Introduction To Metrology

Meaning of Metrology

- Metrology is the science of measurement.
- Metrology may be divided depending upon the quantity to be measured like metrology of length, metrology of time.
- But for engineering purposes, it is restricted to measurement of length and angles and other qualities which are expressed in linear or angular terms.
- In the broader sense it is not limited to length measurement but is also concerned with industrial inspection and its various techniques.

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- Metrology is mainly concerned with:

  (1) Establishing the units of measurements, ensuring the uniformity of measurements.

  (2) Developing methods of measurement.

  (3) Errors of measurement.

  (4) Accuracy of measuring instruments and their care.

  (5) Industrial inspection and its various techniques.

Legal Metrology

- **Legal Metrology**

  Legal metrology is directed by a national organization which is called national service of Legal metrology. It includes a no. of international organization whose ultimate object is to maintain uniformity of measurement throughout the world.

- The activities of legal metrology are:

  (1) Control of measuring instruments.

  (2) Testing of prototype/models of measuring instruments.

  (3) Examination of measuring instrument to verify its conformity.

Necessity and importance of Metrology

- In design, design engineer should not only check his design from the point of view of the strength or economical production, but he should also keep in mind how the dimensions specified can be checked or measured.
- Higher productivity and accuracy can be achieved by properly understood, introduced the Metrology.
- You can improve the measuring accuracy and dimensional and geometrical accuracies of the product.

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- Proper gauges should be designed and used for rapid and effective inspection.
- Also automation and automatic control, which are the modern trends for future developments, are based on measurement. Digital instruments also we can used for inspection.

Quality control – Metrology as a means to achieve

- Whenever parts must be inspected in large numbers hundred percent inspection of each part is not only slow and costly but in addition does not eliminate all of the defective pieces.
- Mass inspection tends to be careless, operators become fatigue and inspection gauge become worn or out of adjustment more frequently.
- Quality control enables an inspector to sample the part being produced in a mathematical manner and to determine whether or not the entire stream of production is acceptable.

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- The following steps must be taken while using quality control techniques.

1) Sample the stream of product.
2) Measure the desired dimension.
3) Calculate the deviations of the dimensions from the mean dimension.
4) Construct a control chart.
5) Plot succeeding data on the control chart.

Objectives of Metrology:

- The basic objective of a measurement is to provide the required accuracy at a minimum cost.

1. Complete evaluation of newly developed products.
2. Determination of Process Capabilities.
3. Determination of the measuring instrument capabilities and ensure that they are quite sufficient for their respective measurements.
4. Minimising the cost of inspection by effective and efficient use of available facilities.

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5. Reducing the cost of rejects and rework through application of statistical quality control techniques.
6. To standardise the measuring methods.
7. To maintain the accuracies of measurement.
8. To prepare design for all gauges and special inspection fixtures.

Process of measurement:

- The sequence of operations necessary for the execution of measurement is called process of measurement.
- There are main three important elements of measurement,

  (1)

  - Measurand is the physical quantity or property like length, angle, diameter, thickness etc. to be measured.

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(2) Reference:

- It is the physical quantity or property to which quantitative comparisons are made.

(3) Comparator:

- It is the means of comparing measuring measurand with some reference.

- Suppose a fitter has to measure the length of M.S. plate- he first lays his rule along the flat. He then carefully aligns the zero end of his rule with one end of M.S. flat and finally compares the length of M.S. flat with the graduations on his rule by his eyes. In this example, the length of M.S. flat is a measurand, steel rule is the reference and eye can be considered as a comparator.

Methods of Measurement:

- The methods of measurement can be classified as:

  (1) Direct method:

  - This is a simple method of measurement, in which the value of the quantity to be measured is obtained directly without the calculations.
  - For example, measurements by scales, vernier callipers, micrometers, bevel protector etc.
  - This method is most widely used in production. This method is not very accurate because it depends on human judgment.

  (2) Indirect method:

  - In indirect method the value of quantity to be measured is obtained by measuring other quantities which are functionally related to required value.
  - for example, angle measurement by sine bar, measurement of shaft power by dynamometer etc.

Measuring system:

- A measuring system is made of five elements:

  These are:

  (1) Standard

  (2) Work piece

  (3) Instrument

  (4) Person

  (5) Environment

- The most basic element of measurement is a standard without which no measurement is possible.
- Once the standard is chosen select a work piece on which measurement will be performed.
- Then select a instrument with the help of which measurement will be done.
- The measurement should be performed under standard environment.
- And lastly there must be some person or mechanism to carry out the measurement.

Accuracy:

- Accuracy is defined as the closeness of the measured value with true value.

OR

- Accuracy is defined as the degree to which the measured value agrees with the true value.
- Practically it is very difficult to measure the true value and therefore a set of observations is made whose mean value is taken as the true value of the quantity measured.

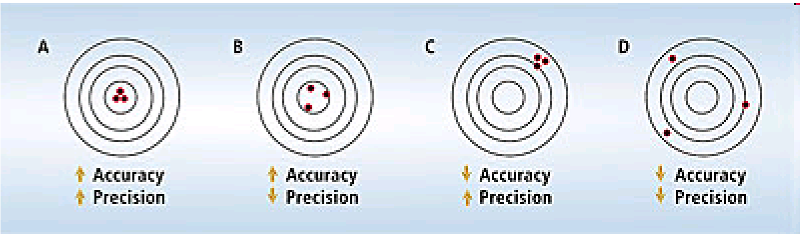
Precision:

- A measure of how close repeated trials are to each other.

OR

- The closeness of repeated measurements.
- Precision is the repeatability of the measuring process. It refers to the group of measurements for the same characteristics taken under identical conditions.
- It indicated to what extent the identically performed measurements agree with each other.
- If the instrument is not precise it will give different results for the same dimension when measured again and again.

Distinction between Precision and Accuracy



- Figure shows the difference between the concepts of accuracy versus precision using a dartboard analogy that shows four different scenarios that contrast the two terms.
- A: Three darts hit the target center and are very close together = high accuracy and precision
- B: Three darts hit the target center but are not very close together = high accuracy, low precision
- C: Three darts do not hit the target center but are very close together = low accuracy, high precision
- D: Three darts do not hit the target center and are not close together = low accuracy and precision

Factors affecting the accuracy of the measuring system:

- The basic components of an accuracy evolution are the five elements of a measuring system such as:

1. Factors affecting the calibration standards.
2. Factors affecting the work piece.
3. Factors affecting the inherent characteristics of the instrument.
4. Factors affecting the person, who carries out the measurements.
5. Factors affecting the environment.

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1. Factors affecting the standard. It may be affecting by:
   - Coefficient of thermal expansion,
   - calibration internal
   - stability with time
   - elastic properties
   - geometric compatibility
2. Factors affecting the work piece, these are
   - cleanliness, surface finish, surface defects etc.
   - elastic properties
   - hidden properties
   - arrangement of supporting workpiece.

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3 .Factors affecting the inherent characteristics of instrument.

- Scale error
- effect of friction, hysteresis, zero drift
- calibration errors
- repeatability and readability
- constant geometry for both workpiece and standard

4. Factors affecting person:

- training skill
- ability to select the measuring instruments and standard
- attitude towards personal accuracy achievements
- sense of precision appreciation

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5. Factors affecting environment:

- temperature, humidity etc.
- clean surrounding and minimum vibration enhance precision
- temperature equalization between standard, workpiece and instrument,
- thermal expansion effects due to heat radiation from lights, heating elements, sunlight and people.

The above analysis of five basic metrology elements can be composed into the acronym.

SWIPE for convenient reference

Where, S- standard

W- Workpiece

I- Instrument

P- Person

E- Environment

Sensitivity:

- Sensitivity may be defined as the rate of displacement of the indicating device of an instrument, with respect to the measured quantity.
- Sensitivity of thermometer means that it is the length of increase of the liquid per degree rise in temperature. More sensitive means more noticeable expansion.

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- In other words, sensitivity of an instrument is the ratio of scale spacing to the scale division value. For example, if on a dial indicator, the scale spacing is 1 mm and the scale division value is 0.01 mm then sensitivity is 100. It is also called as amplification factor or gearing ratio.

Readability:

- Readability refers to the ease with which the readings of a measuring instrument can be read.
- Fine and widely spaced graduation lines improve the readability.
- To make the micrometers more readable they are provided with venier scale or magnifying devices.

Calibration:

- The calibration of any measuring instrument is necessary to measure the quantity in terms of standard unit.
- It is carried out by making adjustments such that the read out device produces zero output for zero input.

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- The process whereby the magnitude of the output of a measuring instrument is related to the magnitude of the input force driving the instrument (i.e. Adjusting a weight scale to zero when there is nothing on it).
- The accuracy of the instrument depends on the calibration.
- If the output of the measuring instrument is linear and repeatable, it can be easily calibrated.

Magnification:

- Magnification is the process of enlarging something only in appearance, not in physical size so that it is more readable.

(The stamp appears larger with the use of a magnifying glass.)

Repeatability:

- It is the ability of the measuring instrument to repeat the same results for the measurements for the same quantity, when the measurements are carried out

  - by the same observer,

  - with the same instrument,

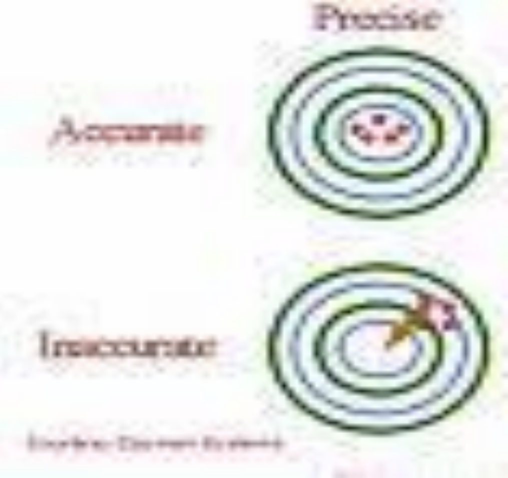
  - under the same conditions,

  - without any change in location,

  - without change in the method of measurement,

  - the measurements are carried out in short intervals of time.

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



Reproducibility:

- Reproducibility is the closeness of the agreement between the results of measurements of the same quantity, when individual measurements are carried out:

  - by different observers,

  - by different methods,

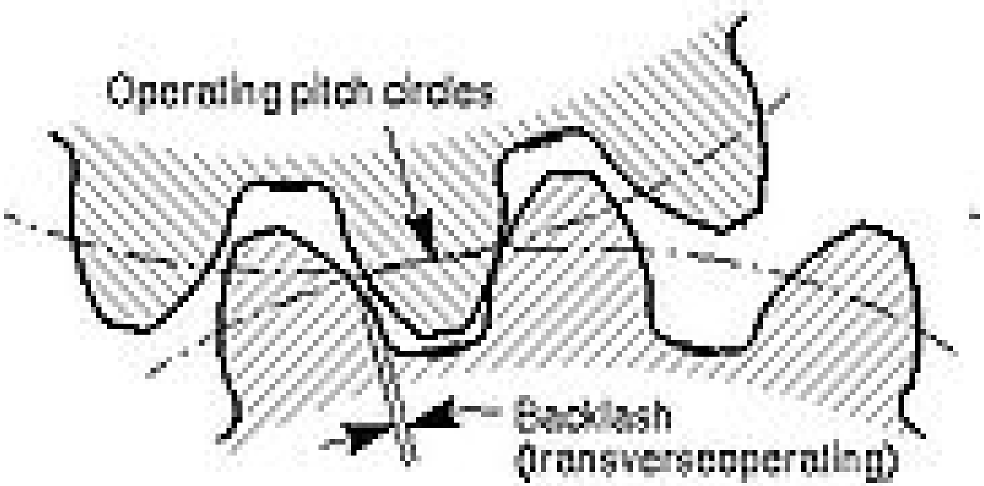
  - using different instruments,

  - under different conditions, locations, times etc.

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

Backlash:

- In [Mechanical Engineering](), **backlash**, is clearance between mating components, sometimes described as the amount of lost motion due to clearance or slackness when movement is reversed and contact is re-established.



Hysteresis:

- It is the difference between the indications of a measuring instrument when the same value of measured quantity is reached by increasing or decreasing that quantity.
- It is caused by friction, slack motion in the bearings and gears, elastic deformation, magnetic and thermal effects.

Drift:

- It is an undesirable gradual deviation of the instrument output over a period of time that is unrelated to changes in input operating conditions or load.
- An instrument is said to have no drift if is reproduces the same readings at different times for same variation in measured quantity.
- It is caused by wear and tear, high stress developed at some parts etc.

Threshold:

- The min. value below which no output change can be detected when the input of an instrument is increased gradually from zero is called the threshold of the instrument.
- Threshold may be caused by backlash.

Resolution:

- When the input is slowly increased from some non-zero value, it is observed that the output does not change at all until a certain increment is exceeded; this increment is called resolution.
- It is the min. change in measured variable which produces an effective response of the instrument.
- It may be expressed in units of measured variable

Dead zone and Dead Time:

Dead Zone:

- The largest change of input quantity for which there is no change of output of the instrument is termed as dead zone.
- It may occur due to friction in the instrument which does not allow the pointer to move till sufficient driving force is developed to overcome the friction loss.
- Dead zone caused by backlash and hysteresis in the instrument.

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<u>Dead Time:</u>

- The time required by a measurement system to begin to respond to a change in the measurand is termed as dead time.
- It represents the time before the instrument begins to respond after the measured quantity has been changed.

Errors in measurements:

- It is never possible to measure the true value of a dimension, there is always some error.
- The error in the measurement is the difference between the measured value and the true value of measured dimensions.
- The error in measurement may be expressed either as on absolute error or as a relative error.

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<u>Absolute error:</u>

- True absolute error: It is the algebraic difference between the result of measurement and the conventional true value of the quantity.
- Apparent absolute error: If the series of measurement are made then the algebraic difference between one of the results of measurement and the arithmetical mean is known as apparent absolute error.

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Relative error:

- It is the quotient of absolute error and the true value or the arithmetical mean for series of measurement.

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- <u>Types of errors:</u>

  During measurement several types of error may arise, these are:

  1. Static errors which includes:
     - (a) Reading errors
     - (b) Characteristic errors
     - (c) Environmental errors
  2. Instrumental loading errors.
  3. Dynamic errors.

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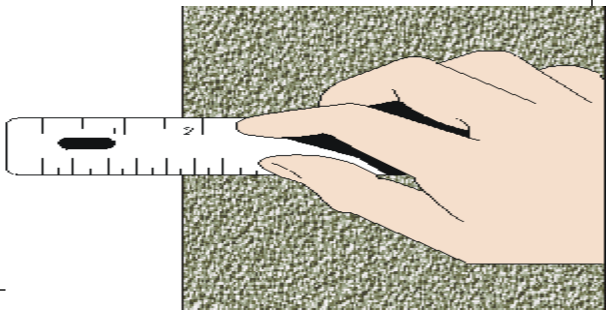
<u>1.Static errors:</u>

- These errors result from the physical nature of various components of measuring system. There are three basic sources of static errors:

(a) <u>Reading errors:</u>

- These errors occur due to carelessness of operators. These do not have any direct relationship with other types of errors within the measuring system.



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Reading errors include:

- Parallax error:

  parallax errors arise on account of pointer and scale not being in same plane, we can eliminate this error by having the pointer and scale in same plane.
- Wrong scale reading and wrong recording of data.
- Inaccurate estimates of average reading.
- Incorrect conversion of units in calculations.

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(b) <u>Characteristics error:</u>

- It is defined as the deviation of the output of the measuring system from the theoretical predicated performance or from nominal performance specifications.
- Linearity errors, repeatability, hysteresis are the characteristics errors if theoretical output is straight line. Calibration error is also included in characteristics error.

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(c) Environmental errors:

- These error result from the effect of surrounding such as temperature, pressure, humidity etc. on measuring system.
- It can be reduced by controlling the atmosphere according to the specific requirement.

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2. <u>Instrument loading error:</u>

- Loading errors results from the change in measurand itself when being measured.
- Instrument loading error is the difference between the value of measurand before and after the measurement.
- For example a soft or ductile component is subjected to deformation during measurement due to the contact pressure of the instrument and cause a loading error. The effect of this error is unavoidable.

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3. Dynamic errors:

- Dynamic error, also called measurement error, is the difference between the true value of measuring quantity and value indicated by measurement system if no static error is assumed.
- These errors can be broadly classified as:

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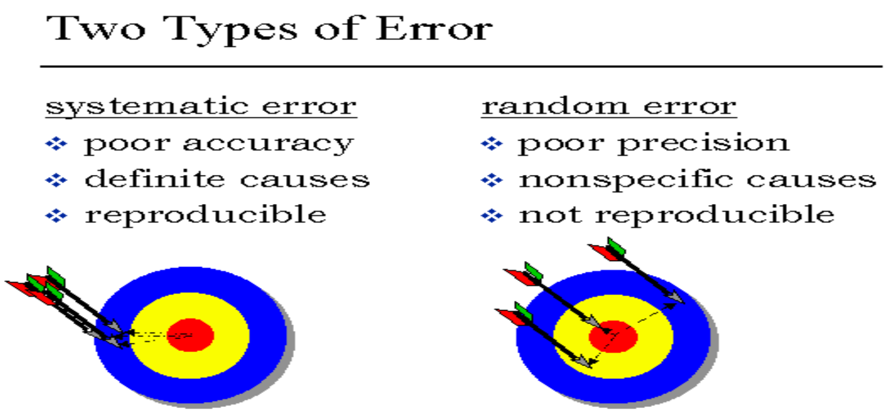
(a) Systematic or controllable errors:

- These errors are controllable in both their magnitude and stress. These can also be determined and reduced. These are due to:

(1) Calibrations errors:

- The actual length of standards such as scales will vary from nominal value by small amount. This will cause an error in measurement of constant magnitude.



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(2) Atmospheric error:

- Variation in atmospheric condition (i.e temperature, pressure and moisture content) at the place of measurement from that of internationally agreed standard values (20’ temp. and 760 mm of Hg pressure) can give rise to error in measurand size of the component.

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(3) Stylus pressure:

- Another common source of error is the pressure with which the workpiece is pressed while measuring. Though the pressure involved is generally small but this is sufficient enough to cause appreciable deformation of both the stylus and the workpiece.

-Variations in force applied by the anvils of micrometer on the work to be measured results in the difference in its readings. In this case error is caused by the distortion of both micrometer frame and workpiece.

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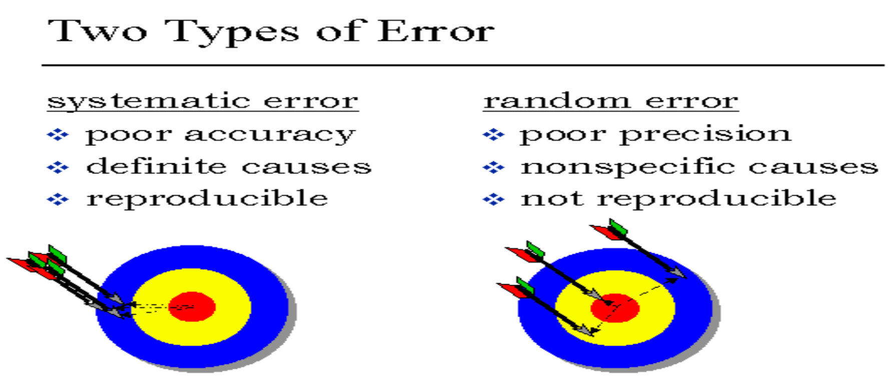
(4) Avoidable errors:

- These errors may occur due to parallax, non alignment of workpiece centers, improper location of measuring instruments such as a thermometer in sunlight while measuring temperature.

(b) Random errors:

- The random errors occur randomly and the specific causes of such errors cannot be determined. The likely sources of this type of error are:

- Small variations in the position of setting standard and workpiece.
- Slight displacement of lever joints in the measuring instrument.
- Friction in measuring system.
- Operator errors in reading scale.



Difference between Systematic and Random errors:

Systematic error

- These errors are repetitive in nature and are of constant & similar form.
- These errors result from improper conditions.

Random error

- These are non consistent. The sources giving rise to such errors are random.
- Such errors are inherent in the measuring system.

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- Expect personal errors all other systematic errors can be controlled in magnitude and sense.
- If properly analyzed these can be determined and reduced or eliminated.
- Specific causes, magnitudes and sense of these errors cannot be determined from the knowledge of measuring system.
- These errors cannot be eliminated, but the results obtained can be corrected.

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- These errors includes calibration errors, variation in atmosphere, pressure, misalignment error etc.

- These errors includes Small variations in the position of setting standard and workpiece, Slight displacement of lever joints in the measuring instrument, Friction in measuring system, Operator errors in reading scale.