Unit-IV

Miscellaneous Measurement-Part 1

4.1 Dimension : thickness and its units
4.1.1 types:
- Differential roller type
- Inductive pickup
- capacitive pickup
- Radiation type

4.2 Laser based length measurement
4.3 Camera based width measurement
4.4 Basic colour sensor.
4.5 Magnetic reed switch

Thickness

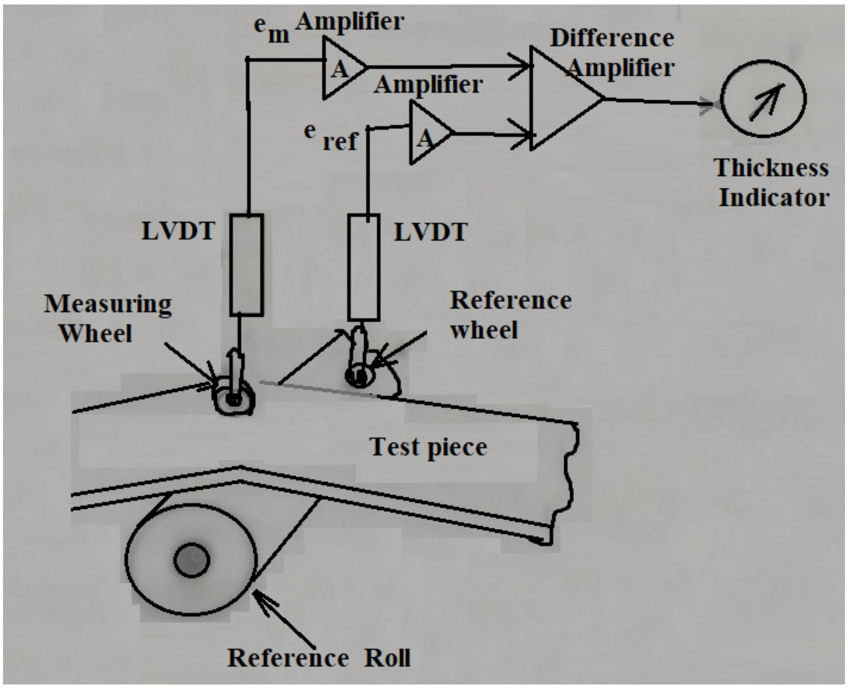
Definition-

The distance between the top and bottom sides or front and back surfaces of an object is called **thickness** of that object.

Units:

- Centimeter (cm)
- Meter (m)
- Millimeter (mm)
- Micrometer (μ m) – microns.

Differential roller LVDT.



Construction and Working

In contact-type thickness gauge, the measurement is performed with the physical contact of the instrument (transducer) and the test piece. The familiar micrometer or Vernier caliper gauges are suitable only for non continuous sampling or batch quality control and calibration measurements, because the contact points would wear out and the accuracy would be reduced with continuous use.

1) The differential dial gauge adapts the calipers to continuous measurement by using rolling contact points and indicating the difference between a reference wheel , usually on a calendar roll, and the measuring wheel on the sheet stock.

2) Thickness signal is derived from the output of a linear variable differential transformer (LVDT)

3) The thickness t can be calculated as

$$t = k(e_m - e_{ref})$$

where, t = thickness of test piece (mm)

k = calibration constant (mm/volt)

e_m = output of measuring LVDT (volt)

e_{ref} = output of reference LVDT (volt)

The output voltage of the LVDT can be calculated as

$$e_{out} = (e_{s2} - e_{s1})$$

where, e_{out} = output signal of LVDT (volt)

e_{s1} = output signal of 1^{st} secondary winding of LVDT (volt)

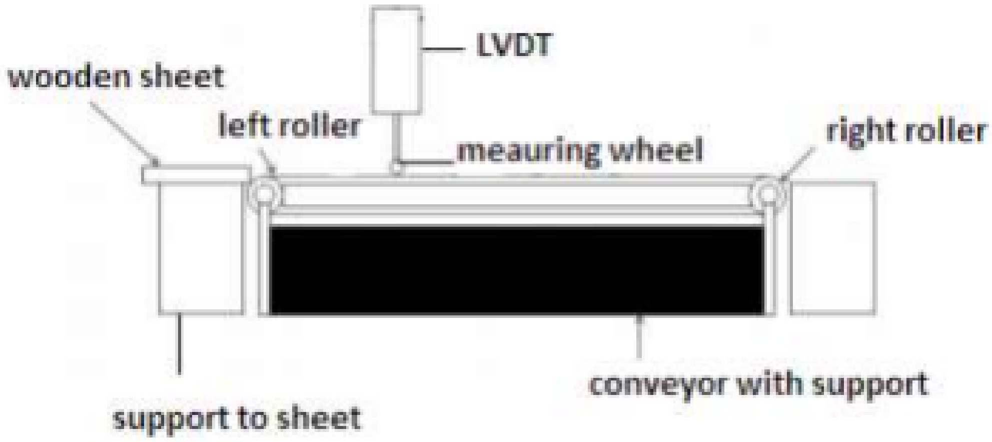
e_{s2} = output signal of 2^{nd} secondary winding of LVDT (volt)

The difference between the secondary voltages caused by displacement of the movable iron core (armature) is linearly proportional to the displacement. With the proper power source and input mechanism, dimensional gauging from point 0.0254 mm to several cm(0.001 in. to several inches) is possible. The accuracy is independent on the finish of the calendar roll. A single roller dial gauge contacting the stock would rely on the accuracy of the backing roll for overall accuracy.

Other contact-type thickness meters are available which work on electrical methods for the measurement of thickness of a stock or a product, e.g.

1. Inductive type,
2. Capacitive type,
3. Ultrasonic vibration type.

OR



Construction and Working

- Above fig. shows a basic schematic diagram for the measurement of thickness using LVDT.
- A sheet material whose thickness is to be measured is placed on the conveyor belt.
- At a particular distance from the measuring sensor's LVDT, the object is placed on the belt.
- The conveyor is programmed to move the sheet at a particular speed towards the LVDT.
- LVDT sensor is installed with a measuring wheel attached to the core which is freely suspended from rigid support to move on the conveyor.
- LVDT converts the thickness of the sheet into voltage which is proportional to the thickness of the object.
- As the wooden sheet reaches the LVDT, displacement of the measuring wheel takes place due to the thickness of the sheet. This displacement of LVDT core will cause change in mutual inductance of the coil which results in change in the output of LVDT
- This change in the output is analogous to the thickness of the sheet. The output of LVDT is given to a local controller and for further transmission and Data acquisition. The sheet can be collected at the second roller of the conveyor.

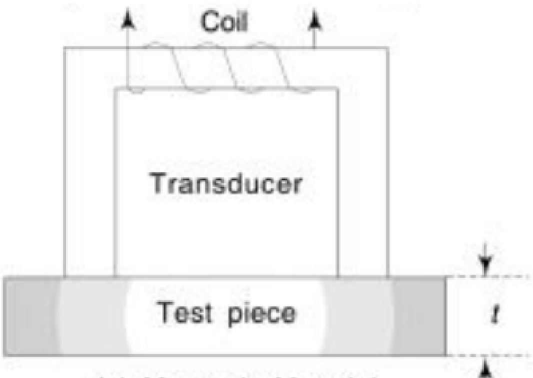
Thickness α Voltage

Inductive Pickup Thickness Transducer

Inductive methods of thickness measurement use
i) Reluctance variation transducer and
ii) Eddy current transducer

i) Reluctance Variation transducer measures thickness of Magnetic as well as non magnetic material.
These devices measure change in inductance of a magnetic coil caused by the test object.

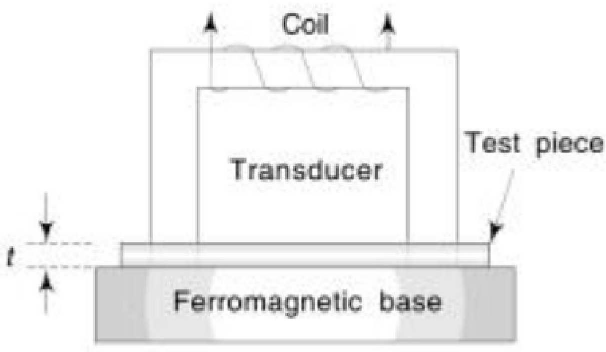
A) Measurement of thickness of magnetic material



(a) Magnetic Material

1. Reluctance variation transducer has a U shaped magnetic core over which a coil is wound
2. The test piece completes the magnetic circuit
3. Inductance of the coil depends on the reluctance of the magnetic circuit
4. The reluctance, in terms, depends upon the thickness of the test piece.
5. Higher the thickness, lower is the reflectance and higher is the inductance
6. Therefore the inductance of the coil provides a measure of the thickness of the magnetic test piece

B) Measurement of thickness of non-magnetic material



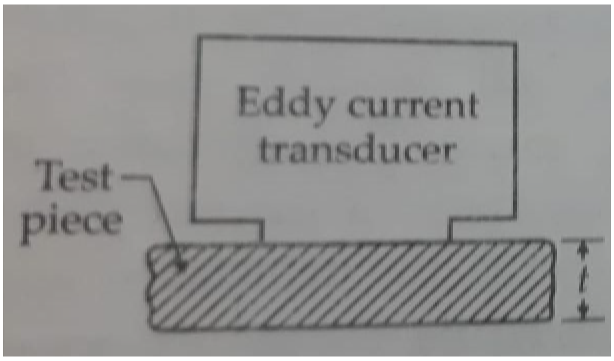
(b) Non-magnetic Material

1. Reluctance variation transducer has a U shaped magnetic core over which a coil is wound.
2. A non-magnetic material is deposited or placed on a magnetic base.

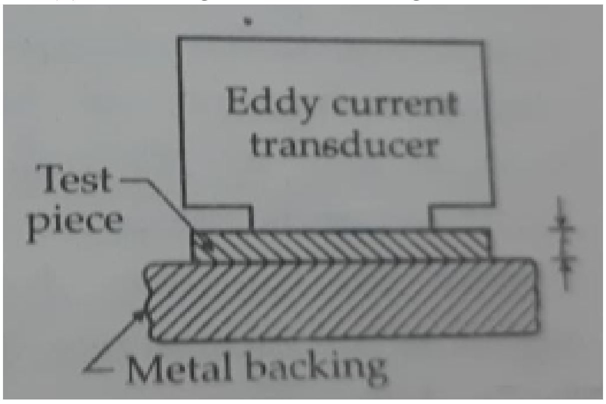
3. The ferromagnetic base is so thick that the reluctance of the magnetic circuit is determined by the distance between the ends of the U core and the base plate i.e. by the thickness of the test piece.
4. An increase in thickness causes an increase in reluctance and a decrease in inductance.
5. Thus by measuring inductance the thickness can be known

ii) Eddy current transducer

They use eddy currents to find the thickness of the test object.



(a) Non magnetic conducting material



(b) Non magnetic non conducting material

Explanation:

- It consists of a coil mounted on an insulated Core.
- The cail is excited by an alternating current supply.
- The alternating magnetic field produces Eddy Currents in the taste place or its backing.
- The magnetic field produced by Eddy Currents opposes the magnetic field of the coil and therefore the inductance of the coil is reduced.
- This system is suitable for measurement of thickness of both magnetic and non magnetic materials, as well as non-conducting coatings like Paints on a metal backing.
- In the case of conducting materials the higher the thickness of the test piece , Higher will be the Eddy current and lower would be the inductance of the coil.
- The measurement of thickness of a non conducting material is done by depositing it on a metal backing.

If the thickness of the non conducting test piece is large the Eddy current transducer head and the metal backing are separated by a larger distance and therefore Eddy Currents are small and consequently the inductance of the coil is large.

Metal coatings of thickness as low as 50 or 75 nm and Aluminium films down to a thickness of 125-500 pm of can be measured with the help of Eddy current transducer.

• The material whose thickness is to be measured is called a test piece. It can be -

i. Magnetic and conductive (Iron).
ii. Non-magnetic and conductive (copper and aluminum).
iii. Non-magnetic and Non-conductive (Bakelite).

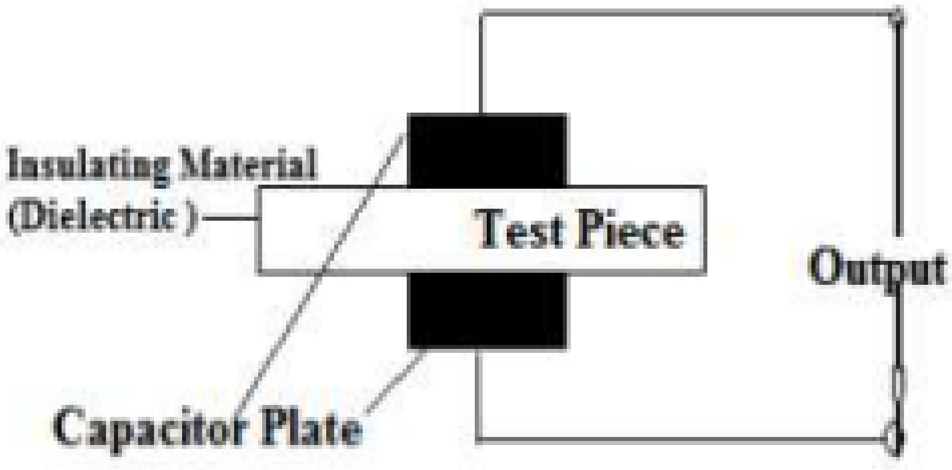
Advantages

1. Measurement of thickness of aluminum sheet 125-500 pm
2. Easy to align
3. Excellent reapeatability

Disadvantages

1. Physical contacts causes error in the measurement
2. It shows temperature sensitivity
3. Inherently low power output

Capacitive Pickup Thickness Transducer



Explanation:

• The capacitive transducer is used to measure thickness of a given material.

Two metal electrodes are placed on the two sides of insulating material being tested.

This arrangement forms a parallel plate capacitor , the two electrodes acting as the two plates with insulating material acting as the dielectric.

The capacitance depends upon the thickness of the insulating material under test. Thus by measuring capacitance of the system, the thickness of the insulating material can be determined.

$$C = \frac{\varepsilon A}{d}$$

Where,

$C =$ Capacitance in Farads

$\varepsilon =$ Permittivity of dielectric (absolute, not relative)

$A =$ Area of plate overlap in square meters

$d =$ Distance between plates in meters

As shown in the above equation, Capacitance is inversely proportional to the distance between the plates.

Its output is calibrated to indicate Thickness.

Advantages:

1. Capacitive transducers require very little force to operate them.
2. They are extremely sensitive
3. They have good frequency response.

Disadvantages:

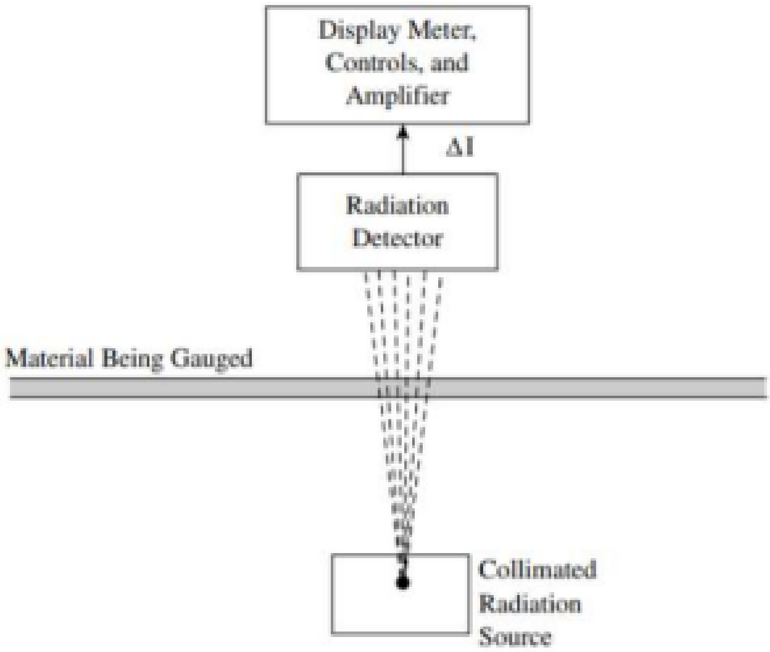
1. The performance is affected by dirt and other contaminants
2. They are sensitive to temperature variations and signal get distorted.
3. Moisture content and air gap are the main sources of error.

Application

This method is used for **insulator** material thickness measurement.

Radiation type Thickness Transducer

It is a Non-contact type of thickness measurement method



Radiation Source

This component generates the radiation that will be applied for measurement. The source may be either natural (radioactive isotope) or artificial (XRay tube), and may project a radiation pattern that is sensitive to alignment with the housing aperture. The beta-radioisotope is used to measure the thickness of sheets or the thickness of coatings on sheets.

• **Material Under Measurement** – Material under measurement may be flat rolled, sheet / strip products, composed of various metals (e.g., steel, aluminum, and copper / brass alloys, etc.) The strip may be stationary or moving.

• **Detection System** – Transmitted / scattered radiation, I (in photons/sec), that results from the incident radiation, I_0 , penetrating the strip, is collected and measured by this device, which is typically located above the strip and aligned to the optical axis of the radiated beam.

• **Detector** – Collected incident radiation is converted to an electrical signal that is functionally related to the radiation intensity.A radiation detector such as Geiger Muller tube , ionization chamber or a scintillation counter is used for measuring the amount of radiation reaching the detector

• **Preamplifier** – The feeble detector signal is amplified to usable amplitudes by a high gain, low noise electrometer / trans-conductance amplifier. To reduce signal noise and interference, it is desirable to place the preamplifier as close as possible to the detector and mounted in a shielded, hermetically sealed enclosure.

• **Signal Processing** – The amplified detector signal requires wide bandwidth signal processing (in both time and amplitude) to render a calibrated measurement of the intensity of the received radiation (i.e., related to material absorption / attenuation). This processing can be provided by real-time digital signal processors or Field Programmable Gate Arrays

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- The attenuation of radiation from x-rays or radioactive decay by matter is utilized in the radiation absorption gauge to measure the thickness of the material. The equation is

$$\Delta I = I_o [1 - \exp(-\mu t)]$$

using averaged ionization current for signal,

where ΔI = change in ionization current when absorber is inserted

I_o = ionization current without absorber

μ = absorption coefficient ($cm^2/\mu g$)

t = thickness ($\mu g/cm^2$)

The display is calibrated to indicate thickness.

Advantages

- It gives the thickness measurement of sheets in rapid motion
- Measure thickness without contact with the material under test.

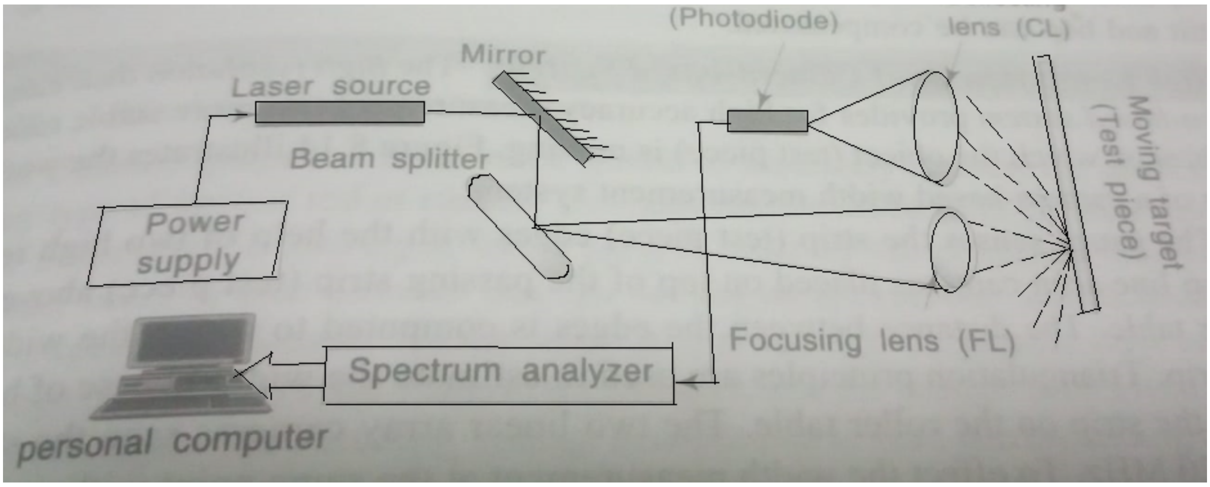
Disadvantages

- These are subjected to error because of radioactive decay of source and dependance of absorption coefficient on the composition of material
- Frequent calibration checks are required for better accuracy.

Applications

1. used for heavy metals and thick test pieces
2. used for thin metal sheets or foil or paper, rubber and plastics
3. used to measure the thickness of sheets or the thickness of coating on sheet
4. used for hot or cold, stationary or moving strips of paper, plastic, glass, rubber or metal over a wide range of thickness.

4.2 Laser based length measurement



Working and Construction -

The laser Doppler velocimeter (LDV) works on traditional laser Doppler principle, which states that any light beam coming in contact with the moving object will experience the shift in a frequency depending upon its direction and speed. The frequency of light/ sound received from the moving object varies depending on its velocity. Therefore, the frequency of light or sound emitted or scattered by the object which is approaching the observer will increase and the frequency will reduce if the object moves away from the observer. This technique uses 'dual beam' or 'Differential Doppler technique.'

The differential Doppler technique involves a laser beam split into two beams of equal intensity, which are focused and crossed at the point of measurement.. The measurement volume consists of fringes formed due to intersection of the two beams. The tiny particle in the measurement volume scatter light when they cross the light fringes but no light is scattered when they cross the dark fringes. The scattered light is collected by lens and focussed on to the photodetector. The distance between the fringes is given by

$$d = \lambda / (2 sin\, \theta/2) \text{ ---------------------------------------(1)}$$

where, d = The distance between the fringes

λ = wavelength of laser light

θ = angle between the two beams

hence, the velocity v of the moving target is given by,

$$v = d/t \text{ ---(2)}$$

Where, t = time taken by particle to move from one fringe to another.

Therefore, by putting value of *d* from Eq. (1) into Eq. (2), the velocity is given by

$$\begin{aligned} v &= \lambda/\{(2 sin\,\theta/2) * t)\} \\ &= (\lambda * f)/(2 sin\,\theta/2) \end{aligned}$$

where, *f* = change in the frequency.

Hence, the Doppler Shift frequency is given as,

$$f = [(2 * v)/\lambda] * sin\,\theta/2 \quad \text{--(3)}$$

Figure illustrates the working of a laser Doppler velocimeter. It consists of the various components such as : laser source with power supply, Mirror, Beam splitter, Focussing lens (FL), Collecting lens (CL), Photo detector (Photodiode), and Spectrum analyzer.

The laser beam emitted from the laser source is split into two beams of equal intensity using a beam splitter. The two beams are then converged on the moving object whose speed (length) is to be measured using a converging lens. The scattered light from the moving object is collected and focussed onto the optical detector (photodiode) by a collecting lens. This detector converts the optical signal to an electrical signal whose frequency is analyzed in a spectrum analyser. Once the frequency is found out, the speed and the length of the moving object is calculated by integration. The observed speed and the length is displayed on the computer by interfacing the spectrum analyzer with the computer.

Advantages

1. Laser is a helpful tool for non-contact measurements and gives accurate results since it is a monochromatic and coherent beam of light with minimum deviation.

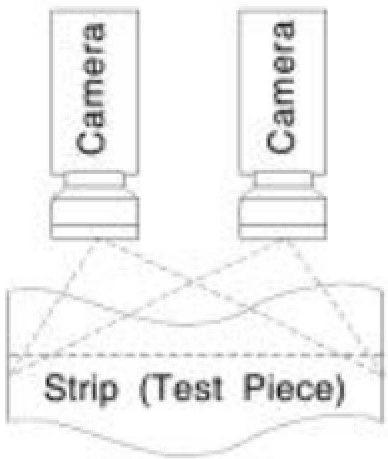
2. LDVs can be used for both velocity and length measurement of a moving object.

3. It is a useful tool to improve industrial processes and monitor them more closely to account for any deviation either due to the process Or poor resolution of the instruments used for various levels of automation.

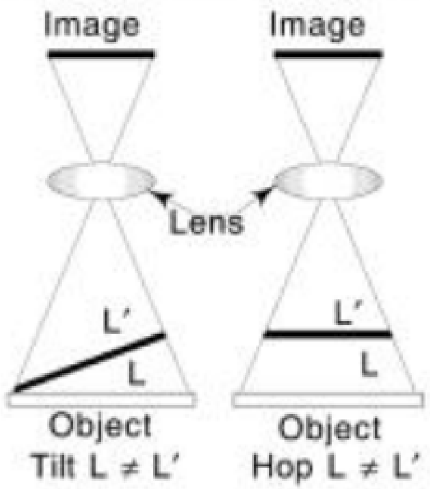
Applications

1. Measurement of length of hot steel strips in hot Rolling Mills for cut-to-length applications.
2. Speed and length measurements of any moving object in steel, wire, paper or textile industries.
3. Measurement of vibration of inaccessible parts and components.

4.3 Camera based width measurement



Stereoscopic Vision Principle



Hop/Tilt Measurement

Working and construction

Camera based width measurement system is a non-contact type instrument extremely useful for on-line width measurement of Steel strip in hot and cold Rolling Mills of steel industry. It is available in two configurations.

Stereoscopic vision based system

The stereoscopic vision-based system can be used where the strip thickness changes substantially. Also the errors due to tilt and hop can be compensated.

High resolution dual camera based system

The high resolution dual camera-based system provides for high accuracy measurements on more stable roller tables on which the object (test piece) is moving.

The gauge senses the strip (test piece) edges with the help of two high resolution line scan cameras placed on top of the passing strip at a space above the roller table. The distance between the ages is computed to derive the width of the strip. Triangulation principles are used to estimate the width in case of hop or tilt of the strip on the roller table. The two Linear array cameras scan the strip at about 20 MHz. To effect the width measurement at the same point with respect to the strip, a common clock controller clocks the cameras.

In the stereoscopic configuration, each of the cameras has a view of the complete strip. The field of view can be adjusted to measure a wide range of widths. The resolution of the camera is about 1 mm. Higher resolution can be achieved for the vertical camera configuration.
Data from both line scan cameras are captured at the same time. These data are processed in a computer. Sophisticated age detection algorithm is applied to detect the edges of the strip. Various other correction logics are applied like lens aberration correction, camera angle compensation, etc. To improve the measuring accuracy, inter-pixel interpolation technique is applied.

Advantages

1. This instrument has high accuracy.
2. Lens error compensation and temperature compensation are provided.
3. This instrument helps in on-line Width Control.

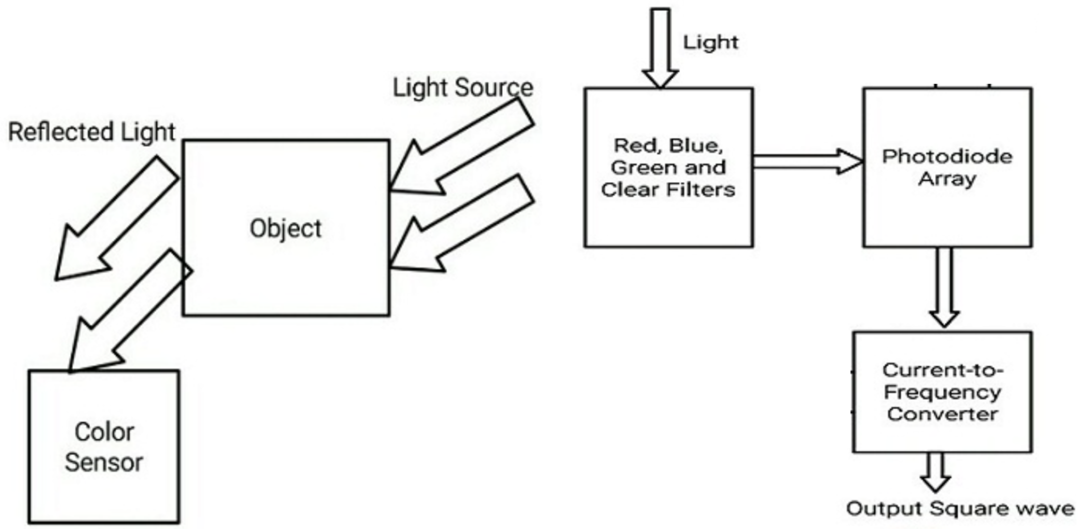
Applications

1. Width measurement can be done of both cold and hot rolled Steel strips and slabs in a steel industry
2. Width profile of the strip can also be measured along the length of the strip for control.

4.4 Colour Sensor

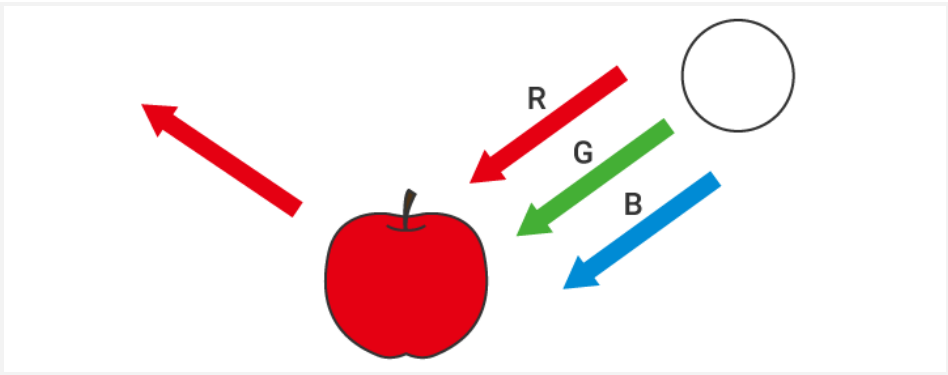
A colour sensor is a type of "photoelectric sensor" which emits light from a transmitter, and then detects the light reflected back from the detection object with a receiver.
A color sensor detects the color of the material. It can detect the received light intensity for red, blue and green respectively, making it possible to determine the colour of the target object.
These sensors are also equipped with filters to reject the unwanted IR light and UV light.

Working Principle

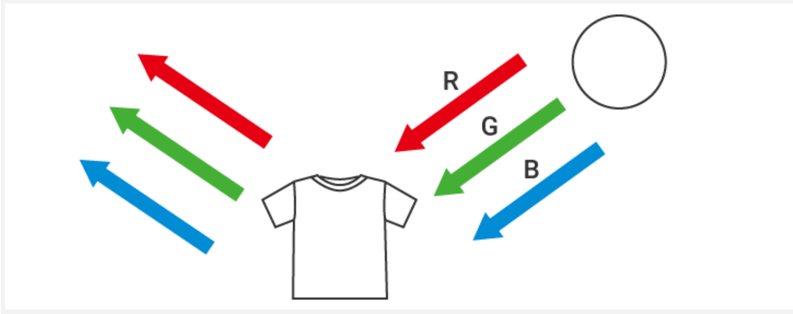


To detect the colour of material three main types of equipment are required. A light source to illuminate the material surface, a surface whose color has to be detected and the receivers which can measure the reflected wavelengths.
Colour sensors contain a white light emitter to illuminate the surface. Three filters with wavelength sensitivities at 580 nm, 540nm, 450nm to measure the wavelengths of red, green and blue colors respectively.

The received light intensity of red, blue and green are detected, and the ratio of light received is calculated.
If light containing the red, blue, and green wavelengths is shown on a red object, only red light will be reflected.
* The white circle in the diagram represents a white light source.



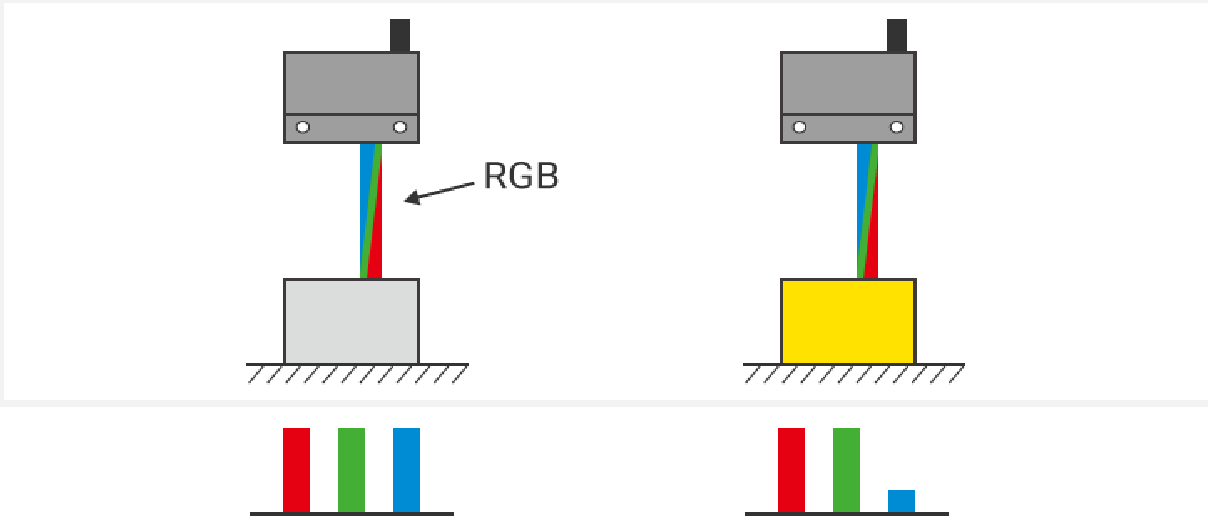
For a white object, all three colours of red, blue, and green are reflected. The white circle in the diagram represents a white light source.



The ratio of the red, green, and blue reflections vary according to the colour of the object.

Object colour	Reflected light		
	Red	Green	Blue
Red	✓		
Yellow	✓	✓	
Green		✓	
Blue			✓
White	✓	✓	✓
Black			

By calculating the ratio of the intensity of the red, green, and blue light received, it is possible to distinguish differences in the colour or appearance of the object.



Differences can be detected
Left: Received light ratio 1:1:1
Right: Received light ratio 4:4:1

Advantages of Color sensor

1. It helps in sorting objects based on three color approaches. It also helps in counting objects.
2. Automated systems can be built using color sensors which help in completion of work in less time.
3. Human intervention is not needed.
4. Powerful and large memory color sensor ICs are available at low cost.
5. It is easy to change or modify manufacturing setups without even reprogramming the sensor device.

Disadvantages of Color sensor

1. The approach is costly for small scale industries.
2. It does color matching or identification in applications requiring only pass/fail output.
3. Operating distance range of the color sensors are a matter of concern.

Applications of colour sensors

1. Calibration devices for color monitor
2. Color printers, and plotters
3. Paint, textile, and cosmetic manufacturing,
4. Medical applications such as blood diagnosis, urine sample analysis, and dental surgery.
5. Detect the color of the surfaces
6. Light colour temperature measurement
7. RGB LED consistency control
8. Health fitness systems
9. Industrial process control

Color sensor specifications

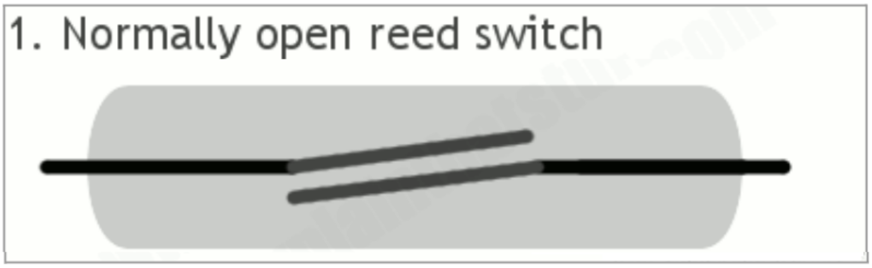
- ➔ Accuracy
- ➔ Environmental condition
- ➔ Wavelength range
- ➔ Calibration
- ➔ Resolution
- ➔ Cost
- ➔ Repeatability
- ➔ Frequency

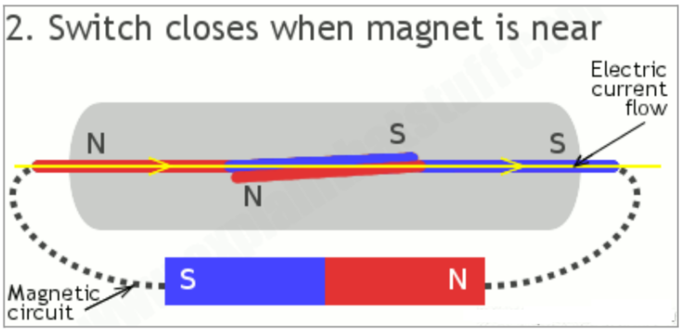
4.5 Magnetic reed switch

- The **reed switch** is an electrical switch operated by an applied magnetic field.
- The switch looks like a small glass capsule with electrical leads poking out of each end.
- The switching mechanism consists of two ferromagnetic blades, separated by only a few microns. When a magnet approaches these blades, the two blades pull toward one another. Once touching, the blades close the normally open (NO) contacts, allowing electricity to flow.
- Some reed switches also contain a non-ferromagnetic contact, which forms a normally closed (NC) output. An approaching magnet will disconnect the contact and pull away from the switching contact.
- Contacts are constructed from a variety of metals, including tungsten and rhodium. Some varieties even use mercury, which must be kept in the proper orientation to switch correctly. A glass envelope filled with inert gas—commonly nitrogen— seals the contacts at an internal pressure under one atmosphere. Sealing isolates the contacts, which prevents corrosion and any sparks that might result from contact movement.

Normally open

As magnet is brought up to the reed switch, the entire switch effectively becomes a part of a "magnetic circuit" that includes the magnet (the dotted line in the artwork shows part of the magnetic field). The two contacts of the reed switch become opposite magnetic poles, which is why they attract and snap together. It doesn't matter which end of the magnet approaches first: the contacts still polarize in opposite ways and attract one another. A reed switch like this is **normally open (NO)** (normally off), unless a magnet is positioned right next to it, when it switches on, allowing a current to flow through it.

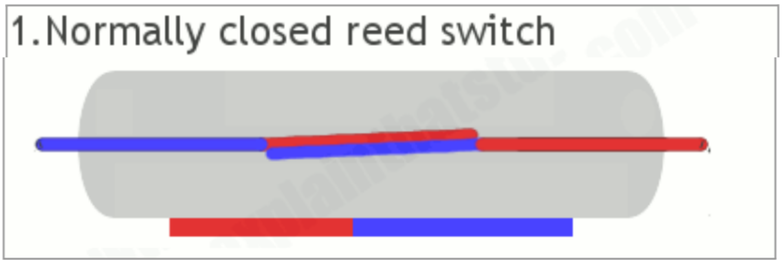


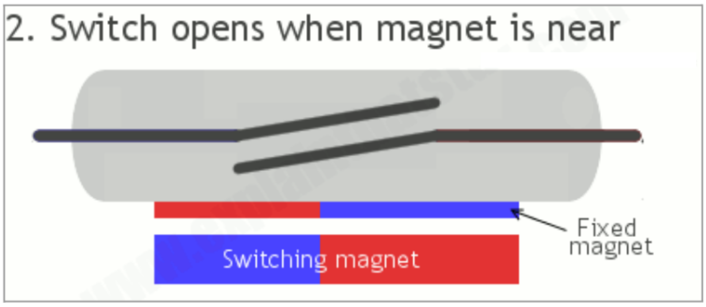


Take the magnet away and the contacts—made from fairly stiff and springy metal—push apart again and return back to their original positions.

Normally closed

Some reed switches work in the opposite way: the two contacts are normally snapped together and when a magnet is brought up to the switch, spring apart. Reed switches like this are called **normally closed (NC)** (normally switched on), so electricity flows through them most of the time. The easiest way of making one is to take a normally open switch and fix a magnet permanently to its glass case, flipping it over from its open to its closed state. This entire unit (normally open reed switch with magnet attached) becomes normally closed reed switch. If a second magnet is brought up to it, with a magnetic field of opposite polarity to that of the first magnet, this new field cancels out the field of the first magnet so, a reed switch with two contacts sprung apart.





Real reed switches have contacts that are only a few microns (millionths of a meter) apart—roughly ten times thinner than a human hair—so the movement isn't visible to the naked eye.

Advantages

1. Superior electrical isolation to their solid-state counterpart,
2. less electrical resistance due to closed contacts.
3. Reed switches can work with a variety of voltages, loads and frequencies, as the switch functions simply as a connected or disconnected wire.
4. high reliability
5. Because of their sealed construction, they can operate in explosive environments
6. Inexpensive,
7. Require no standby power,
8. Can function with both ac and dc electrical loads.
9. No mechanical wear
10. compact compared to mechanical switches
11. protected from atmospheric corrosion.

Disadvantages

1. Relatively slow

Applications

1. burglar alarms
2. Reed switches are primarily used for proximity and sensing applications
3. **Laptops**
4. **Safety**
5. **Automotive-** impact, speed, braking, door positions, fluid and fuel levels,
6. **Refrigerators**

Specifications

Parameter	Reed switch
Form Factor	Moving parts/electromechanical
Physical size	< 4 mm long (glass encapsulate)
Touch-free sensing	Yes
Voltage Switching Range	0 – 1000 V
Switching time	< 100 µs to operate
Load switching	Switches loads directly
Switch operations in a lifetime	Billions
ESD Protection Required	No
Vibration limits	10 g
Power required to sense & operate	No
Operating Temperature	0° – 70°C, outside of which temperatures will affect performance.
Polarity sensitive	No
Latching capability	External circuit required

Important specifications for reed switches include pole and throw switch configurations, electrical specifications, physical dimensions and other features.

Pole and Throw Configurations

Pole and throw configurations for reed switches can be:

- Single pole single throw (SPST)
- Single pole double throw (SPDT)
- Double pole single throw (DPST)
- Double pole double throw (DPDT)

Electrical Specifications

Important electrical switch specifications to consider when searching for reed switches include:

- Current rating
- AC voltage rating
- DC voltage rating
- Power rating

Dimensions

Important dimensions to consider include:

- Glass encapsulated length
- Total length including leads
- Diameter

Features

- hermetically sealed,
- resistant or waterproof.