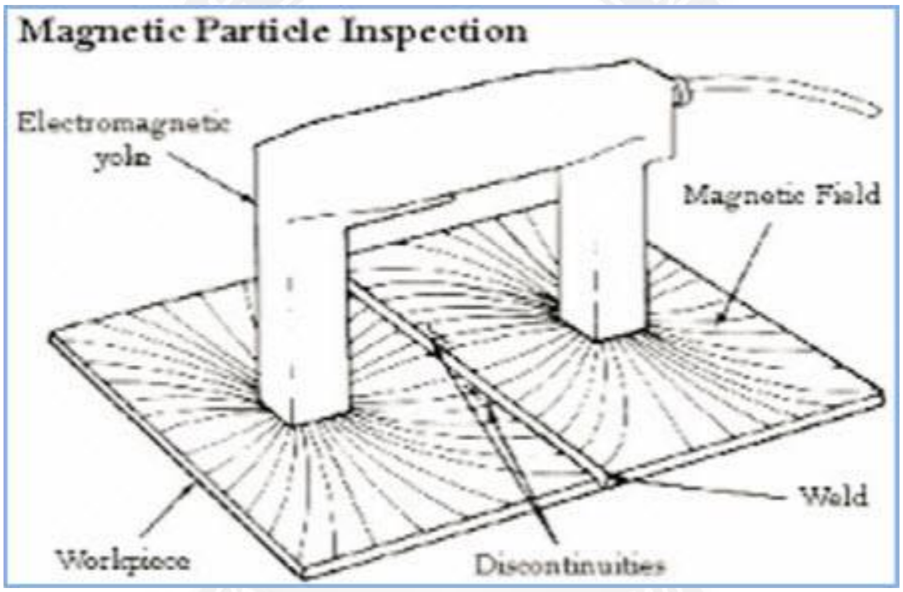
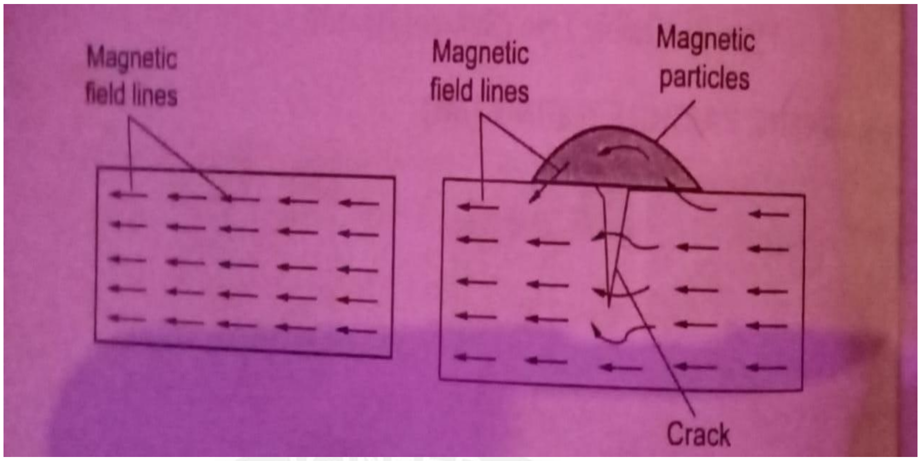
3.4 MAGNETIC PARTICLE TESTING (MT)

- A magnetic field is established in a component made from ferromagnetic material. The magnetic lines of force travel through the material and exit and reenter the material at the poles.
- Defects such as crack or voids cannot support as much flux, and fo some of the flux outside of the part.
- Magnetic particles distributed over the component will be attracted areas of flux leakage and produce a visible indication.



1. PRINCIPLE

- ❖ This NDT process uses magnetic fields to find discontinuities at or t the surface of ferromagnetic materials. The magnetic field can be with a permanent magnet or an electromagnet, which requires a current be applied.
- ❖ The magnetic field will highlight any discontinuities as the magnetic field lines produce leakage, which can be seen by using magnetic particles are drawn into the discontinuity.



Principle of working

2. MAGNETIC PROPERTIES OF MATERIALS

(a) HYSTERESIS LOOP

- A hysteresis loop shows the relationship between the induced magnetic flux density B and the magnetizing force H. It is often referred to as the B H loop.
- From the hysteresis loop, a number of primary magnetic properties of material can be determined.
- Retentivity, Residual Magnetism or Residual Flux, Coercive For Permeability and Reluctance.

(b) PERMEABILITY

- Permeability describes how easily a material can be magnetized; a material with a high permeability is easier to magnetise than a material with a low permeability.
- A material's permeability is determined by dividing the magnetising force applied to a material into the magnetic flux density achieved in the material -permeability has no units.
- There are three material categories that are related to permeability: diamagnetic .paramagnetic and ferromagnetic.

(a) Diamagnetic materials: It have a permeability value slightly less. It will slightly repel a magnetic field.

(b) **Paramagnetic materials:** It have a permeability value slightly greater It is slightly easier for the magnetic flux to pass through the paramagnetic material than to travel through the vacuum.

(c) **Ferromagnetic materials:** It have a permeability value much higher, that it is much easier for the magnetic flux to pass through the ferromagnetic material than to pass through the vacuum. Ferromagnetic materials are very strongly attracted by a magnetic field.

3. COMPONENTS IN MAGNETIC PARTICLE INSPECTION (MPI)

(a) Permanent magnet

(b) Electromagnetic Yoke

(c) Current flow probes

(d) Flexible coil

(e) Adiscent cable

(a) Permanent magnets

- ❖ Permanent magnets are sometimes used for magnetic porticleinspectin the source of magnetism. The two primary types of permanent magnets are bar magnets and horseshoe (yoke) magnets

(b) Electromagnetic Yoke

- ❖ An electromagnetic yoke is a very common piece of equipment that is used to establish a magnetic field. It is basically made by wrapping an electrical coil around a piece of soft ferromagnetic steel.

(c) Current flow probes

- ❖ Probes are handheld electrodes that are pressed against the surface of the component being inspected to make contact for passing electrical current through the metal.

(d) Adjacent cable

- ❖ Coils and conductive cables are used to establish a longitudinal magnetic field within a component. When a preformed coil is used, the component is placed against the inside surface on the coil. Coils typically have three or five turns of a copper cable within the molded frame.

(e) Portable Power Supplies

- ❖ Portable power supplies are used to provide the necessary electricity to the prods, coils or cables. Power supplies are commercially available in a variety of sizes.

4. WORKING OF MAGNETIC PARTICLE TESTING

(a) Pretreatment

- ❖ The surface must be free of grease, oil or other moisture that could keep particles from moving freely.
- ❖ A thin layer of paint, rust or scale will reduce test sensitivity but can sometimes be left in place with adequate results.

(b) Apply the magnetizing force (magnetic particle)

- ❖ Use permanent magnets, an electromagnetic yoke, prods, means to establish the necessary magnetic flux.

(c) Dust on the dry magnetic particles

- ❖ Dust on a light layer of magnetic particles.

(d) Gently blow off the excess powder

- ❖ With the magnetizing force still applied, remove the excess powder the surface with a few gentle puffs of dry air.
- ❖ The force of the air needs to be strong enough to remove the particles but not strong enough to dislodge particles held by flux leakage field. Non Destructive Testing.

(e) Detect the defects

- ❖ Look for areas where the magnetic particles are clustered with the help of visual aids like illuminating light, microscope, naked eyes and magnifying glass etc.

(f) Post Treatment

- The surface of material should be demagnetized (or) cleaned using demagnetizer (or) demagnetizing equipment.

6. ADVANTAGES

- Can find both surface and near sub-surface defects.
- This inspection formats are extremely portable and low cost.
- Rapid inspection with immediate results.
- Indications are visible to the inspector directly on the specimen surface.
- Can detect defects that have been smeared over.
- Can inspect parts with irregular shapes (external splines, crankshafts connecting rods, etc.).
- The method can be adapted for site or workshop use.
- It is inexpensive compared to radiography.
- Large or small objects can be examined.

7. LIMITATIONS

- The specimen must be ferromagnetic (e.g. steel, cast iron)
- Paint thicker than about 0.005" must be removed before inspection
- Post cleaning and post demagnetization is often necessary
- Maximum depth sensitivity is typically adopted as 0.100" (deeper under perfect conditions)
- Alignment between magnetic flux and defect is important
- Insensitive to internal defects
- Require magnetization and demagnetization of materials to be inspected
- Require power supply for magnetization
- Coating may mask indication
- Material may be burned during magnetization

8. APPLICATIONS

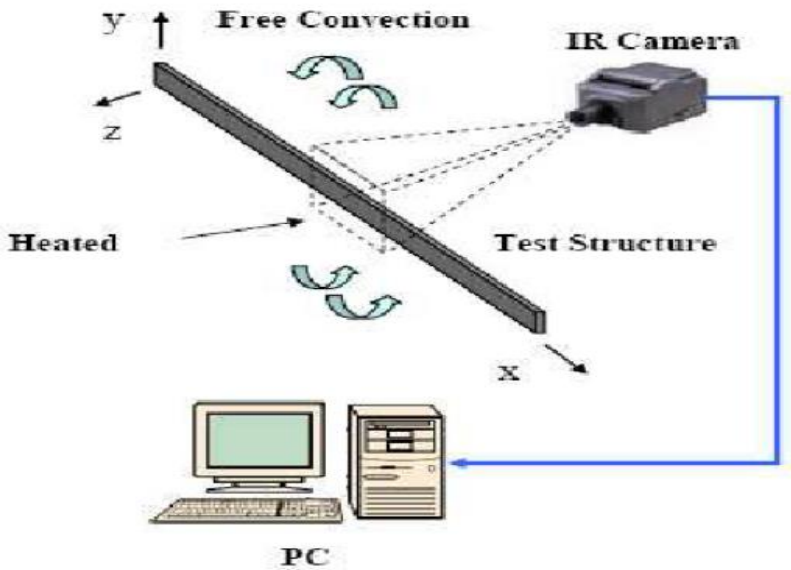
- Magnetic particle testing or inspection (MT or MPI testing) quality control and materials testing in all major industries. This castings, forgings, plates, extruded components, weld joints, electrics electronic component manufacturing, production of steel, pressure ships, bridges, motor vehicles, machinery and jet engines.

- ❖ The flaws to be detected include cracks, inclusions, pipe, lami bursts and flakes.
- ❖ Testing effective in detecting fatigue cracks during in-service maintenance inspection of power plants, cement plants, sugar plants, petroleum refinery machinery components and structures.

Mainly used to find,

- Fatigue Cracks Grinding Cracks
- Inclusions in aerospace blooms, billets, and bars
- Quenching Cracks Shrink Cracks
- Stress Corrosion Cracking → Welding Defects

3.5 THERMOGRAPHY TEST



- Infrared testing or thermography uses sensors to determine the wave length of infrared light emitted from the surface of an object, which can be to assess its condition.
- A thermographer views an object with a thermal imager to measure b infrared emitted from the surface. However, to confuse matters, e sources behind the imager can reflect from the surface making the objects appear hotter than it really is. Even the heat from the body of the thermographer can cause this effect on objects at ambient temperature.

1. PRINCIPLE

- The usual method is to use a specially television camera with an infrared sensitive detector and a lens which transmits infrared radiation. Such cameras can operate at normal video rates.

2. TYPES OF THERMOGRAPHY

- **Passive thermography** uses sensors to measure the wavelength of the emitted radiation and if the emissivity is known or can be estimated, the temperature can be calculated and displayed as a digital reading or as a false Colour image.

- **Active thermography** induces a temperature gradient through a structure. Features within it that affect the heat flow result in surface temperature variations that can be analyzed to determine the condition of a component. Often used to detect near surface delamination or bonding defects in composites.
- **The external excitations/optical excitations** or may be the external energy says so generally this energy is delivered to the surface and then propagated through the material until it encounters flaw example photographic classes for heat pulsed simulations, halogen lamps for periodic heating.
- **Internal excitations/mechanical excitations** so generally the energy is injected into the specimen in order to stimulate exclusively the defects.

1. BASIC AIDS OR COMPONENTS IN THERMOGRAPHY

- **Thermographic camera** so it is also known as infrared camera or may the thermal imaging camera. It is a device that forms a heat zone using infrared radiation it operates in wavelengths as long as 14 nanometer.
- There are two basic types of thermographic camera. One is called cooled infrared detectors another one is called the uncooled infrared detectors.
- **Control unit** is which sets the level of adjustment for halogen lamp heater.
- **Pe/image processing unit** which displays the defect unit after deep process of unit.

2. WORKING OF VARIOUS THERMOGRAPHY TESTING METHODS

(a) Lock in vibrothermography method

- A very short pulse- usually in the units of milliseconds - is used to excite the object.

- A ultrasonic transducer is typically used as an excitation source.
- The advantage of this method is the speed of the analysis and a possibility to estimate the defects depth.
- The disadvantage is a limited to of detection capabilities based on geometrical orientation of defects.

(b) Lock In Thermography Method

- Lock-In thermography is a periodic excitation method). When the input energy (Halogen lamps) wave penetrates the object's surface, it absorbed.
- The reflected portion of the wave causing an interference pattern in the local surface temperature.

(c) Pulsed thermography method

- Pulsed thermography is classical optical excitation thermography technique. In pulsed thermography, high-energy lamps are often used to produce a uniform heating source on the specimen surface.
- The heat transmits through the inspected specimen to the subsurface defects or damages, and then returns to the specimen surface.
- A uniform temperature rise will be recorded if there are no defects in the specimen. If there are defects such as voids or delamination, a localized high temperature zone will be observed above the defect due to the insulation effect.

3. ADVANTAGES

- Data collection system can record temperature changes with time
- High-speed, portable, and non-contact
- Ability to inspect large areas
- Effective prevention of test scrap
- Contactless testing with low thermal stress
- Simple analysis of large, uneven surfaces
- Categorization of different types of defects

4. DISADVANTAGES

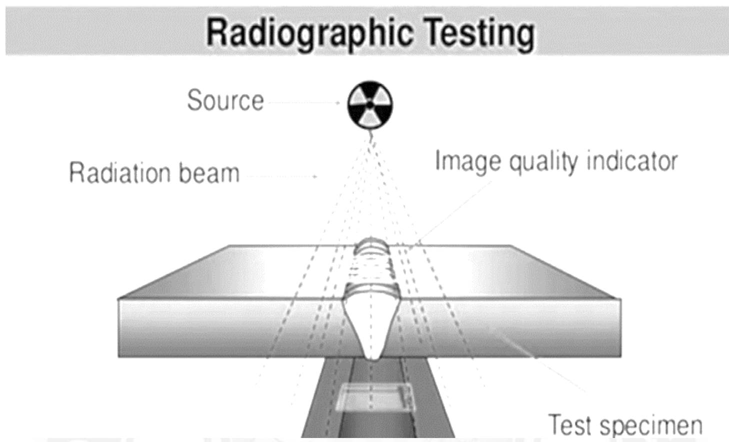
- Risk of damage the sample(e.g., overheating)
- Limitations of inspected thickness
- Variable emissivity of materials
- Dependence from thermal contrast
- Expensive instrumentation require qualified personnel accuracy

7. APPLICATIONS

- Used largely in Aerospace industry Automotive industry and Power industry.
- Quality assurance for bonded, welded, soldered and other joints by means of cavity detections (e.g. on vehicle interior parts).
- Localization of defects in joints such as cavities, defective welding seams/points.
- Testing of metallic and non-metallic materials/material compounds.
- Tests of internal structures, such as fractures or impacts in honeycomb lightweight constructions.

3.6 RADIOGRAPHIC TESTING

- Radiographic Testing (RT) is a non-destructive testing (NDT) methods which uses either x-rays or gamma rays to examine the inter of manufactured components identifying any flaws or defects.



- X-rays are commonly used for thin or less dense materials while rays are used for thicker or denser items.
- The term radiography usually implies a radiographic process that produces a permanent image on film (conventional radiography) or paper (radiography or x ray radiography), although, in a broad sense, it refers t forms of radiographic inspection.
- When inspection involves viewing of a real-time image on a fluorescence screen or image intensifier, the radiographic process is termed real inspection. When electronic, non-imaging instruments are used to measure the intensity of radiation, the process is termed radiation gaging.
- Neutron radiography refers to radiographic inspection using neutrons rather than electromagnetic radiation.

1. PRINCIPLE

- In Radiography Testing the test-part is placed between the radiation sou and film (or detector). The radiation passed through a test piece to dec defects.

3. BASIC COMPONENTS OF RADIOGRAPHIC TESTING

(a) Source

- X-rays are generated by directing a stream of high speed electrons target material such as tungsten, which has a high atomic number. the electrons are slowed or stopped the interaction with the particles of the target, X-radiation is produced.
- The neutron, energy is released in the form of gamma rays. Two e most common industrial gamma-ray sources for industrial radiography Iridium-192 and Cobalt-60.

(b) Radiographic Film

- When X-rays or gamma-rays or light strike the film, some of the halogen atoms are liberated from the silver halide crystal and thus leaving the silver atoms alone.
- This change is detected by a method is called a "latent (hidden) image. When the film is exposed to a chemical solution (developer) the reaction results in the formation of black.

4.WORKING PRINCIPLE OF RADIOGRAPHIC TESTING

- The testing specimen part to be placed between the radiation source (x or gamma source) and a piece of film which records the defect data.
- The undefeated part will stop some of the radiation. Thicker and den area will allow less radiation to pass through. The discontinuity allow rays to pass.
- The property of the film will vary with the amount of radiation reaching the film through the test object. These differences in "absorption" can be recorded on film, or electronically. The energy of the radiation affects its penetrating power.
- Higher energy radiation can penetrate thicker and denser materials.
- The radiation energy and exposure time must be controlled to properly image the region of interest.

3. RADIOGRAPH FILM ANALYSIS

- If an object has a high density, ie a thicker object, it absorbs more radiation causing less radiation to hit the film, which produces a lighter image.

- If an object has a low density, ie when the through section is reduced or there is a lower-density material such as slag (compared to the surrounding material), it will absorb less radiation causing more radiation to hit the film, producing a darker image.
- The image on the film cannot initially be seen; this is called the latent image and can only be seen when the film is developed. The quality of this image mainly depends upon two properties.
- Density- This is the degree of blackness on the radiograph. There will be minimum and maximum amounts of density to make the radiograph readable and give the required sensitivity.
- Contrast- Radiographic contrast is the degree of difference between density fields on a radiograph. If there are only blacks and whites on a radiograph, this would be high contrast. If only tones of a similar density are on the graph, this would be low contrast.

6. SAFETY ASPECTS OF RADIATION TEST

- **Film badges/TLDs (thermoluminescent dosemeters)**

  The detectors worn by all industrial radiographers that measure the dose a radiographer receives over a period of time, usually one month.

- **Survey meters (dose rate meters)**

  The instruments that can measure dose rates per unit time.

7.ADVANTAGES

- Both surface and internal discontinuities can be detected.
- Permanent test record is obtained.
- Minimum surface preparation required.

8. DISADVANTAGES

- Highly directional (sensitive to flaw orientation) Depth of discontinuity is not indicated.
- It requires a two-sided access to the component
- Many safety precautions for the use of high intensity radiation Many hours of technician training prior to use.
- Access to both sides of sample required.
- Orientation of equipment and flaw can be critical.
- Determining flaw depth is impossible without additional angled exposures.
- Expensive initial equipment cost.

9. APPLICATIONS

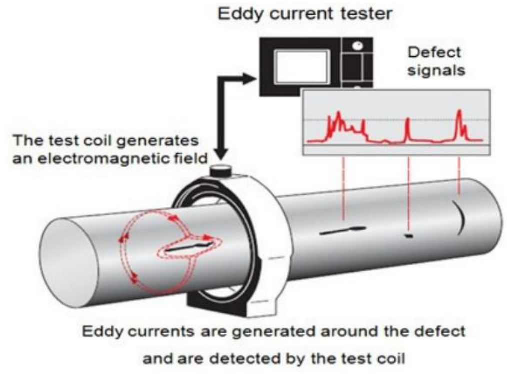
- Industrial Radiographic testing is used extensively on castings and weldments.
- Radiography is also well suited for testing of semiconductor devices for cracks, broken wires, unsoldered connections, foreign material and misplaced components.
- Sensitivity of radiography to various types of flaws depends on many factors, including type of material, type of flaw and product form.
- Both ferrous alloys can be radiographed, as well as non-metallic materials and composites.

Used in fields of,

- Aerospace industries
- Military defense
- Offshore industries
- Marine industries
- Power-gen industries
- Petrochem industries
- Waste Management
- Automotive industries
- Manufacturing industries
- Transport industries

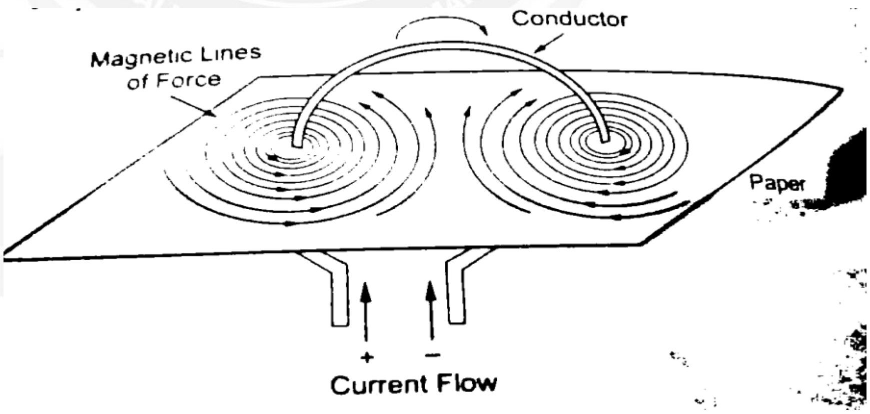
3.7 ELECTROMAGNETIC TESTING (ET) OR EDDY CURRENT TESTING

- This testing method uses an electric current or magnetic field which is passed through a conductive part.
- Eddy current testing uses an alternating current coil to induce an electromagnetic field into the test piece, alternating current field measurement and remote field testing both uses a probe to introduce a magnetic field, with RFT generally used to test pipes.



1. PRINCIPLE

- An electromagnetic inductor is used to generate a magnetic field. When this field is introduced in the surface of the test piece, it generates so called “eddy currents” in the material.



2. COMPONENTS OF EDDY CURRENT TESTING

- **Eddy probe (AC source, Electromagnetic coil, Display unit, Receiver coil, Exciting coil) –**AC voltage source for the purpose of the test can generate a primary electromagnetic alternating field. The exciter coil and the receiver coil normally have coil axes parallel to each other, so that the primary alternating magnetic field of the exciter coil induces an AC voltage in the receiver coil.

4. WORKING OF EDDY CURRENT TESTING

- When eddy current probe brought close to the testing material alternating current flows through a wire coil and generates an oscillating magnetic field.
- The electrical currents are called eddy currents because the flow in c at and just below the surface of the material. The Eddy Current gee new superposed magnetic field. This field is detected by a receiver coil.
- Interruptions in the flow of eddy currents, caused by Imperfection dimensional changes, or changes in the materials conductive permeability properties, can be detected with the proper equipment probs.
- Eddy current testing can be used on all electrically conducting material with a reasonably smooth surface. The figure shows the difference flawless and flaw surface with impedance graph.
- The test equipment consists of a generator (AC power supply), a test coil and recording equipment, eg a galvanometer or an oscilloscope
- Used for crack detection, material thickness measurement (corrosion detection), sorting materials, coating thickness measurement, metal detection, etc.

4. THE STRENGTH OF THE EDDY CURRENTS PRODUCED DEPENDS ON

- Electrical conductivity of the specimen
- Magnetic permeability (for a ferromagnetic specimen)

- Stand-off distance between the specimen and coil.
- AC frequency used in the exciting coil dimensions of the coil and specimen.

5.FACTORS THAT AFFECT EDDY CURRENT INSPECTION

- Material conductivity
- Permeability
- Frequency
- Geometry
- Proximity/Lift-Off
- Depth of Penetration
- Eddy Current Testing and Industry

6. ADVANTAGES

- Sensitive to small cracks and other defects
- Detects surface and near surface defects
- Inspection gives immediate results Equipment is very portable
- Method can be used for much more than flaw detection.
- Minimum part preparation is required
- Test probe does not need to contact the part
- Inspects complex shapes and sizes of conductive materials Able to detect surface and near-surface cracks as small as 0.5mm
- Able to detect defects through several layers, including non-conductive surface coatings, without interference from planar defects
- Effective on test objects with physically complex geometries
- Provides immediate feedback

7. LIMITATIONS

- Can only be used on conductive materials
- The depth of penetration is variable
- Very susceptible to magnetic permeability changes.
- Unable to detect defects that are parallel to the test object's surface
- Only conductive materials can be inspected
- Surface must be accessible to the probe
- Skill and training required
- Surface finish and roughness may interfere
- Reference standards needed for setup

- ❖ Depth of penetration is limited
- ❖ Flaws such as delamination that lie parallel to the probe coil winding probe scan direction are undetectable.

8.APPLICATIONS

- ❖ It is often applied for surface crack detection and material sorting. Materia sorting is used to ensure that the proper materials are component materials or assembly features (such as the orientation position of a subcomponent in an assembly).
- ❖ **Weld Inspection -** To scan the surface for open surface cracks on well caps and in heat affected zones.
- ❖ **Conductivity Testing** - Eddy current testing's ability to measure conductivity can be used to identify and sort ferrous & nonferrous alloy and to verify heat treatment.
- ❖ **Surface Inspection-** Surface cracks in machined parts and metal stod can be readily identified with eddy current.
- ❖ **Corrosion Detection-** Low frequency probes can be used to locate corrosion on second and third layers of metal that cannot be inspected ultrasonically.
- ❖ **Bolt Hole Inspection**- Cracking inside bolt holes can be detected using bolt hole probes, often with automated rotary scanners.
- ❖ **Tubing inspection** - Both in-line inspection of tubing at the manufacturing stage and field inspection of tubing like heat exchangers are common eddy current applications. Both cracking and thickness variations can be detected.