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G. PULLAIAH COLLEGE OF ENGINEERING AND TECHNOLOGY
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Department of Mechanical Engineering

Bridge course
On
Metrology & Measurements

Length

The measurement or extent of something from end to end; the greater of two or the greatest of three dimensions of an object.

Zero Line

It is a line along which represents the basic size and zero (or initial point) for measurement of upper or lower deviations.

Basic size

It is the size with reference to which upper or lower limits of size are defined.

Shaft and Hole

These terms are used to designate all the external and internal features of any shape and not necessarily cylindrical.

Hole Designation: By upper case letters from A, B, … Z, Za, Zb, Zc (excluding I, L, O, Q, W and adding Js, Za, Zb, Zc) - 25 nos. Indian Stds

Shaft Designation: By lower case letters from a, b, … z, za, zb, zc (excluding i, l, o, q, w and adding js, za, zb, zc) - 25 nos.

Speed

The speed of a wave depends on the medium the wave is traveling through. If the medium does not change as a wave travels, the wave speed is constant.

Wavelength

The distance, measured in the direction of propagation of a wave, between two successive points in the wave that is characterized by the same phase of oscillation

Taper

Part of an object in the shape of a cone (conical)

Tapering (mathematics): in geometry, or in the casual description of a shape or object, a gradual thinning or narrowing towards one end

Surface roughness

Surface roughness often shortened to roughness, is a component of surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. In surface metrology, roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface. However, in practice it is often necessary to know both the amplitude and frequency to ensure that a surface is fit for a purpose.

Gear

A gear or cogwheel is a rotating machine part having cut teeth, or cogs, which mesh with another toothed part to transmit torque. Geared devices can change the speed, torque, and direction of a power source. Gears almost always produce a change in torque, creating a mechanical advantage, through their gear ratio, and thus may be considered a simple machine. The teeth on the two meshing gears all have the same shape. Two or more meshing gears, working in a sequence, are called a gear train or a transmission. A gear can mesh with a linear toothed part, called a rack, thereby producing translation instead of rotation.

Lathe

A lathe is a tool that rotates the work piece about an axis of rotation to perform various operations such as cutting, sanding, knurling, drilling, or deformation, facing, turning, with tools that are applied to the work piece to create an object with symmetry about that axis.

Boring machine

In machining, boring is the process of enlarging a hole that has already been drilled (or cast) by means of a single-point cutting tool (or of a boring head containing several such tools), such as in boring a gun barrel or an engine cylinder. Boring is used to achieve greater accuracy of the diameter of a hole, and can be used to cut a tapered hole. Boring can be viewed as the internal-diameter counterpart to turning, which cuts external diameters

Milling machine

Milling is the machining process of using rotary cutters to remove material[1] from a workpiece by advancing (or feeding) in a direction at an angle with the axis of the tool.[2][3] It covers a wide variety of different operations and machines, on scales from small individual parts to large, heavy-duty gang milling operations. It is one of the most commonly used processes in industry and machine shops today for machining parts to precise sizes and shapes

Transducers

A transducer is a device that converts one form of energy to another. Usually a transducer converts a signal in one form of energy to a signal in another

Transducers are often employed at the boundaries of automation, measurement, and control systems, where electrical signals are converted to and from other physical quantities (energy, force, torque, light, motion, position, etc.). The process of converting one form of energy to another is known as transduction.

Transducer types

Passive

Passive sensors require an external power source to operate, which is called an excitation signal. The signal is modulated by the sensor to produce an output signal. For example, a thermistor does not generate any electrical signal, but by passing an electric current through it, its resistance can be measured by detecting variations in the current and/or voltage across the thermistor.

Active

Active sensors generate electric signals in response to an external stimulus without the need of an additional energy source. Such examples are a photodiode, and a piezoelectric sensor, thermocouple.

Sensors

A sensor is a device that receives and responds to a signal or stimulus.[5] Transducer is the other term that is sometimes interchangeably used instead of the term sensor, although there are subtle differences. A transducer is a term that can be used for the definition of many devices such as sensors, actuators, or transistors.

Actuators

An actuator is a device that is responsible for moving or controlling a mechanism or system. It is operated by a source of energy, which can be mechanical force, electrical current, hydraulic fluid pressure, or pneumatic pressure, and converts that energy into motion. An actuator is the mechanism by which a control system acts upon an environment. The control system can be simple (a fixed mechanical or electronic system), software-based (e.g. a printer driver, robot control system), a human, or any other input.

Bidirectional

Bidirectional transducers convert physical phenomena to electrical signals and also convert electrical signals into physical phenomena. Examples of inherently bidirectional transducers are antennae, which can convert conducted electrical signals to or from propagating electromagnetic waves, and voice coils, which convert electrical signals into sound (when used in a loudspeaker) or sound into electrical signals (when used in a microphone). Likewise, DC electric motors may be used to generate electrical power if the motor shaft is turned by an external torque.

Resistance

As its name implies, a resistor is an electronic component that resists the flow of electric current in a circuit. Electrical resistance is analogous to friction in a mechanical system. They both convert energy to heat and dissipate it to the surrounding environment, so electrical resistance can sometimes be thought of as a braking or damping mechanism in a circuit.

Inductance

An inductor is an electronic component consisting simply of a coil of wire. A constant electric current running through an inductor produces a magnetic field. If the current changes, so does the magnetic field. The unit for inductance is the henry (H), named after Joseph Henry, an American physicist who discovered inductance independently at about the same time as English physicist Michael Faraday. One henry is the amount of inductance that is required to induce one volt of electromotive force when the current is changing at one ampere per second

Capacitance

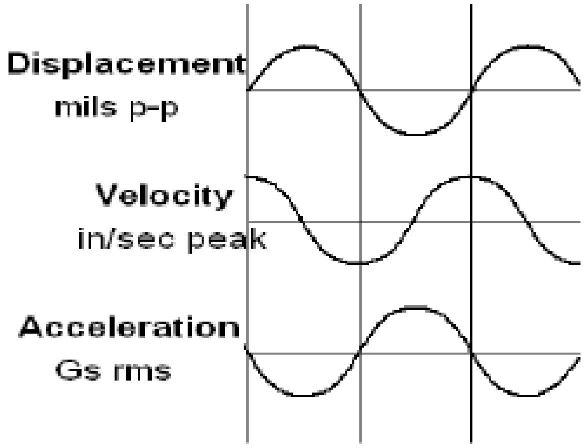
Capacitance is the ability of a device to store electric charge. An electronic component that stores electric charge is called a capacitor. The earliest example of a capacitor is the Leyden jar. This device was invented to store a static electric charge on conducting foil used to line the inside and outside of a glass jar.

The simplest capacitor consists of two flat conducting plates separated by a small gap. The potential difference, or voltage, between the plates is proportional to the difference in the amount of the charge on the plates. This is expressed as $Q = CV$, where Q is charge, V is voltage and C is capacitance.

Acceleration and vibration

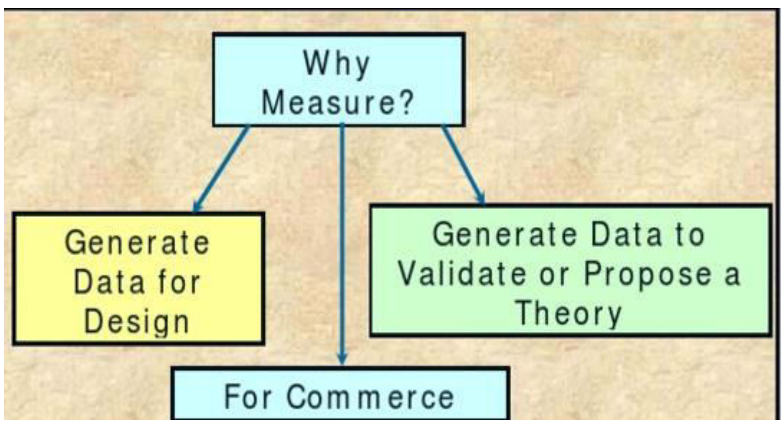
The displacement of a vibrating object as a measure of its vibration amplitude. The displacement is simply the distance from a reference position, or equilibrium point. In addition to varying displacement, a vibrating object will experience a varying velocity and a varying acceleration. Velocity is defined as the rate of change of displacement

Acceleration is defined as the rate of change of velocity, and in the English system, is usually measured in units of G, or the average acceleration due to gravity at the earth's surface.



Mechanical Measurements

Why make measurements?



We recognize three reasons for making measurements as indicated in Figure. From the point of view of the course measurements for commerce is outside its scope.

Engineers design physical systems in the form of machines to serve some specified functions. The behavior of the parts of the machine during the operation of the machine needs to be examined or analyzed or designed such that it functions reliably. Such an activity needs data regarding the machine parts in terms of material properties. These are obtained by performing measurements in the laboratory.

The scientific method consists in the study of nature to understand the way it works. Science proposes hypotheses or theories based on observations and need to be validated with carefully per formed experiments that use many measurements. When once a theory has been established it may be used to make predictions which may themselves be confirmed by further experiments.

Measurement categories

1.Primary quantity

2. Derived quantity

3. Intrusive – Probe method

4. Non-intrusive

Measurement categories are described in some detail now.

1. Primary quantity:

It is possible that a single quantity that is directly measurable is of interest. An example is the measurement of the diameter of a cylindrical specimen. It is directly measured using an instrument such as vernier calipers. We shall refer to such a quantity as a primary quantity.

2. Derived quantity:

There are occasions when a quantity of interest is not directly measurable by a single measurement process.

The quantity of interest needs to be estimated by using an appropriate relation involving several measured primary quantities. The measured quantity is thus a derived quantity. An example of a derived quantity isthe determination of acceleration due to gravity (g) by finding the period (T) of a simple pendulum of length (L). T and L are the measured primary quantities while g is the derived quantity.

3. Probe or intrusive method:

Most of the time, the measurement of a physical quantity uses a probe that is placed inside the system. Since a probe invariably affects the measured quantity the measurement process is referred to as an intrusive type of measurement.

4. Non-intrusive method:

When the measurement process does not involve insertion of a probe into the system the method is referred to as being non-intrusive. Methods that use some naturally occurring process like radiation emitted by a body to measure a desired quantity relating to the system the method may be considered as non-intrusive. The measurement process may be assumed to be non-intrusive when the probe has negligibly small interaction with the system. A typical example for such a process is the use of laser Doppler velocimeter (LDV) to measure the velocity of a flowing fluid.

General measurement scheme

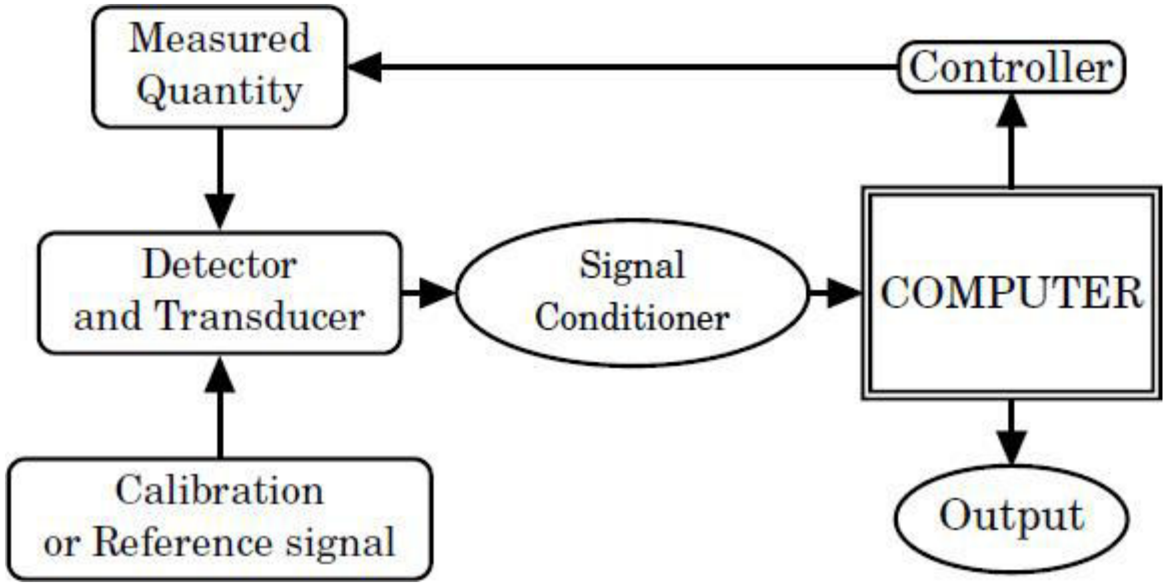


Figure shows the schematic of a general measurement scheme. Not all the elements shown in the Figure may be present in a particular case. The measurement process requires invariably a detector that responds to the measured quantity by producing a measurable change in some property of the detector. The change in the property of the detector is converted to a measurable output that may be either mechanical movement of a pointer over a scale or an electrical output that may be measured using an appropriate electrical circuit. This action of converting the measured quantity to a different form of output is done by a transducer.

The output may be manipulated by a signal conditioner before it is recorded or stored in a computer. If the measurement process is part of a control application the computer can use a controller to control the measured quantity. The relationship that exists between the measured quantity and the output of the transducer may be obtained by calibration or by comparison with a reference value. The measurement system requires external power for its operation.

Some issues

1. Errors – Systematic or Random

2. Repeatability

3. Calibration and Standards

4. Linearity or Linearization

Any measurement, however carefully it is conducted, is subject to measurement errors. These errors make it difficult to ascertain the true value of the measured quantity. The nature of the error may be ascertained by repeating the measurement a number of times and looking at the spread of the values. If

the spread in the data is small the measurement is repeatable and may be termed as being good. If we compare the measured quantity obtained by the use of any instrument and compare it With that obtained by a standardized instrument the two may show different performance as far as the repeatability is concerned. If we add or subtract a certain correction to make the two instruments give data with similar spread the correction is said to constitute a systematic error. The spread of data in each of the instruments will constitute random error. The process of ascertaining the systematic error is calibration. The response of a detector to the variation in the measured quantity may be linearor non-linear. In the past the tendency was to look for a linear response as the desired response. Even when the response of the detector was non-linear the practice was to make the response linear by some manipulation. With the advent of automatic recording of data using computers this is not necessary since software can take care of this aspect.

Quantity

• Property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed as a number and a reference (A reference can be a measurement unit, a measurement procedure, a reference material, or a combination of such.)

• Quantity can be a general quantity (e.g. length) or particular quantity (e.g.wavelength of Sodium D line)

Measurand

• Quantity intended to be measured

Estimate (of the measurand); called also MEASURED QUANTITY VALUE

• measured value of a quantity measured value

• quantity value representing a measurement result

Measurement error

• measured quantity value minus a reference quantity value

Metrology

Metrology is science of measurement and its application

Metrology includes all theoretical and practical aspects of measurement, whatever the measurement uncertainty and field of application.

Usually the concept of metrology is limited to Science of measurement studying the relationship between measurands and their estimates (measured quantity values)

Accuracy

Accuracy closeness of agreement between a measured quantity value and a true quantity value of a measurand

Precision

Precision closeness of agreement between indications or measured quantity values obtained by replicate measurements on the same or similar objects under specified conditions

Calibration

Calibration operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication

Adjustment

Adjustment set of operations carried out on a measuring system so that it provides prescribed indications corresponding to given values of a quantity to be measured

Traceability

Traceability property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty

Definitions of base units

Kilogram: The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram.

Metre: The metre is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second.

Second: The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom.

Kelvin: The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

Mole: The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12.

When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.

Ampere: The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2 × 10-7 newton per metre of length.

NOTE 1: Direct realisation of the SI ampere is very difficult in practice

NOTE 2: N = kg · m · s-2 ⇒ Depends on the prototype of kg

Candela: The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 x 1012 hertz and that has a radiant intensity in that direction of 1/683 watt per steradian