Unit 1
Linear Measurements, Tolerances and Gauging

Definition of Metrology:

Metrology is the science of measurement. Metrology includes all theoretical and practical aspects of measurement. Metrology is concerned with the establishment, reproduction, conservation and transfer of units of measurement & their standards.

For engineering purposes, metrology is restricted to measurements of length and angle & quantities which are expressed in linear or angular terms. Measurement is a process of comparing quantitatively an unknown magnitude with a predefined standard**.**

Objectives of Metrology: The basic objectives of metrology are;

- To provide accuracy at minimum cost.
- Thorough evaluation of newly developed products, and to ensure that components are within the specified dimensions.
- To determine the process capabilities.
- To assess the measuring instrument capabilities and ensure that they are adequate for their specific measurements.
- To reduce the cost of inspection & rejections and rework.
- To standardize measuring methods.
- To maintain the accuracy of measurements through periodical calibration of the instruments.
- To prepare designs for gauges and special inspection fixtures.\

Inspection: checking the dimension of other defects of a part which has already being produced.

Need 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 manufacturing processes.
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.

Errors in measurements:

Errors accompany any measurement, however well it is conducted. The error may be inherent in the measurement process or it may be induced due to variations in the way the experiment is conducted. The errors may be classified as:

1. Systematic errors (Bias):

Systematic errors due to faulty or improperly calibrated instruments. These may be reduced or eliminated by careful choice and calibration of instruments. Sometimes bias may be linked to a specific cause and estimated by analysis. In such a case a correction may be applied to eliminate or reduce bias. Bias is an indication of the accuracy of the measurement. Smaller the bias more accurate the data

2. Random errors:

Random errors are due to non-specific causes like natural disturbances that may occur during the measurement process. These cannot be eliminated. The magnitude of the spread in the data due to the presence of random errors is measure of the precision of the data. Smaller the random error more precise is the data. Random errors are statistical in nature. These may be characterized by statistical analysis.

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 agreed standard value of temperature pressure are:

(i) Temperature= 20^{o}C

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

If the ambient condition various from the above standard values the measured value will be erroneous.

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 alignment

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.

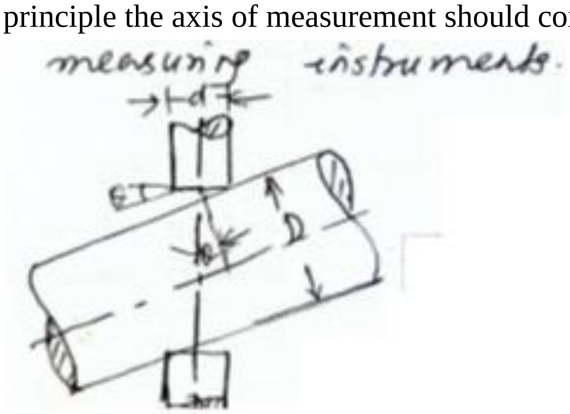


Fig. 1.1 Error due to alignment

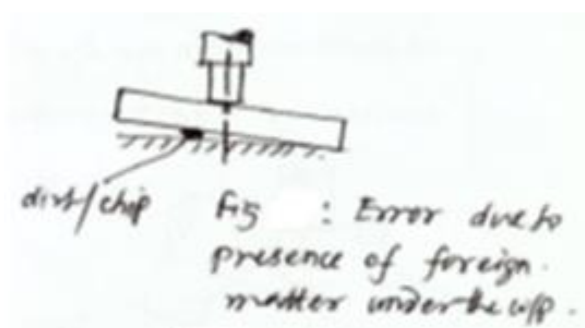


Fig. 1.2 Error due to presence of foreign matter under w/p

5. 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.

6. Error due to location

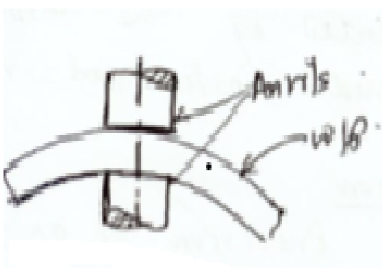
If the datum surface is not perfectly flat or if any foreign matter such as dirt chip etc. are present between the datum and w/p error occurs in measurement as shown in fig 1.2.

7. 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.

8. Error due to poor contact

The measured dimension will be greater than the actual dimension due to poor contact as shown in fig 1.3.



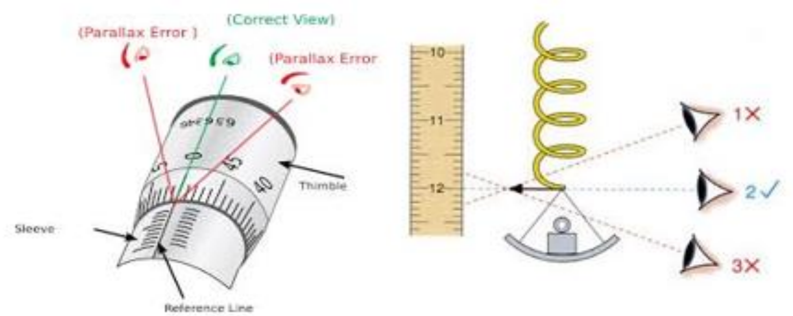


Fig. 1.3 Error due to poor contact Fig. 1.4 Parallax error

9. 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.

10. Parallax error

It occurs when line of vision is not directly in line with measuring scale.

Some important terminologies used in measurement

1. 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. 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 these catering the more precise is the measurement. Thus lower the value of the more precise is the measurement.

2. 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.

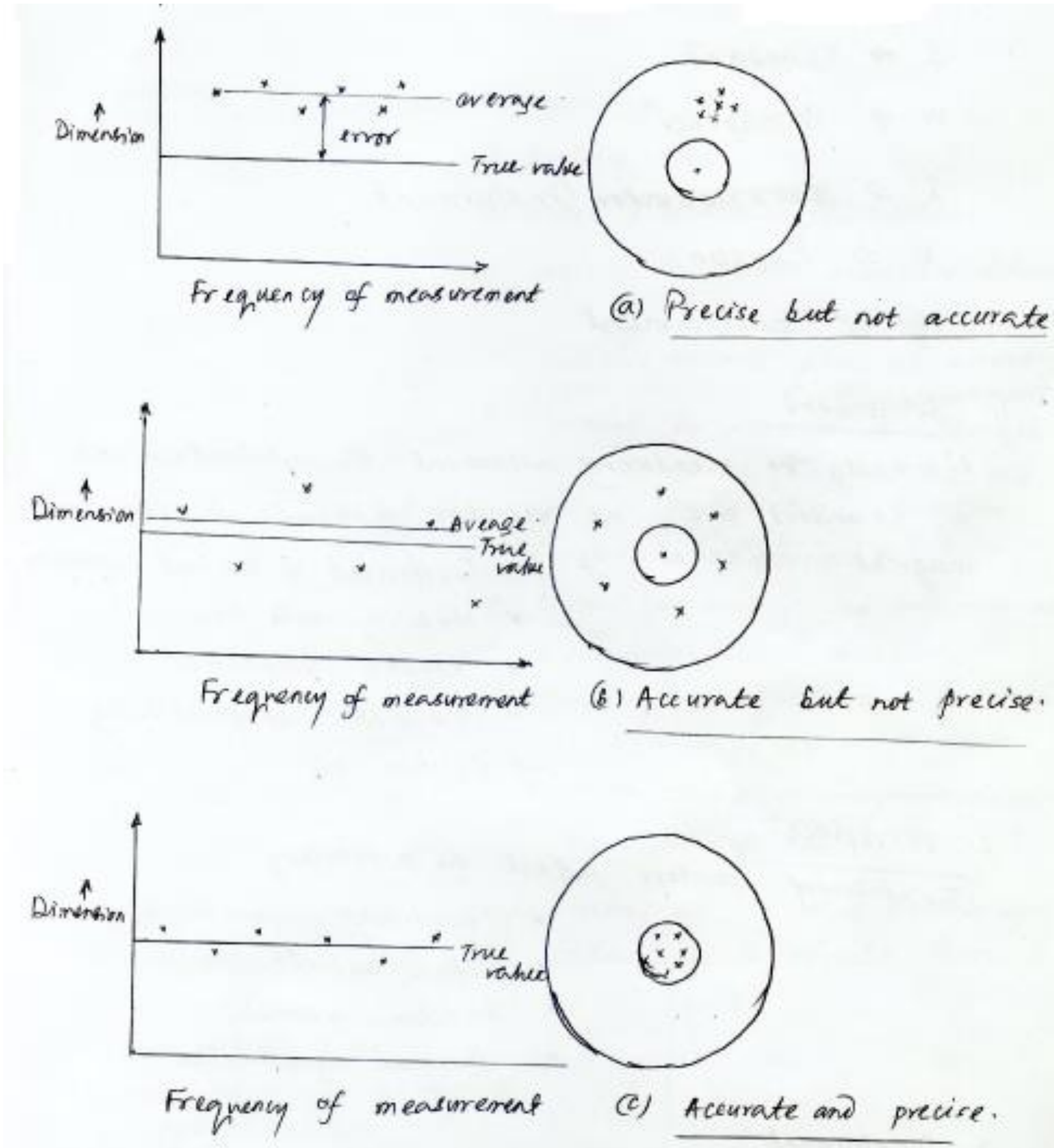


Fig. 1.5 Accuracy and Precision

3. 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 0.01mm 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.

4. 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.

5. Repeatability

It is the ability of the measuring instrument to repeat the same results when measurements 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.

6. 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.

7. 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.

8. 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.

Definition of Standards:

A standard is defined as "something that is set up and established by an authority as rule of the measure of quantity, weight, extent, value or quality".

For example, a meter is a standard established by an international organization for measurement of length. Industry, commerce, international trade in modern civilization would be impossible without a good system of standards.

Role of Standards: The role of standards is to achieve uniform, consistent and repeatable measurements throughout the world. Today our entire industrial economy is based on the interchangeability of parts the method of manufacture. To achieve this, a measuring system adequate to define the features to the accuracy required & the standards of sufficient accuracy to support the measuring system are necessary.

STANDARDS OF LENGTH

In practice, the accurate measurement must be made by comparison with a standard of known dimension and such a standard is called "Primary Standard". The first accurate standard was made in England and was known as "Imperial Standard yard" which was followed by International Prototype meter" made in France. Since these two standards of length were made of metal alloys they are called 'material length standards'.

International Prototype meter:

This standard was established originally by International bureau of weights & Measures in year 1875.The upper surface of the web is highly polished & the graduations are engraved on the upper surface of the web which coincides with the neutral axis of the section. According to this standard the length of meter is defined as the straight line distance, at 0oC, between the engraved lines of pure platinum-iridium alloy (90% platinum & 10% iridium) of 1020 mm total length and having a 'WEB' cross section as shown in fig.

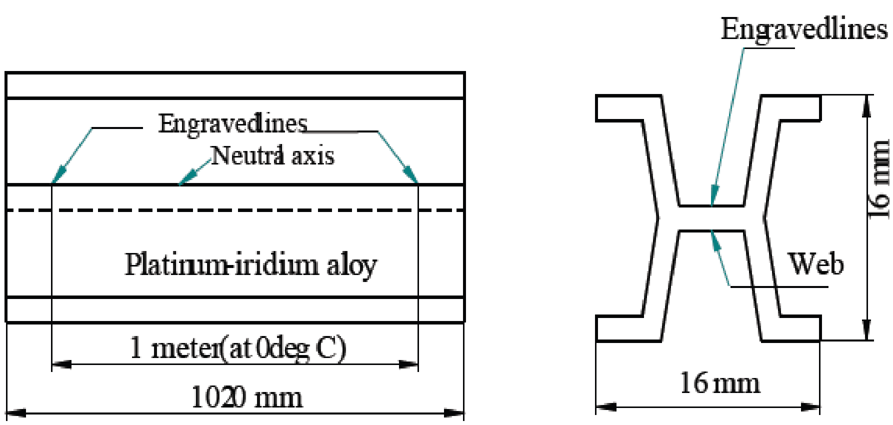


Fig. 1.6 international standard meter

1 Yard = 0.9144 Meter

Imperial Standard yard:

An imperial standard yard, shown in fig, is a bronze (82% Cu, 13% tin, 5% Zinc) bar of 1 inch square section and 38 inches long. A round recess, 1 inch away from the two ends is cut at both ends upto the central or 'neutral plane' of the bar.

Further, a small round recess of (1/10) inch in diameter is made below the center. Two gold plugs of (1/10) inch diameter having engravings are inserted into these holes so that the lines (engravings) are in neutral plane.

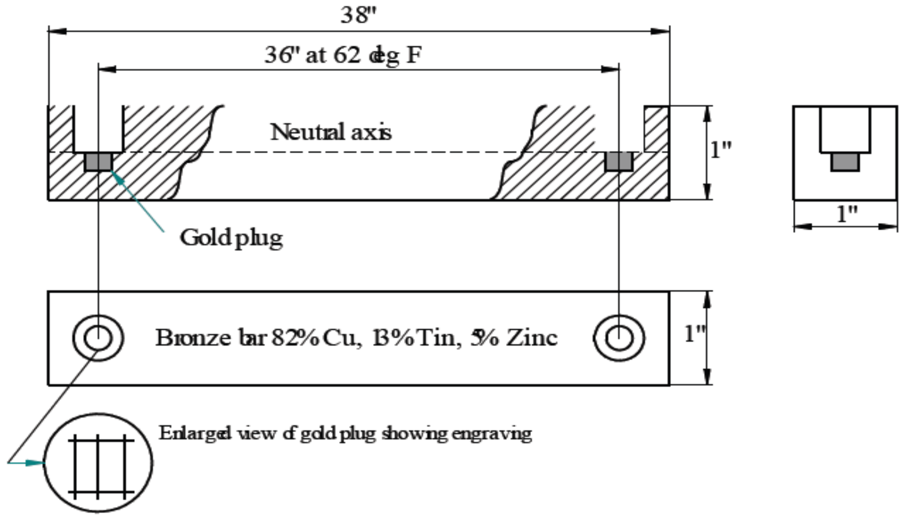


Fig 1.7 Imperial Standard yard

Yard is defined as the distance between the two central transverse lines of the gold plug at 620F. The purpose of keeping the gold plugs in line with the neutral axis is to ensure that the neutral axis remains unaffected due to bending, and to protect the gold plugs from accidental damage.

Disadvantages of Material length standards:

1. Material length standards vary in length over the years owing to molecular changes in the alloy.
2. The exact replicas of material length standards were not available for use somewhere else.
3. If these standards are accidentally damaged or destroyed then exact copies could not be made.
4. Conversion factors have to be used for changing over to metric system.

Light (Optical) wave Length Standard:

Because of the problems of variation in length of material length standards, the possibility of using light as a basic unit to define primary standard has been considered. The wavelength of a selected radiation of light and is used as the basic unit of length. Since the wavelength is not a physical one, it need not be preserved & can be easily reproducible without considerable error.

In 1907 the international Angstrom (A^o) unit was defined in terms of wavelength of red cadmium in dry air at 15^{o}C.According to this standard meter was defined as equal to 1650763.73 wavelengths of the red orange radiation of Krypton 86 gas.

1 meter = 1650763.73 wavelengths.

Advantages of using wave length standards:

1. Length does not change.
2. It can be easily reproduced if destroyed.
3. This primary unit is easily accessible to any physical laboratories.
4. It can be used for making measurements with much higher accuracy than material standards.
5. Wavelength standard can be reproduced consistently at any time and at any place.

Subdivision of standards:

The imperial standard yard and the international prototype meter are master standards & cannot be used for ordinary purposes. Thus based upon the accuracy required, the standards are subdivided into four grades namely;

1. Primary Standards
2. Secondary standards
3. Tertiary standards
4. Working standards

Primary standards:

They are material standard preserved under most careful conditions. These are not used for direct measurements but are used once in 10 or 20 years for calibrating secondary standards.

Ex: International Prototype meter, Imperial Standard yard.

Secondary standards:

These are close copies of primary standards w.r.t design, material & length. Any error existing in these standards is recorded by comparison with primary standards after long intervals. They are kept at a number of places under great supervision and serve as reference for tertiary standards. This also acts as safeguard against the loss or destruction of primary standards.

Tertiary standards:

The primary or secondary standards exist as the ultimate controls for reference at rare intervals. Tertiary standards are the reference standards employed by National Physical laboratory (N.P.L) and are the first standards to be used for reference in laboratories & workshops. They are made as close copies of secondary standards & are kept as reference for comparison with working standards.

Working standards:

These standards are similar in design to primary, secondary & tertiary standards. But being less in cost and are made of low grade materials, they are used for general applications in metrology laboratories.

LINE STANDARDS:

When the length being measured is expressed as the distance between two lines, then it is called “Line Standard”.

Examples: Measuring scales, Imperial standard yard, International prototype meter, etc.

Characteristics of Line Standards:

1. Scales can be accurately engraved but it is difficult to take the full advantage of this accuracy. ***Ex:*** A steel rule can be read to about ± 0.2 mm of true dimension.
2. A scale is quick and easy to use over a wide range of measurements.
3. The wear on the leading ends results in ***'under sizing'***
4. A scale does not possess a 'built in' datum which would allow easy scale alignment with the axis of measurement, this again results in 'under sizing'.
5. Scales are subjected to parallax effect, which is a source of both positive & negative reading errors'
6. Scales are not convenient for close tolerance length measurements except in conjunction with microscopes.

END STANDARDS

When the length being measured is expressed as the distance between two parallel faces, then it is called ***'End standard'.*** End standards can be made to a very high degree of accuracy.

Ex: Slip gauges, Gap gauges, Ends of micrometer anvils, etc.

Characteristics of End Standards:

1. End standards are highly accurate and are well suited for measurements of close tolerances as small as 0.0005 mm.
2. They are time consuming in use and prove only one dimension at a time.
3. End standards are subjected to wear on their measuring faces.
4. End standards have a 'built in' datum, because their measuring faces are flat &parallel and can be positively located on a datum surface.
5. They are not subjected to the parallax effect since their use depends on ***"feel".***
6. Groups of blocks may be ***"wrung"*** together to build up any length. But faulty wringing leads to damage.
7. The accuracy of both end & line standards are affected by temperature change.

SLIP GAUGES:

Slip gauges are rectangular blocks of steel having cross section of 30 mm face length & 10 mm face width as shown in fig.

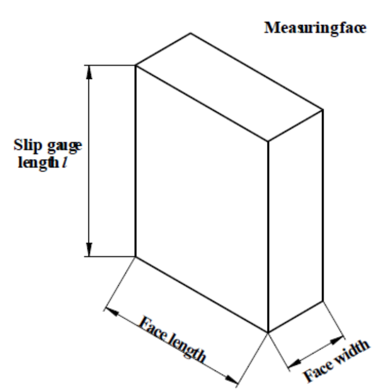


Fig 1.8 Slip gauge block

Slip gauges are blocks of steel that have been hardened and stabilized by heat treatment. They are ground and lapped to size to very high standards of accuracy and surface finish. A slip gauge is a precision length measuring standard consisting of a ground and lapped metal or ceramic block.

When correctly cleaned and wrung together, the individual slip gauges adhere to each other by molecular attraction and, if left like this for too long, a partial cold weld will take place. If this is allowed to occur, the gauging surface will be irreparable after use, hence the gauges should be separated carefully by sliding them apart. They should then be cleaned, smeared with petroleum jelly (Vaseline) and returned to their case.

Wringing of Slip Gauges:

Slip gauges are wrung together to give a stack of the required dimension. In order to achieve the maximum accuracy the following precautions must be taken.

- Use the minimum number of blocks.
- Wipe the measuring faces clean using soft clean chamois leather.
- Wring the individual blocks together by first pressing at right angles, sliding & then twisting.

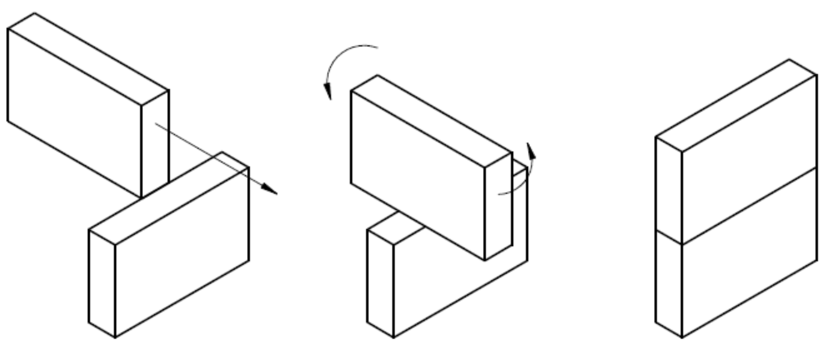


Fig 1.9 Wringing of Slip Gauges

M-87 Set of Slip Gauges:

Range (mm)	Steps (mm)	No of pieces
1.001 to 1.009	0.001	9
1.01 to 1.49	0.01	49
0.5 to 9.5	0.5	19
10 to 90	10	9
1.0005	--	01
Total		87

M-45 Set of Slip Gauges:

Range (mm)	Steps (mm)	No of pieces
1.001 to 1.009	0.001	9
1.01 to 1.09	0.01	9
1.1 to 1.9	0.1	9
1 to 9	1	9
10 to 90	10	9
Total		45

Important notes on building of Slip Gauges:

• Always start with the last decimal place.

• Then take the subsequent decimal places.

• Minimum number of slip gauges should be used by selecting the largest possible block in each step.

Importance of limits system in mass production:

In the early days, majority of the components were actually matted together, their dimensions being adjusted until the required type of fit was obtained. But with the passage of time, engineers and workers realized that the variations in the sizes of the parts had always present and that such variations could be restricted but not avoided. It has also been realized that exact size components are difficult to produce. Any attempt towards very closed dimensions of a product will increase cost of the production. The functional aspects of the component may be achieved even without going for its exact dimensions using limits, fit and tolerances. This reduces the unit cost of production and increases the rate of production.

For example, a shaft of exact 10.00 mm diameter is difficult to produce by machining process. But if you provide tolerance, i.e. the amount of variation permitted in the size, then such parts can be easily produced. A dimension 10 ± 0.05 means a shaft may be produced between 10.05 and 9.95. These two figures represent limit and the difference, (10.05 – 9.95) = 0.10 is called tolerance.

Terminology of limit systems:

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

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

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

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

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

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

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

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

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

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

Unilateral Tolerance:

Tolerances on a dimension may either be unilateral or bilateral. When the two limit dimensions are only on one side of the nominal size, (either above or below) the tolerances are said to be unilateral. For unilateral tolerances, a case may occur when one of the limits coincide with the basic size.

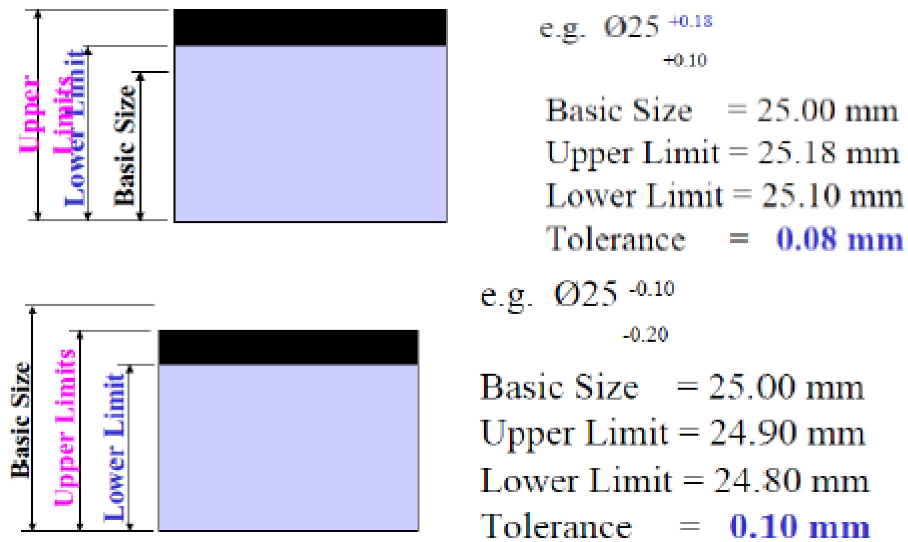


Fig 1.10 Unilateral tolerance system

Bilateral Tolerance:

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

Schematic representation of tolerances:

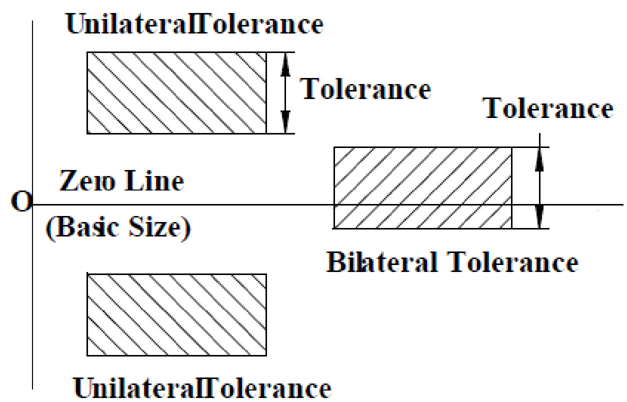


Fig 1.11 Unilateral and bilateral system of tolerance

SYSTEM OF FITS: ***Fit*** is an assembly condition between ‘Hole’ & ‘Shaft’.

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

Clearance fit can be sub-classified as follows:

- Loose Fit
- Running Fit
- Slide Fit or Medium Fit

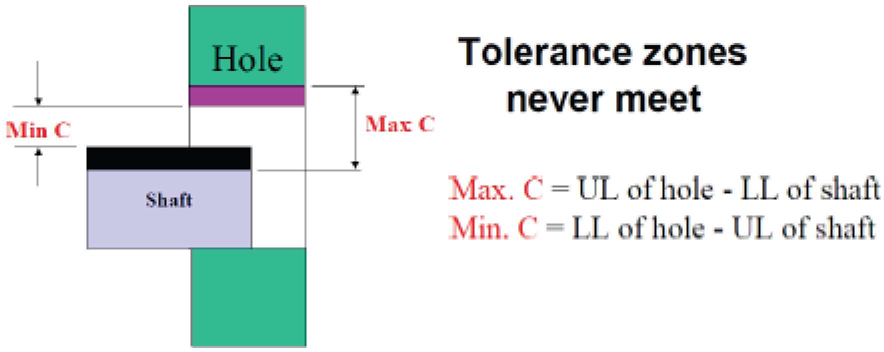


Fig 1.12 Clearance fit

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

Ex: Bearing bushes, Keys & key ways

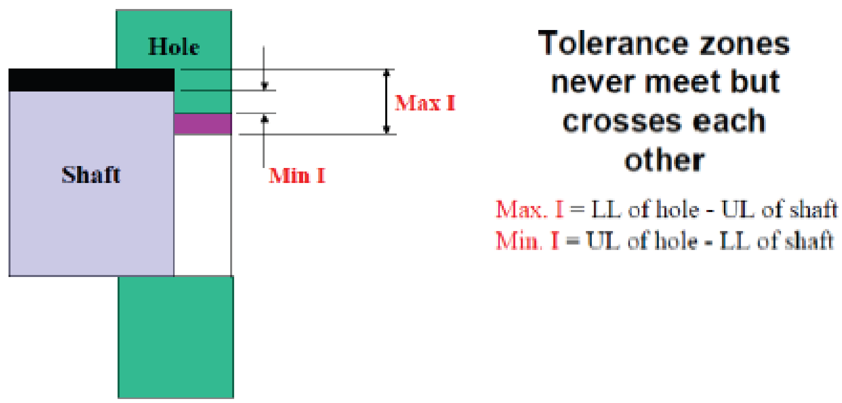


Fig 1.13 Interference fit

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

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

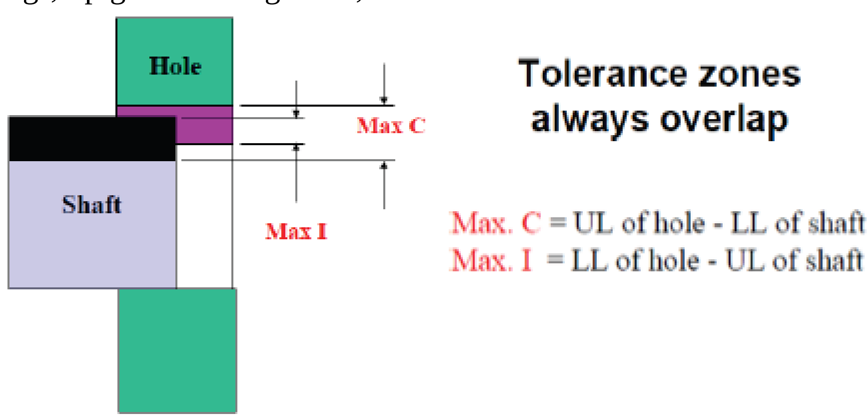


Fig 1.14 Transition fit

Interchangeability:

Interchangeability occurs when one part in an assembly can be substituted for a similar part which has been made to the same drawing. Interchangeability is possible only when certain standards are strictly followed. ***Universal interchangeability*** means the parts to be assembled are from two different manufacturing sources. ***Local interchangeability*** means all the parts to be assembled are made in the same manufacturing unit.

Selective Assembly:

In selective assembly, the parts are graded according to the size and only matched grades of mating parts are assembled. This technique is most suitable where close fit of two components assembled is required. Selective assembly provides complete protection against non-conforming assemblies and reduces machining costs as close tolerances can be maintained. Suppose some parts (shafts & holes) are manufactured to a tolerance of 0.01 mm, then an automatic gauge can separate them into ten different groups of 0.001 mm limit for selective assembly of the individual parts. Thus high quality and low cost can be achieved. Selective assembly is used in aircraft, automobile industries where tolerances are very narrow and not possible to manufacture at reasonable costs.

SYSTEMS OF FIT:

There are two systems of fit for obtaining clearance, interference or transition fit. These are:

1. Hole basis system (Figure 1.15)
2. Shaft basis system (Figure 1.16)

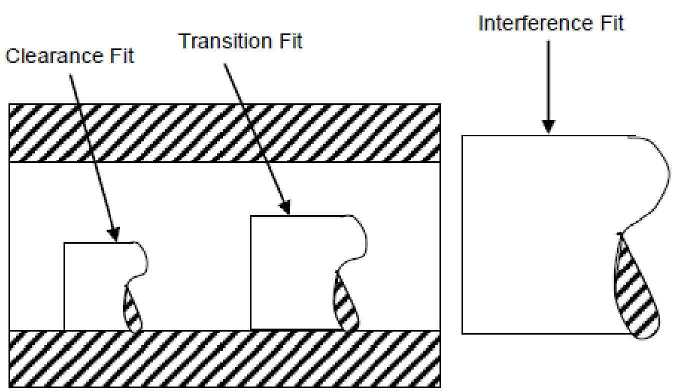


Fig. 1.15 Hole basis system

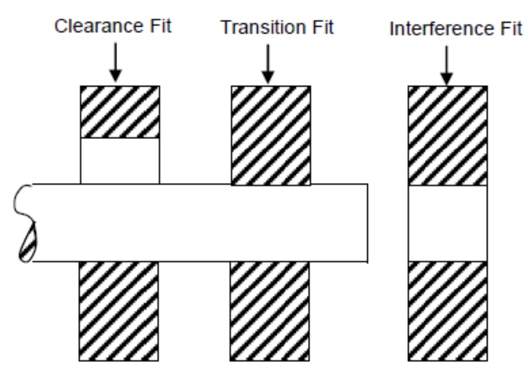


Fig. 1.16 Shaft Basis System

Hole Basis System

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

The hole basis system is commonly used because it is more convenient to make correct holes of fixed sizes, since the standard drills, taps, reamers and broaches etc. are available for producing holes and their sizes are not adjustable. On the other hand, size of the shaft produced by turning, grinding, etc. can be very easily varied.

Shaft Basis System

In the shaft basis system, the size of the shaft is kept constant and different fits are obtained by varying the size of the hole. Shaft basis system is used when the ground bars or drawn bars are readily available. These bars do not require further machining and fits are obtained by varying the sizes of the hole.

In this system, the upper deviation (fundamental deviation) of shaft is zero, i.e. the high limit of the shaft is same as basic size and the various fits are obtained by varying the low limit of shaft and both the limits of the hole.

Gauges:

Gauges are inspection tool of rigid design, without a scale, which serves to check the dimensions of manufacturing parts. Gauge do not indicate the actual value of the inspected part of the component. They are used to determine whether the part is made within the specified limit.

PLAIN GAUGES

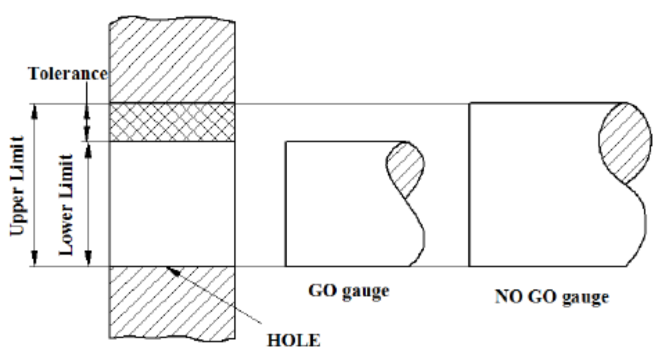
Gauges are inspection tools which serve to check the dimensions of the manufactured parts. Limit gauges ensure the size of the component lies within the specified limits. They are non-recording and do not determine the size of the part. Plain gauges are used for checking plain (Unthreaded) holes and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

LIMIT GAUGING

Limit gauging is adopted for checking parts produced by mass production. It has the advantage that they can be used by unskilled persons. Instead of measuring actual dimensions, the conformance of product with tolerance specifications can be checked by a ‘GO’ and ‘NO GO’ gauges. A ‘GO’ gauge represents the maximum material condition of the product (i.e. minimum hole size or maximum shaft size) and conversely a ‘NO GO’ represents the minimum material condition (i.e. maximum hole size or minimum shaft size)

Plug gauges:

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



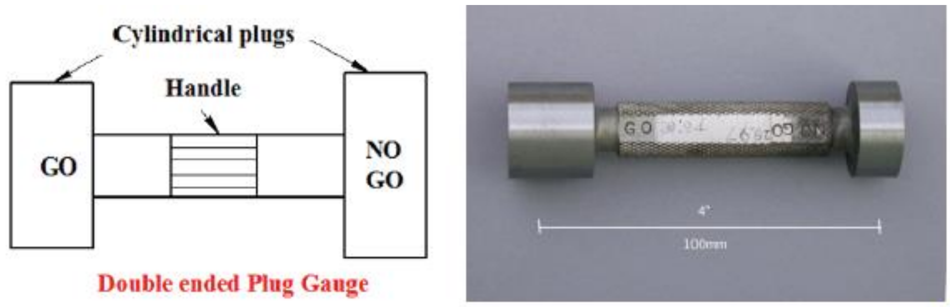


Fig 1.17 Plug gauges

Progressive plug gauges:

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

Fig 1.18 Progressive plug gauges

Ring gauges:

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

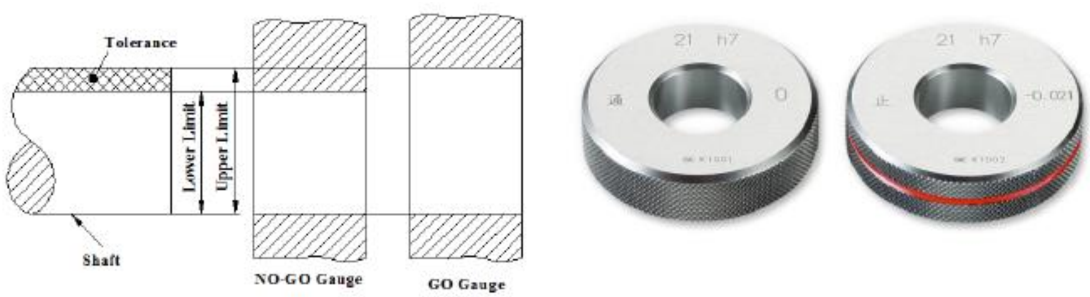


Fig 1.19 Ring gauges

SNAP (or) GAP GAUGES:

A snap gauge usually consists of a plate or frame with a parallel faced gap of the required dimension. Snap gauges can be used for both cylindrical as well as non-cylindrical work as compared to ring gauges which are conveniently used only for cylindrical work. Double ended snap gauges can be used for sizes ranging from 3 to 100 mm. For sizes above 100 mm upto 250 mm a single ended progressive gauge may be used.

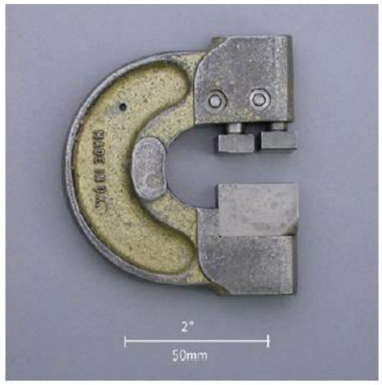


Fig 1.20 snap gauges

Taylor's Principle of Gauge Design:

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

'GO' Limit: This designation is applied to that limit of the two limits of size which corresponds to the maximum material limit considerations, i.e. upper limit of a shaft and lower limit of a hole. The GO gauges should be of full form, i.e. they should check shape as well as size.

No Go' Limit: This designation is applied to that limit of the two limits of size which corresponds to the minimum material condition, i.e. the lower limit of a shaft and the upper limit of a hole. 'No Go' gauge should check only one part or feature of the component at a time, so that specific discrepancies in shape or size can be detected. Thus a separate 'No Go' gauge is required for each different individual dimension.

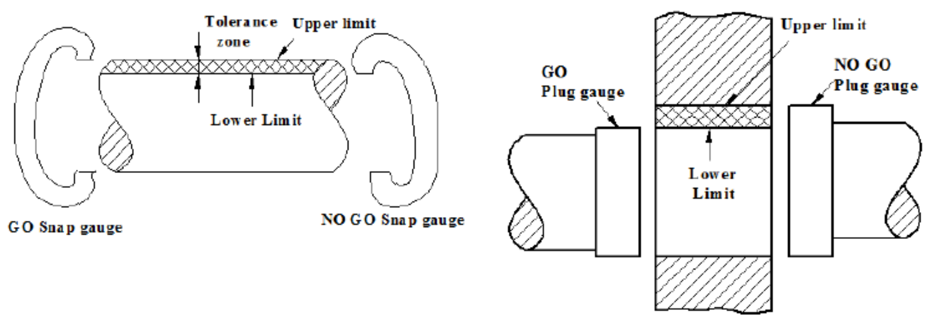
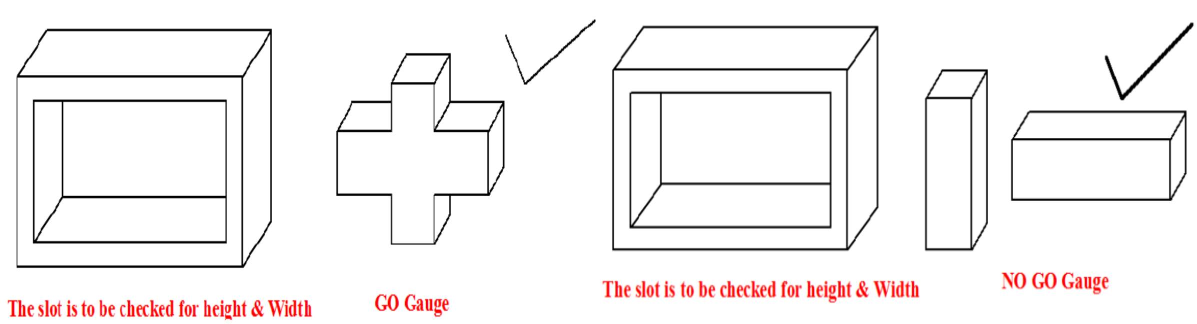


Fig 1.21 Taylor's principle of gauge design

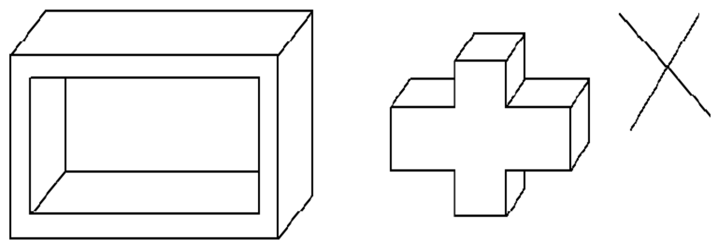
Example to illustrate Taylor's Principle of Gauge Design:



A GO gauge must check the dimensions as well as form (perpendicularity) of the slot at a time. Hence the GO gauge must be as shown in fig on the right.

A NO GO gauge must check the dimensions of the slot one at a time and hence two separate gauges must be used.

If the single gauge as shown is used, the gage is likely to pass a component even if one of the dimensions is less than desirable limit because it gets stuck due to the other dimension which is within correct limit.



The slot is to be checked for height & Width NO GO Gauge

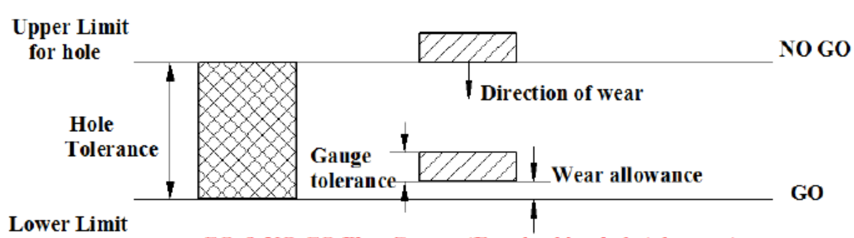
Gauge Tolerance:

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

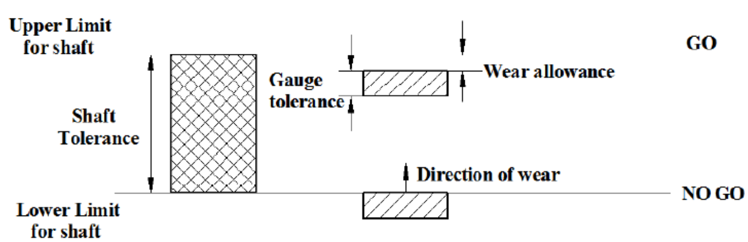
Wear Allowance:

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

PLUG GAUGES: (For checking tolerances on holes)



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



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