## $\mathbf{L}_{\text {aboratory }}$ of $\mathbf{M}_{\text {easurements }}$

## and Instrumentations



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Before we start, It is pertinent to mention here the classic statement made by Lord Kelvin (1824-1907), an eminent scientist, highlighting the importance of metrology: 'When you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge of it is of a meager and unsatisfactory kind. It may be the beginning of knowledge, but you have scarcely in your thought advanced to the stage of science.'

> The science of measurements is called Metrology . In practical applications, metrology is the enforcement, verification, and validation of predefined standards.

The word metrology is derived from the Greek word 'metrologia', which means measure.

Modern manufacturing technology is based on precise reliable dimensional measurements. The term 'legal metrology' applies to any application of metrology that is subjected to national laws or regulations.

Legal metrology ensures the conservation of national standards and guarantees their accuracy in comparison with the international standards, thereby imparting proper accuracy to the secondary standards of the country. Some of the applications of legal metrology are industrial measurement, commercial transactions, and public health and human safety aspects.

## METRロLロGY

Some important terms \& definitions relating to Metrology.....

Inspection is defined as a procedure in which a part or product characteristic, such as a dimension, is examined to determine whether it conforms to the design specification.

Accuracy is the degree of agreement of the measured dimension with its true magnitude. It can also be defined as the maximum amount by which the result differs from the true value or as the nearness of the measured value to its true value, often expressed as a percentage.
Precision is the degree of repetitiveness of the measuring process. It is the degree of agreement of the repeated measurements of a quantity made by using the same method, under similar conditions. In other words, precision is the repeatability of the measuring process.

(a)
(b)

(d)

Fig. 1.1 Accuracy and precision (a) Precise but not accurate (b) Accurate but not precise (c) Precise and accurate (d) Not precise and not accurate

Repeatability is the ability of the measuring instrument to repeat the same results during the act of measurements for the same quantity.

The difference between the true value and the mean value of the set of readings on the same component is termed as an error. Error can also be defined as the difference between the indicated value and the true value of the quantity measured.

$$
E=V_{m}-V_{t}
$$

where $E$ is the error, $V_{m}$ the measured value and $V_{t}$ the true value.

$$
\begin{aligned}
\text { \% error }= & \frac{\text { Error }}{\text { True value }} \times 100 \\
\text { Or } \quad \text { \% error }= & \frac{V_{\mathrm{m}}-V_{\mathrm{t}}}{V_{\mathrm{t}}} \times 100
\end{aligned}
$$

Accuracy of an instrument is always assessed in terms of error.

Sensitivity is the ratio of the change of instrument indication to the change of quantity being measured. In other words, it is the ability of the measuring equipment to detect small variations in the quantity being measured.

## Important::

The permitted degree of sensitivity determines the accuracy of the instrument. An instrument cannot be more accurate than the permitted degree of sensitivity.

Consistent or Consistency of an instrument :When successive readings of the measured quantity obtained from the measuring instrument are same all the time.

## Important::

highly accurate instrument possesses both sensitivity and consistency.

Range is defined as the difference between the lower and higher values that an instrument is able to measure. If an instrument has a scale reading of $0.01-100 \mathrm{~mm}$, then the range of the instrument is $0.01-100 \mathrm{~mm}$, that is, the difference between the maximum and the minimum value.

## Accuracy VS Cost!



Relationship of accuracy with cost

## Unit Prefixes

|  | Metric Prefixes | Symbol | Multiples and Submultiples | Factor |
| :---: | :---: | :---: | :---: | :---: |
|  | Exa | E | 1,000,000,000,000,000,000 | $10^{18}$ |
|  | Peta | P | 1,000,000,000,000,000 | $10^{15}$ |
|  | Tera | T | 1,000,000,000,000 | $10^{12}$ |
|  | Giga | G | 1,000,000,000 | $10^{9}$ |
|  | Mega | M | 1,000,000 | $10^{6}$ |
|  | Kilo | k | 1,000 | $10^{3}$ |
|  | Hecto | h | 100 | $10^{2}$ |
|  | Deca | da | 10 | 10 |
|  | Deci | d | 0.1 | $10^{-1}$ |
|  | Centi | c | 0.01 | $10^{-2}$ |
|  | Milli | m | 0.001 | $10^{-3}$ |
|  | Micro | $\mu$ | 0.000001 | $10^{-6}$ |
|  | Nano | n | 0.000000001 | $10^{-9}$ |
|  | Pico | p | 0.000000000001 | $10^{-12}$ |
|  | Femto | $f$ | 0.000000000000001 | $10^{-15}$ |
|  | Atto | a | 0.0000000000000000001 | $10^{-18}$ |

## METRロLロGY



## Angular Measurements

Angle: The area between two converging lines.
Units: There are three Units of angle is used

## 1. Degrees

2. Radians

## 3. Grads

Degrees: The degree is equal to $1 / 360$ of a complete circle. This is further sub divided into minutes $\&$ seconds. e.g.
$1^{\circ}($ Degree $)=60^{\prime}($ Minutes $)$
$1^{\prime}=60$ " (Seconds)
Conversion form degree to Degree, Minute \& Seconds. (e.g. if the value is in $36.8275^{\circ}$ \& you need to convert it in Degree, Minute \& Seconds)


Step III Multiply "b" with 60 to get the minute i.e. $0.8275 \times 60=49.65-----------------------------------------c$
Step IV Keep the digit before decimal aside \& label it with minute i.e. 49'---------------------------------d

Step VI Multiply "e" with 60 to get second \& round the digit \& label it as seconds i.e.0.65X60=39 ------f
$\underline{36.8275}{ }^{\circ}=36^{\circ} 49^{\prime} 39^{\prime \prime}\left(a^{\circ} d^{\prime} f^{\prime \prime}\right)$

## Metralagy



## Conversion form DMS to Degree:

For example convert $30^{\circ} 30^{\prime} 30^{\prime \prime}$ in Degree
Step I - Keep the Degree aside i.e 30----------------------------a
StepII- Divide minutes with 60 i.e. $30 \div 60=0.5----------------$ -
StepIII- Divide Seconds with 3600 i.e. $30 \div 3600=0.008333--$ c
Step IV- Add $a+b+c$ i.e. $30+0.5+0.0083=30.508333$
Note : Take digit up to 6 digit after decimal.
Radian: The radian is equal to an arc which is the same length as the radius it is projected from. For example if the radius of an arch is 50 mm \& length of the arc is 50 mm then it will be 1 radian.

1 radian is always equal to $57.2958^{\circ}$
To Convert Degree to radian, divide the degree value by 57.2958 .
To Convert Radian to Degree multiply the radian value is multiplied by 57.2958 .
Grads:
This is less common in use. This is very similar to the degree, with two exceptions. First there are 400 grads in a complete circle instead of 360 as in degrees. Grads have no sub units. This is always expressed in decimal forms.
To convert grads to degree multiply by $0.9(360 \div 400)$
To convert degree to grad multiply by $1.111(400 \div 360)$

## METRロLロGY

## Nelection of Instruments for measurements:

There are many measuring instruments, some are different in function \& some are different in degree of accuracy. Those with the least degree of accuracy are most frequently used.
N.B: Instruments those are least accurate does not means they are inaccurate.

General thumb rule is that instruments used for measurements should have the resolution up to $1 / 10^{\text {th }}$ of the tolerance.

## Tolerance

Tolerance is the total amount a dimension may vary. It is the difference between the maximum and minimum limits.

Ways to Express:

1. Direct limits or as tolerance limits applied to a dimension
2. Geometric tolerances
3. A general tolerance note in title block
4. Notes referring to specific conditions

## 1. Direct limits and tolerance values


(A) Direct limits

(B) Tolerance values

## Metralagy



## 1. Direct limits and tolerance values Plus and Minus Dimensions


(A) Unilateral tolerancing

(B) Bilateral tolerancing

## Geometric Tolerance System

Feature Control Frame

Geometric dimensioning and tolerancing (GD\&T) is a method of defining parts based on how they function, using standard ANSI symbols.

Concentricity Symbol


## Important Terms - single part

10.015 Upper Limit (MMC)
9.990 Lower Limit (LMC)


Engineering Dimensioned Drawing


Machined
Part

- Nominal Size - general size, usually expressed in common fractions (10 mm for the slot)
- Basic Size - theoretical size used as starting point (.500" for the slot)
- Actual Size - measured size of the finished part (.501" for the slot)


Engineering Dimensioned
Drawing


- Limits - maximum and minimum sizes shown by tolerances (. 502 and .498 larger value is the upper limit and the smaller value is the lower limit, for the slot)
- Tolerance - total allowable variance in dimensions (upper limit - lower limit) - object dimension could be as big as the upper limit or as small as the lower limit or anywhere in between


## Important Terms - Multiple Parts

- Allowance - the minimum clearance or maximum interference between parts
- $\mathbf{F i t}_{\text {it }}$ degree of tightness between two parts
- Clearance Fit - tolerance of mating parts always leave a space
- Interference Fit - tolerance of mating parts always interfere
- Transition Fit- sometimes interfere, sometimes clear

