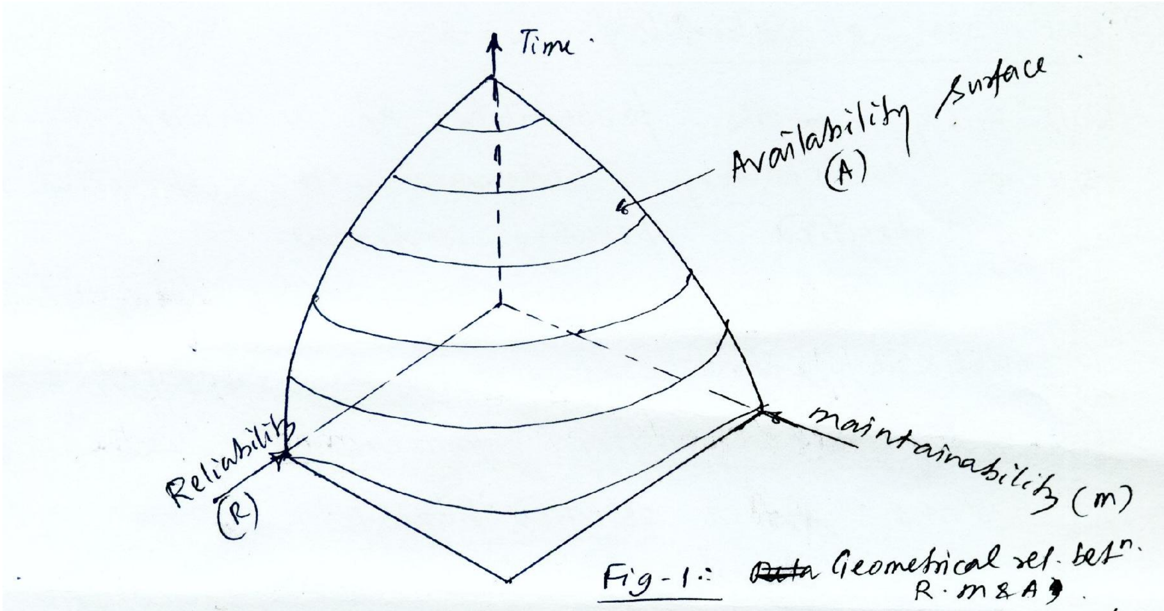
Maintainability: is defined as the probability that a device will be restored to its operational effectiveness within the given period when maintenance action is performed in accordance with the prescribed procure and resources (equipments etc)

Availability

Availability of a particular equipment means that the equipment is functioning and available for use.

Maintainability and Availability are closely related to Reliability. If the reliability of a system is high, there obviously the breakdown will be less frequent and the availability factor would be high similarly if the system is capable of being repaired easily (i.e. it is has high maintainability factor) then also the availability factor would be high. Hence availability is closely related to reliability and maintainability.

Geometrical correlation between Reliability, Maintainability and Availability

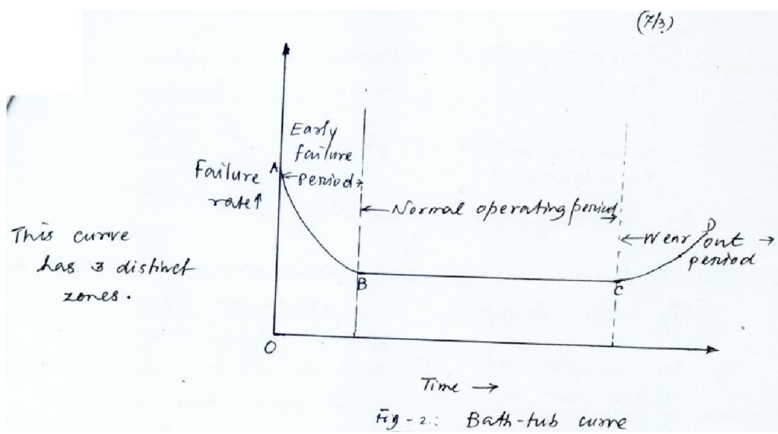


In general the availability of a system is complex function of reliability, maintainability and supply effectiveness. This can be expressed as

As= f (Rs, Ms, Ss)

(C) Failure date analysis Bath tub curne

When a device does not perform satisfaction it is said to be failed. The failure pattern can be obtained from life test result. Complex products of ten follow a familiar pattern of failure. When the failure rate (i.e. No. of failure per unit test time) is plotted against a continuous time scale, the resulting chart is called Bath tub curve (Because of its shape)



1. Infant Mortality Period (or Early Failure Period)

This is characterized by high failure rates. Commonly these are early failures resulting from defects science manufacturing or other deficiencies. The shape is like Weibul distribution with shaping parameters(p) <1. Prior to selling on item, test must be carried out to screen out the defective one.

2. Constant failure rate period (or Normal operating period)

Upon replacement of all the prematurely failing items, the failure rate will reach a lower value (point B) From this point, the failure rate remains fairly constant. These are chance failure which may occur due to

- design
- accident cause by usage

- poor maintenance etc.

The period from B-C is normal operating period. During this period the overage failure rate remains more or less constant. It represents the effective life of product.

3. The wear out period.

These are failure due to

- abrasion /were
- fatigue
- creep
- corrosion
- vibration

The shape is like normal distribution.

[The failure rate (x) can be estimated from the test date by using formula x = No of items failed

Sum of items test time

For example; It a items are tested with the following results out the end of 22 test firs.

4 items fated after 4, 12, 15 and 21 hrs, the rest still operating after 22 hrs. So

$$x = \frac{4}{4+12+15+21+5x22} = 0.025$$

Comparison between failure rate, Reliability, failure density

Let N= No of units at the starting of fortune test

Ns (t)= Number survived after time t,

Nf(t) = Number failed after time 't'.

Probability of failure= Reliability = R (t)= Ns (t)/N

=N-N_f(t)/N

=R(t)=1-N_f(t)/N

For a fixed N, rate of no

Failure- $\frac{dr^{(t)}}{dt} = -\frac{1}{n}\frac{dn_f(t)}{dt}$

Or $\frac{dN_f(t)}{dt} = -nx\frac{dr^{(t)}}{dt}$

Rate at which component fail

The reliability function for the random system failure by chance.

For a random situation, the failure follows Possion's distribution with a prescribed failure rate (x) Where near time between failure MTBF = 1/x)

Now probability of exactly n failure in time 't'

$$p(n,t) = \frac{e^{-xt}.(xt)^{n}}{n1}$$

Where x = average failure rate

Now, R (t)= probability of no failure

R (t) = P (o,t)= e - xt

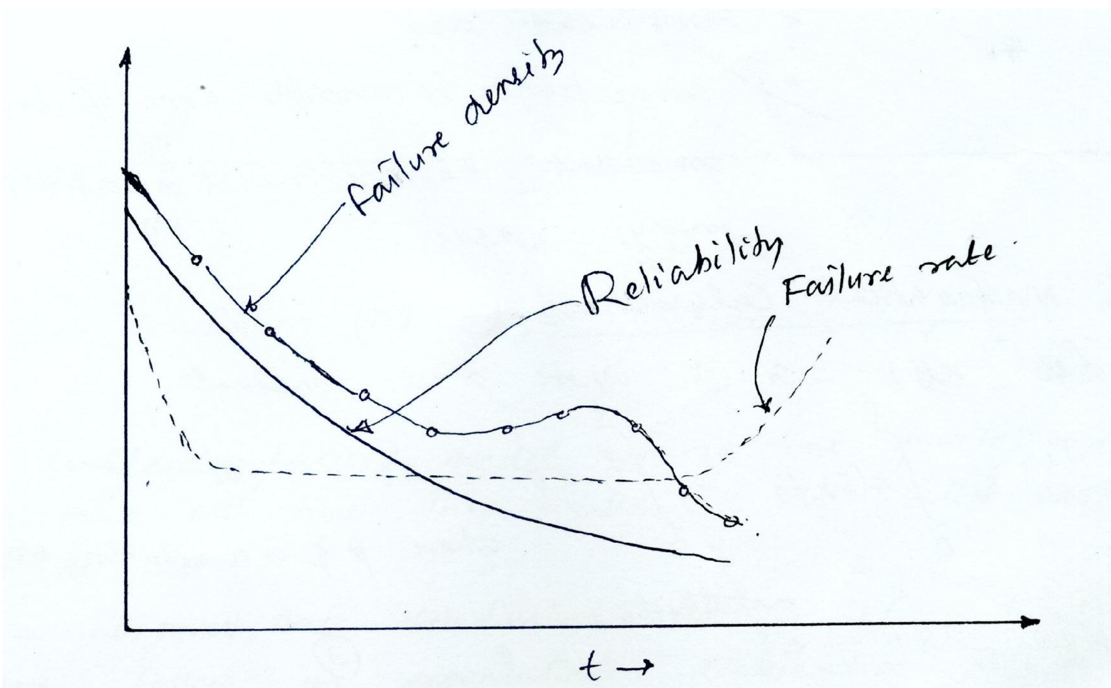
This the reliability function for random failure by chance is an exponential distribution.

Failure density (fd)= No.of failure during a given time/ Total no of items at the begining of test .

Failure rate z (t)= No of failure during a particular time/ Average population during that period.

(General Function)

The relation between= failure rat, failure density and Reliability are shown in the following.



X (c) Hazard models

The failure characteristic exhibited by different classed of components differ from each other.

A arithmetical model is required to represent the failure characteristics is called Hazard model.

General Procedure of the model

At first a function is assumed for the hazard rate, z (t) (Failure)

Next, one has to calculate the reliability and failure density as follows.

Reliability, $R(t) = e^{-\int_0^t z(\xi)\,d\xi}$

Failure density $f_d(t) = z(t)\, e^{-\int_0^t z(\xi)\,d\xi}$

The probability of failure $F(t) = 1 - R(t)$

Mean Time To failure (MTTF) $= \int_0^\infty R(t)\,dt$

Taking one specific case the model is explained

Case-(a) Constant hazard i.e, $z(t) = \text{const} = \lambda$

- simpliest case
- corresponds to middle zone of bath tub curve
- constant hazard model is appropriate in many cases.

Mathematical Calculation

Let $z(t) = \lambda$, (1) where λ is constant

Then $\int_0^t z(\xi)\,d\xi = \int_0^t \lambda\,d\xi = \lambda t$ (2)

where ξ is a dummy variable.

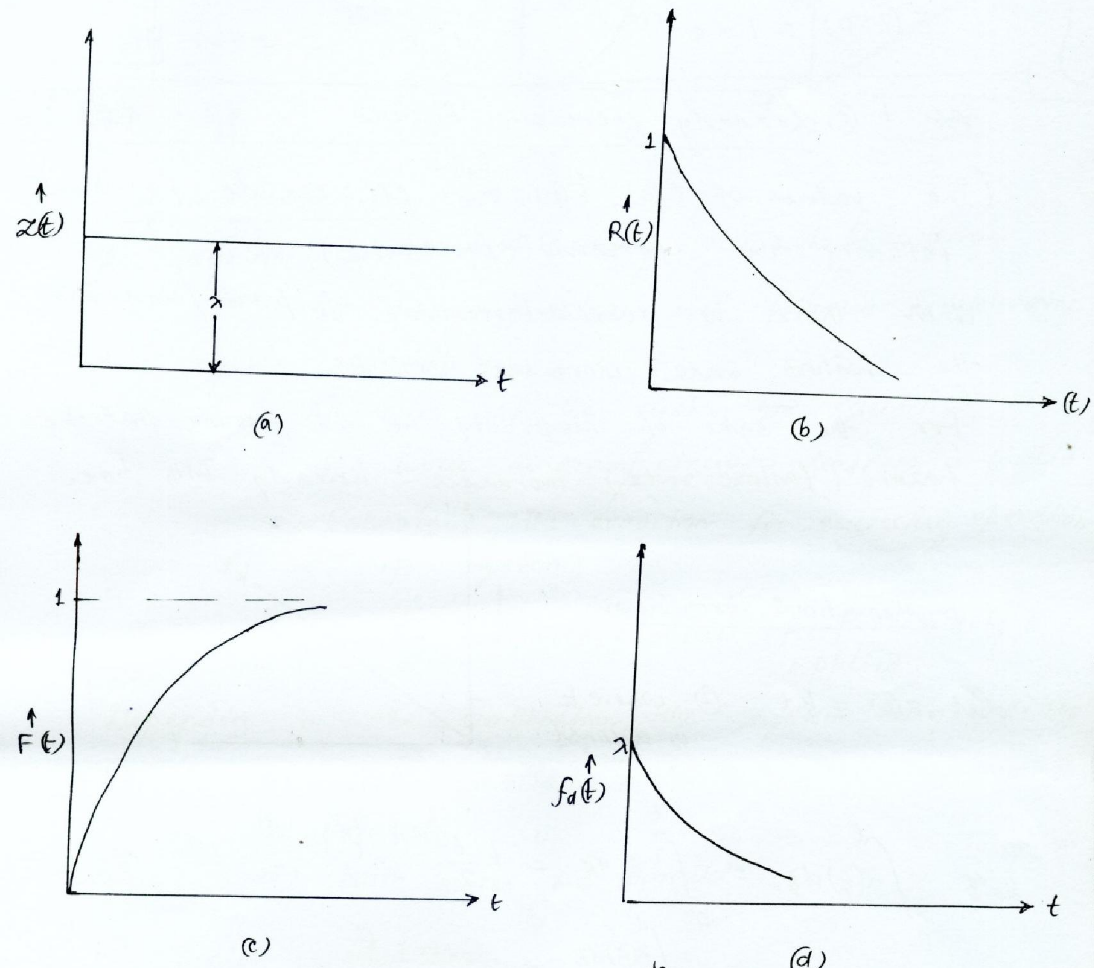
Now $R(t) = e^{-\int_0^t z(\xi)\,d\xi} = e^{-\lambda t}$ (3)

$F(t) = 1 - R(t) = 1 - e^{-\lambda t}$ (4)

(7/7)

$$f_d(t) = z(t)\, e^{-\int_0^t z(\xi)\,d\xi} = \lambda \cdot e^{-\lambda t} \qquad (5)$$

The four functions, $z(t)$, $R(t)$, $F(t)$ and $f_d(t)$ are shown in the following.



$$\text{Mean Time To Failure (MTTF)} = \int_0^\infty R(t)\,dt = \int_0^\infty e^{-\lambda t}\,dt = \left.\frac{e^{-\lambda t}}{\lambda}\right]_0^\infty = \frac{1}{\lambda}$$

The constant hazard model assumes that ports don't deteriorate with time. This model is also called exponential reliability case.

Ex: It is observer that the failure pattern of an electronic system follow an exponential distribution with a mean time to failure of 1000 hrs. What is the probability that the system failure occurs within 750 hrs?

that the system failure occurs within 750 hrs?

Sol^n $MTTF = \frac{1}{\lambda} = 1000 \Rightarrow \lambda = \frac{1}{1000}$

$F(750) = 1 - e^{-\frac{1}{1000} \times 750} = 1 - e^{-0.75} = 0.528$ Ans

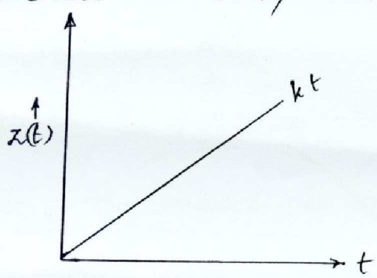
Case-b (c) Linearly increasing hazard i.e, $z(t) = kt$

(The values of $R(t)$, $F(t)$, $f_d(t)$ etc can be found out following the aforesaid procedure.)

When there is wear/deterioration of parts/component, the failure rate increases with time.

For the sake of simplicity, we can assume that the hazard (failure rate) increases linearly with time.

Mathematical formulation



Let $z(t) = kt$ (1) where k is a const.

So $\int_0^t z(\xi)\, d\xi = \int_0^t k\xi\, d\xi = k\frac{t^2}{2}$ (2)

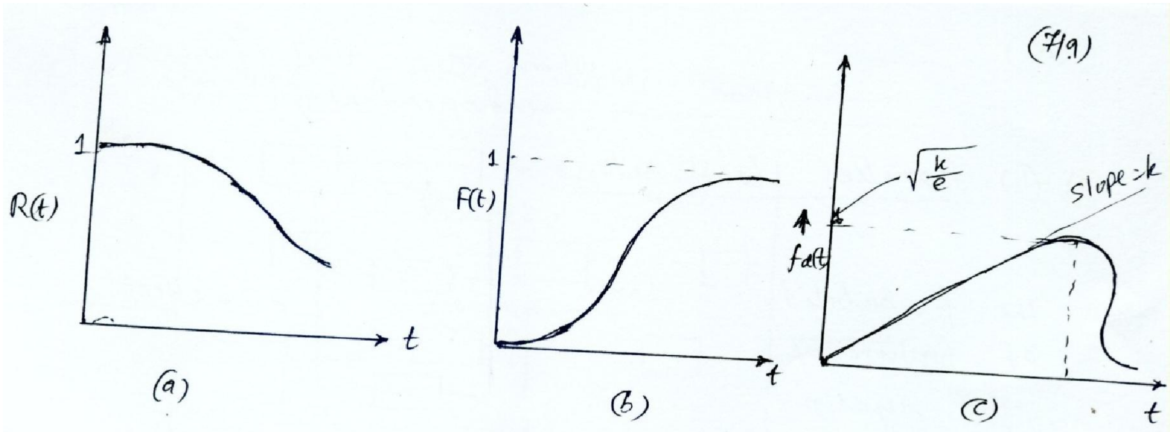
Now $R(t) = e^{-\int_0^t z(\xi) d\xi} = e^{-\frac{k t^2}{2}}$ -(3)

$F(t) = 1 - R(t) = 1 - e^{-\frac{kt^2}{2}}$ (4)

$f_d(t) = z(t)\, e^{-\int_0^t z(\xi) d\xi} = kt\, e^{-\frac{kt^2}{2}}$ - (5)

$MTTF = \int_0^\infty R(t)\, dt = \int_0^\infty e^{-\frac{kt^2}{2}} . dt = \sqrt{\frac{\pi}{2k}}$

(The



(C) System Reliability

A system composed of many elements/subsystem

The following steps are followed to determine the system reliability.

* All units of the system are identified.

* A block diagram/ circuit diagram is plotted(satisfying the condition for successful operation of system)

* finally combination rule of probability is applied.

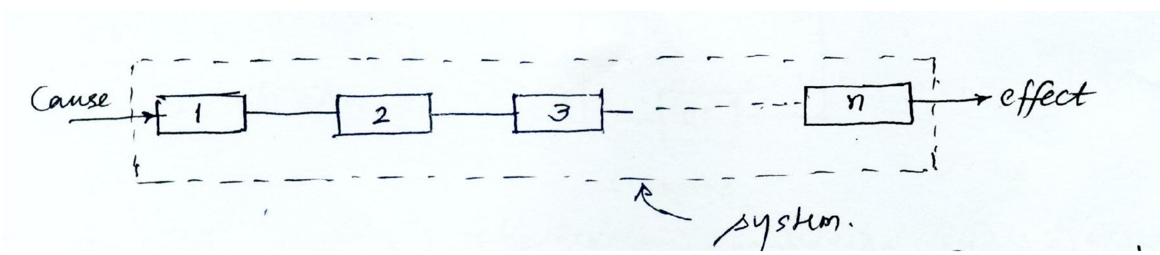
Depending on the combination, the system may be either

(a) series combination

(b) Parallel

(c) Both series and parallel

(C) (a) Series combination

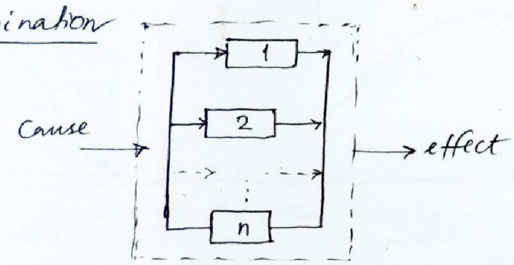


Let in a system, 'n' units are connected is series ie, x1, x2.. xn, as shown above. Let probability of successful operation of respective units be p (x1), P (x2).. P (x3) Now the system reliability

= P (s)= P (X1) x P (x2) x P (x3).. P (Xn)..

(when each unit functions independently)

© (b) Parallel Combination



The probability of failure of the system

$= P(\bar{S}) = P(\bar{X}_1) \times P(\bar{X}_2) \times \cdots P(\bar{X}_n)$ (when unit failures are independent of each other)

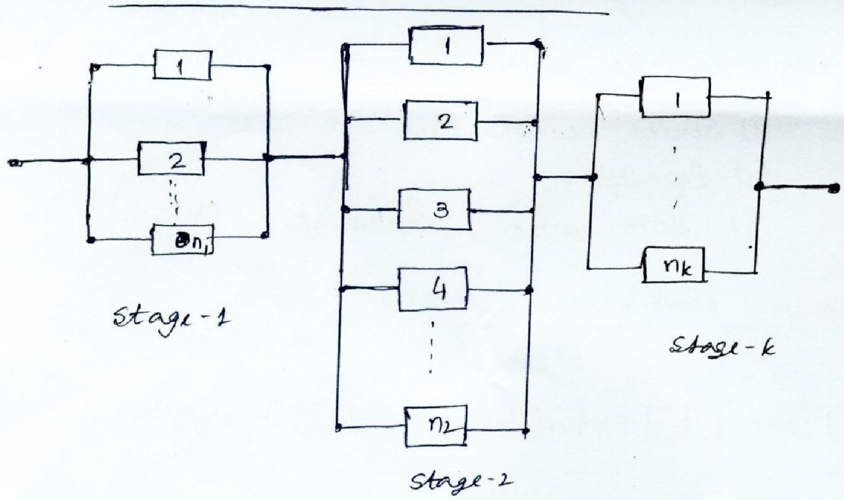
where $P(\bar{x}_1) \rightarrow$ probability of failure of unit ①

$P(\bar{x}_2) \rightarrow$ probability of failure " ②

Now reliability of the system $P(S) = 1 - P(\bar{S})$

$= 1 - [1 - P(X_1)] \times [1 - P(X_2)] \cdots [1 - P(X_n)]$

© (c) Series parallel Combination

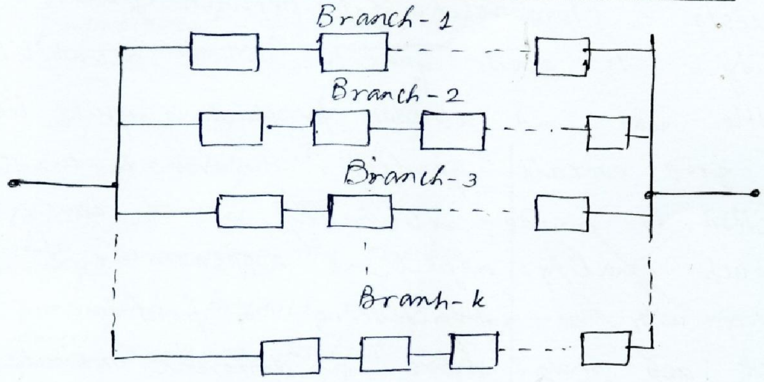


Reliability of stage $i = R_i = 1 - [1 - P(X_{i1})][1 - P(X_{i2})] \cdots$

System reliability $= R_s = R_1 \times R_2 \times \cdots R_k$.

Stage no.

© (d) General parallel series combination



Reliability of branch i = R_i = $P(X_{i1}) \times P(X_{i2}) \cdots P(X_{in})$

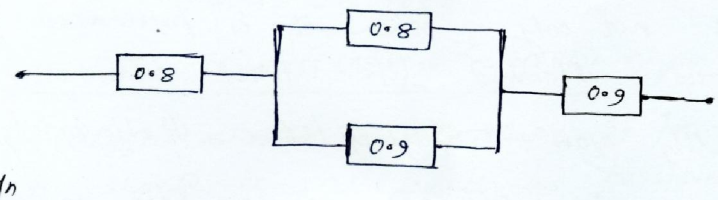
Failure of branch i = $1 - R_i$ = $F(i)$

The probability of failure of the system

$= F(S) = F_1 \times F_2 \times \cdots F_k$

Now system reliability = $R(S) = 1 - F(S)$

Ex Find out the system reliability for the assembly of various elements with their reliabilities as shown below.



Soln

Reliability of middle subsystem $= 1 - [1 - 0.8] \times [1 - 0.9]$

$= 0.98$

Now system reliability $= R(S_1) \times R(S_2) \times R(S_3)$

$= 0.8 \times 0.98 \times 0.9$

$= 0.7056$ Ans

Relationship between Quality and Reliability

Relationship between Quality and reliability

There exist a close relationship between quality and reliability. A good quality without reliability is of little use and reliable product is quite likely to be of good overall quality. However if a minute distinction is made, reliability is not concerned with such quality aspect as appearance. It is essential concerned with the functioning or performance of the product and may have a different method of measurement.

Further, for the products satisfying the same quality requirements, the degree of reliability may be different. This in the case of electric lamp, if the specified requirement for life is minimum of 1000 hrs and 1500 hrs, they would be quality lamps. yet it can be said that the lamps of the second supplier are likely to be more reliable as the probability of their survival at the specified period would be over.

In other words, reliability is that something extra which turns a satisfactory (trouble free) service not only when it is purchased but throughout its intended life that is.

Quality now t quality later= Reliability

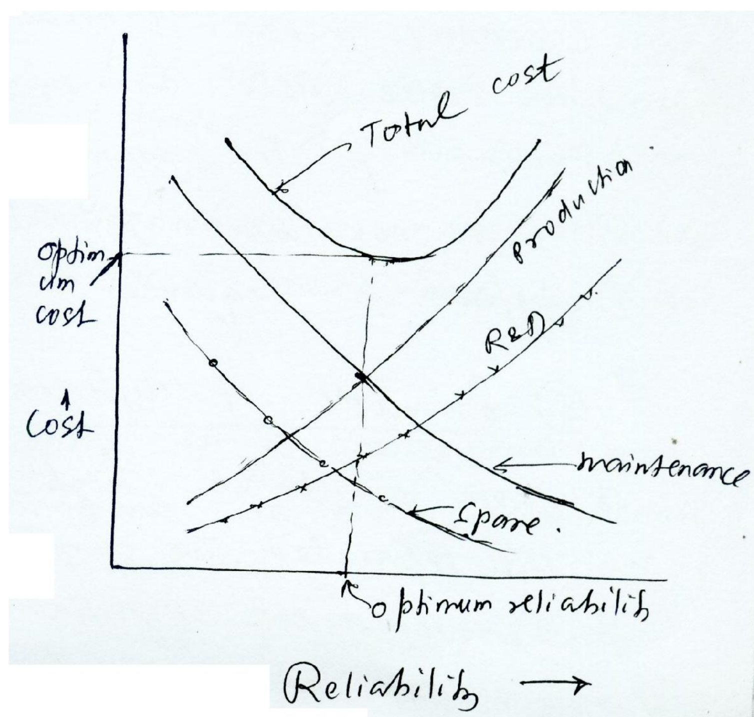
Statistical techniques have on important part to play in reliability. The are extremely useful in setting standards for reliability in process improvement and control to meet these standard and in testing and analysis of manufactured products for ascertaining their reliability.

(c**) Reliability Improvement**

Product reliability can be increased by the following techniques.

(1) Improvement of components.

If we use components with high reliability it will require more time and money. Therefore, the objective in not to produce a component with the highest reliability, but to develop system with the highest reliability, which reflect on optimum total cost (as shown aside) also.



The major items contributing to the total cost are

* Production cost

* research and development cost

* spare cost

* maintenance cost

2**. Through simplification of design**

The design should be as simple as possible ie. The no of parts should be as small as possible. It a product has5 parts with reliability o.i, the system reliability

0.9 x0.9 x0.9 0.x 0.9 x 0.9 = 0. 59, (if all are series connected)

Whereas if there would have been only 3 parts, then the system reliability would be

- 0.9 x 0.9 x 0.9 = 0.73

3. By having redundancy built into the system

Redundant components are provided in the system to take over as soon as the actual component stops functioning.

Ex: using a 4 engine air craft which otherwise.

flies with 3 engines the 4th engine being used as redundant.

(4) Through derating

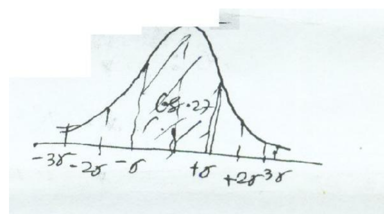
De-rating means providing a large safety margin. It is also used as a method of achieving design reliability. For example a material with tensile strength of 10,000 kg/ cm2 might be prescribed where only 7000 kg/cm2 in required.

(**5) Principle of differential screening.**

From a batch, high, medium and low reliable components are separated. The components in the product are used as per the requirement of reliability. For example high reliable products are used for military use whereas, radium reliable products for commercial purposes.

(6) Principle of Truncation of distribution tails.

The components which fall under 1r limit are not likely to fail easily as those in 3r limits



(7) Robust design/Betts component.

Reliability can be increased by avoiding those component parts which can't stand maximum strength and stress requirement in their intended application.

(8) Principle of burn in screening

It involves short term environmental tests which are conducted under severe stress condition for eliminating parts having low reliability. Water tube is bailer whose normal operating pressure in P kg (cm 2 is tested at 1.5Kg/ um2).

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