NON DESTRUCTIVE TESTING

The science of Non destructive testing is very old. A well known example is that of Archemedes and Hiero's crown. In performing a test to determine if the king has been defrauded by the goldsmiths. The recorded history of NDT started from 1920. But the real revolution in NDT took place during World War II.

Often it is desirable to know the characteristic properties of a product without subjecting it to destructive tests. NDT refers to all the testing methods which permit testing or inspection of material without damaging or impairing its future usefulness.

Examples of Non-destructive tests are the

i) Penetrating liquid method
ii) Ultrasonic test
iii) Radiography
iv) Visual Examination
v) Leakage Testing
vi) Penetrant methods
vii) Magnetic particle inspection
viii) Acoustic methods
ix) Radiography
x) Thermal methods
xi) Electrical methods
xii) Surface and thickness measurement

VISUAL OBSERVATION

Before processing for other tests the subject should be visually observed for external surface perfection, dimensional accuracy and other required parameters. This is applicable in all the testing methods.

So visual inspection of the object should never be omitted whenever it is necessary to detect the presence of possible surface defects. Although it may appear unnecessary to list this as a test method, there has been a tendency to overlook the advantages to be gained by a careful visual inspection using-

i) Low power magnifying glasses as well as microscopes if necessary

ii) Checking of dimensions by use of scales, tapes, micrometers or special gauges may also be considered as a type of visual inspection.

System	Features	Applicability
Liquid penetration	Detection of surface defects which break the surface	Can be used for any metal, many plastics, glass and ceramics
Magnetic particle	Detection of defects which break the surface and sub surface defects	Can only be used for ferro magnetic material (most steels and iron)
Electrical Methods (Eddy current)	Detection of surface defects and sub-surface defects. Can also be used to measure the thickness of non conductor in coating such as paints on a metal.	Can be used for only metal
Ultra sonic	Detection of internal defects but also detect surface flaws	Can be used for most materials
Radiography	Detection of internal defects, surface defects and correctness of part assembles	Can be used for many materials but there is a limit action on the thickness

Visual Examination reveals the surface smoothness and roughness, and the surface defects. The experience of the examiner, his eye sight, lighting conditions at the spot, effect the testing. In fact, certain defects which cannot be properly spotted by very sophisticated methods of testing are located by visual examination e.g. uneven surface. NDT Methods are as tabulated below:

Defects which can be detected by NDT Test

A. Defects which may be introduced during the manufacturing of raw materials or the production of casting.

i) Stress cracking
ii) Shrinkage porosity
iii) Gas porosity
iv) Slag inclusion
v) Segregation

B. Defects which may be introduced during the manufacturing of components

i) Machining faults
ii) Heat treatment defects
iii) Welding defects
iv) Residual Stress cracking

C. Defects which may be introduced during component assembly

i) Missing parts
ii) Incorrectly assembled parts
iii) Additional Welding Defects
iv) Additional stress cracking

D. Defects generated during service life

i) Fatigue
ii) Corrosion
iii) Stress corrosion
iv) Wear
v) Creep
vi) Thermal Instability

Hammer Test (Sonic Test):-When a solid homogeneous object is struck with a hammer, it emits a clear ringing sound, whereas a defective (cracked) object has a well known dull sound. This fact has long been the basis for one of the oldest non- destructive tests. Although it is highly satisfactory for simple forms, experience has shown that complicated shapes modify the sounds and tend to confuse the impactor.

LIQUID PENETRANT INSPECTION (L.P.I)

There are three types of LPI methods

a) Chalk test
b) Dye Penetration Test
c) Zyglo Test

Chalk test: This is a very old process and it is applicable in those fields where DPI or zyglo is not available. In this process, chalk solution is applied on the surface cleaned by K oil. After the chalk coating dries up, component is lightly hammered. The K oil which has gone in the cracks due to capillary action oozes out and indicates the location and (bleeds) Size of flaw or cracks

Dye-Penetration test: It is a technique for detecting discontinuities that are opened to the surface. This method can be used effectively not only for the inspection of ferrous metals but are especially useful for non ferrous metal products and non porous, non metallic materials such as ceramics, plastics and glass because magnetic particle methods are not applicable.

Surface discontinuities such as cracks, seams, laps, laminations or lack of bond are indicated by these methods. This technique reveals flaws such as shrinkage cracks, porosity, fatigue cracks, grinding cracks, seams, forging cracks heat treatment cracks and leaks etc. on weldings , castings, machined parts, cutting tools, pipes and tubes.

In this process three chemicals are used:

1. Cleaner
2. Penetrant
3. Developer

The surface under test must be nicely cleaned. Then the cleaner is applied to dissolve, the residual oil, grease etc.

Cleaner ---→ Kerosene

Wipe off with clean cloth

Subsequently, penetrant normally red in colour is applied and a certain dwelling time is allowed to permit penetration into possible discontinuities.

The liquid is then completely removed from the surface. (The excess penetrant is wiped off). Then either a wet or a dry developer is applied.

Developer → generally white in colour which acts as a "blotter"

It draws the penetrant from the flaw to reveal its presence. This bleeding out of penetrant onto the surface shows the location and general nature and magnitudes of any discontinuities present. To hasten this action, the part may be struck sharply to produce vibrations to force the liquid out of the defect.

The Oil-whitening Test

It is one of the older and cruder penetrant tests used for the detection of cracks too small to be noticed in a visual inspection.

1) Piece is covered with a penetrating oil
2) Rubbed dry and coated with dry whiting
3) In a short time the oil that has beeped into any cracks will be partially absorbed by the whiting, producing cracks.

ZYGLO TEST (fluorescent Penetrant is known as Zyglo);-This is an exhaustive form of D.P.I. Small ferrous and non ferrous components can be processed in bulk for test. In this process the observation is made exclusively under U.V. light.

This test can be performed by dipping the article in a bath of a penetrating fluorescent substance such as anthracene. The solution enters the cracks if any, and remains there. The article is then dried and examined under a quartz tube vapour lamp which is called black light having a wavelength of 3650A, (between visible and ultraviolet). The coating of developer used with it is not fluorescent but is dark when viewed under black light. Pores show as glowing spots, cracks shows fluorescent lines.

STATIFLUX:-Statiflux is a test method for locating cracks in non conducting materials such as plastics, ceramics and glass. The object is first covered with a special penetrant which conditions the defects, the surface is dried

and then a cloud of fine electrically charged particles is blown over the surface, causing a a built-up of powder at the defects.

The penetrant is not required when the non conductor is caused by a conductor as in enamelware.

Magnetic Dust Methods:

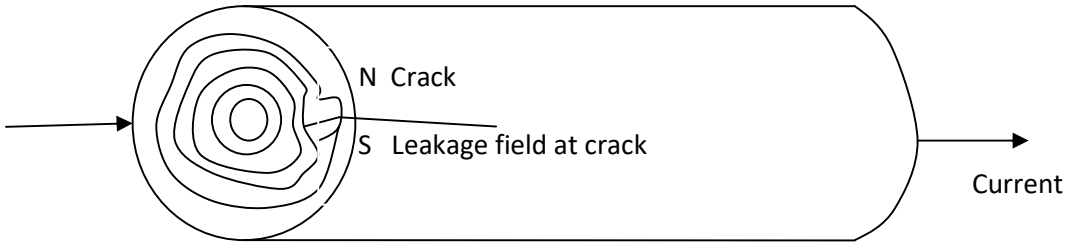
It is performed on magnetic materials like iron, nickel, cobalt etc. It is based on the principle that if there is a flaw in the magnetic material through which a magnetic field is passing, the lines of magnetic flux will be distorted near the flaw.

If the material is defectless, the lines of flux will be uniform.

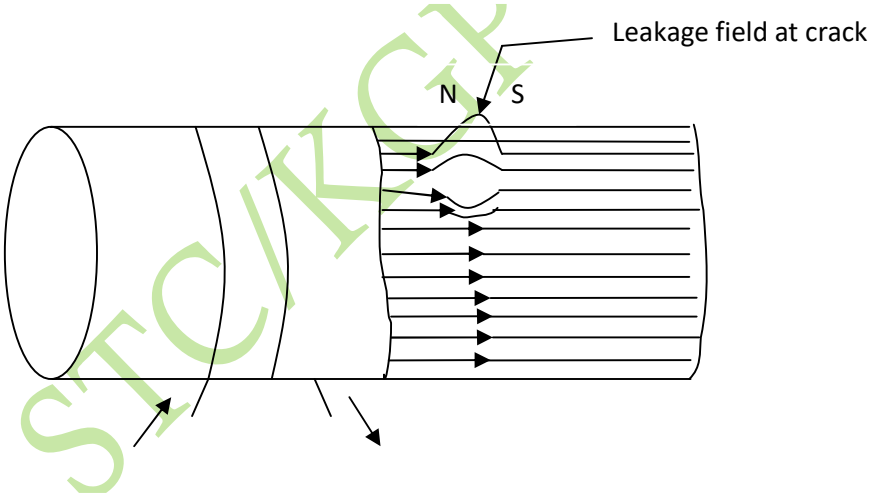
This test is performed by magnetizing the object and then immersing it in a bath of kerosene oil containing fine iron oxide powder. A coloured powder can also be used. If a crack lies it attracts the iron dust as each cracks become a magnetic poles.

Cracks caused by quenching, fatigue failure in welding, blow holes in castings and grinding operations can be detected by this method. The equipment used in this method is known as magnaflux.

Low voltage current, usually 4000 to 10000 amp



Circular field produced by longitudinal currents



Longitudinal field produced by circular current

Direct current is often used since it appears to permit the detection of defects lying more deeply in the section, so the character of available power supply may be the deciding factor.

Inspection Medium

Magnetic powder is generally black magnetic. iron oxide or iron. The powder may be applied dry or wet. It is available in black and red colors

Recent development (Magna glow) It is magnetic particles prepared with a fluorescent coating. Inspection carried out under ultraviolet light so that every crack can be detected clearly.

Advantage and Limitations of MPI (Magnetic particle Inspection)

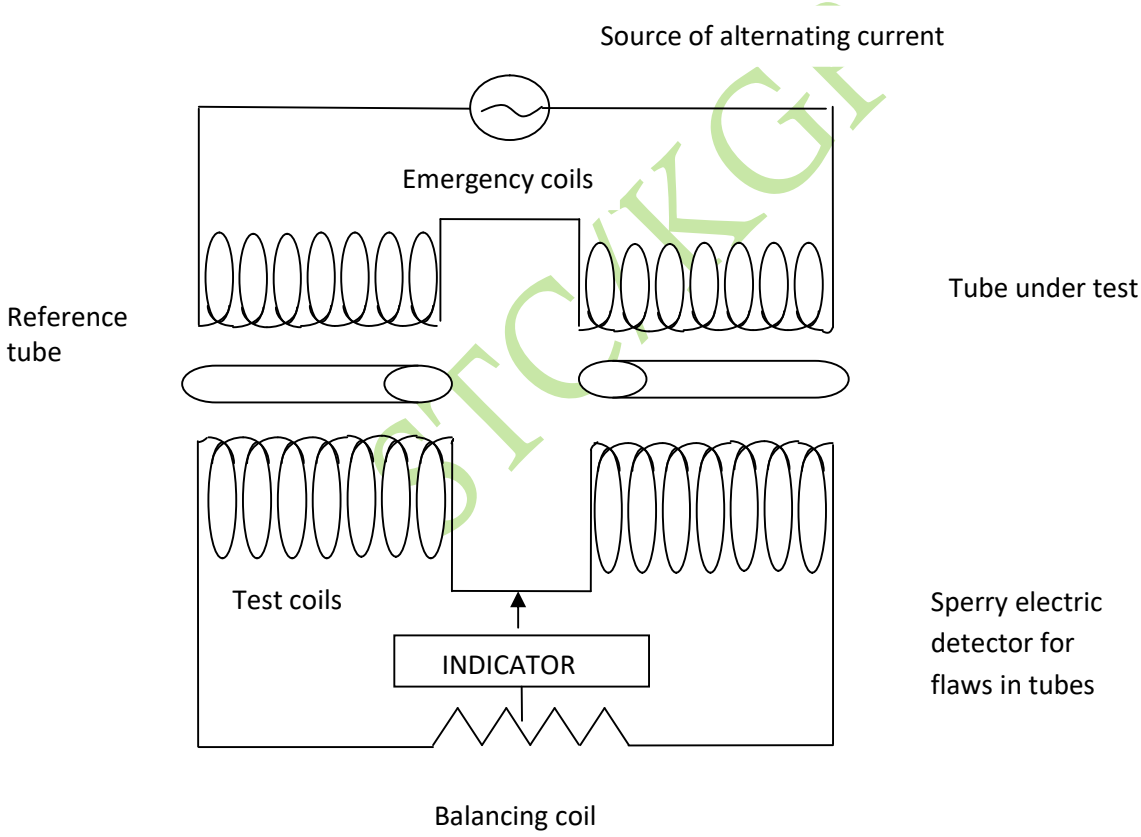
Magnetic particle inspection is a sensitive means of detecting very fine surfaces flaws and in certain situations it is superior to more sophisticated techniques.The equipment necessary is comparatively cheap and there is little need in the way of auxiliary (supporting) equipment.The major limitation of this technique is that it is only suitable for ferromagnetic materials. The sensitivity of MPI is generally very good, But this will be reduced if the surface of the component is covered by a film of paint or other non magnetic layer.

Advantage of dry powders over wet

Dry magnetic powder is not so messy to work. Oil paste suspension is difficult to recover from the work piece. Dry powder is better for locating near surface detector.

Sperry Detector

It is used to detect flaws in Rails, flaws in pipes and tubes.

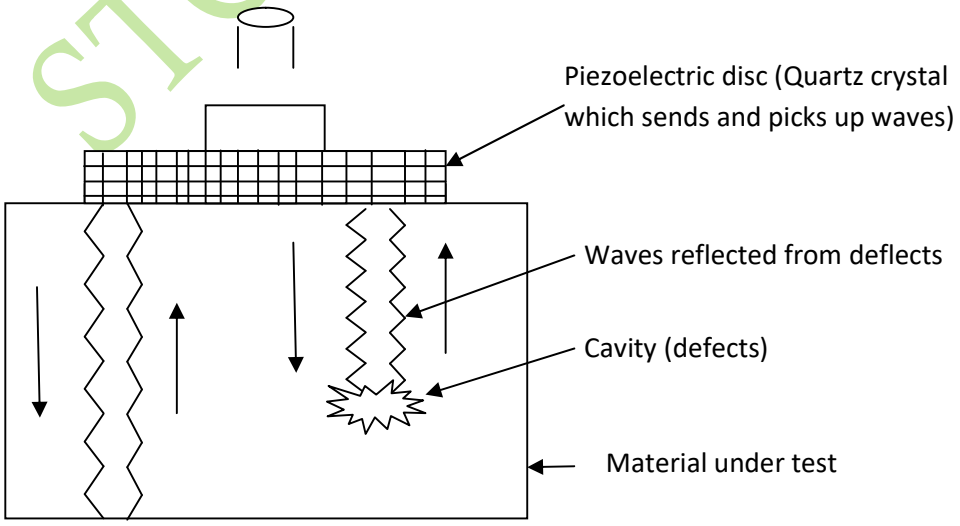


Sperry electric detector for flaws in tubes

When there is no defect present the test coils are in electrical balance. A flaw in the tube under test upsets the balance of the test circuit.

Any flaw in the path of the current will increase the resistance of the circuit will increase the resistance of the circuit and produce a difference in the value of the current which can be measured by suitable measurement.

Ultrasonic Test :-In this method, high frequency sound wave ie. Ultrasonic waves are applied to the object under test by a piezoelectric crystal. If the article is free fron Co axial cable to instrument (probe) lects sound waves without distortion. If there is any flaw in the object, the time taken by the sound wave will be less as the reflection will be from the flaw point and not from the bottom face of the object. The sound signals are received on a cathode ray tube which has a time keeper connected to it. The depth of crack or flaw is calculated from the time interval between the transmission of the sound pulse and the reception of the echo signal.This test is used to find out internal cracks like shrinkage cavities, hot tears, zones of corrosion and inclusion of non metallic substances. It is very fast and reliable method of inspection and is used to test automobile and aero plane components. The frequency of the vibrations used is in the range of 100000 to 20000000 cycles per sec whereas the audible or sonic range is only 16 to 20000 cycles per second. The defects in ferrous, non ferrous, plastics, ceramics etc. can be identifie.



Piezo is derived from the Greek word meaning Press and Piezoelectric effect is the production of electricity in a material by the application of pressure. This effect only occurs in electric insulators and results in the appearance of electric charges on the surface of the mechanically deformed material.

Radiography

X-rays and Gamma rays are extensively used to detect internal defects such as cavities or cracks or portion of variable density in components of large size. This technique is also known as Radiography.

To find out internal defects in welding, forging, casting, press working, impurities and wear and tear of material. This technique is finding more extensive use in the field of physical metallurgy.

The penetrating powers of X rays is lesser than that of gamma rays, therefore X rays are used for small thickness and gamma rays for greater thickness of object.

Gamma rays have shorter wavelength than X rays and have more penetrating power than X rays.

A light sensitive film placed on the far side of the object exposed to the short wave radiation. A picture of light and dark areas obtained.

Dark area shows → lower density

Light area shows → higher density

Exograph film → produced by X rays

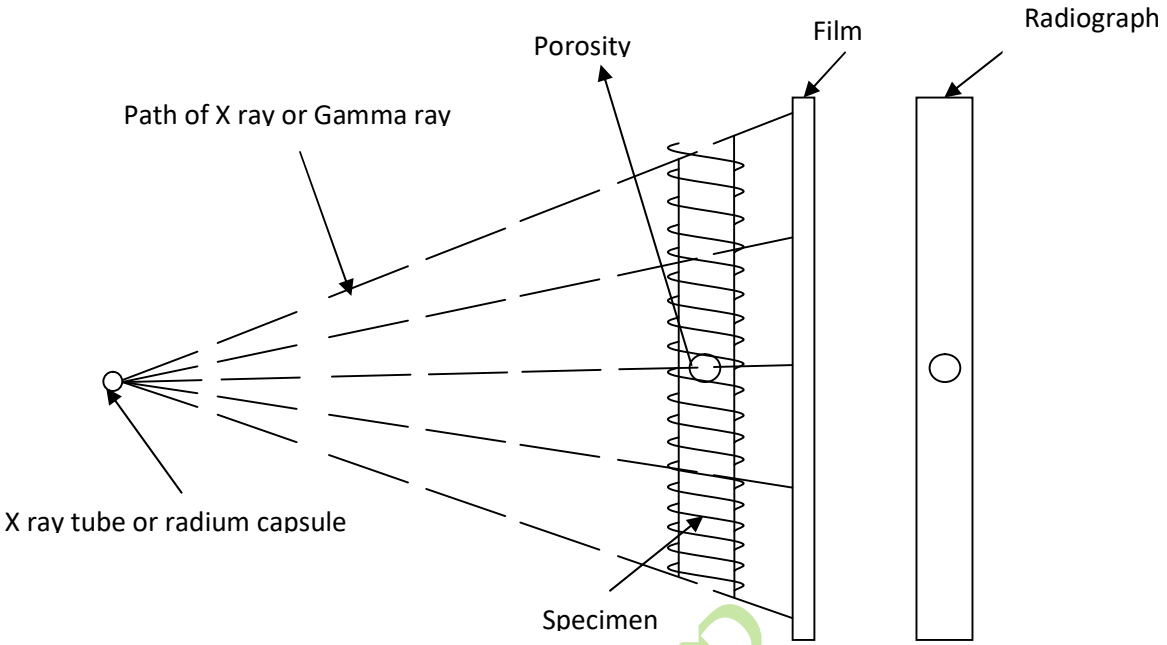
Gamma graph film → produced by gamma rays

Both are called radiographs.

Defects appear on negatives:

Gas cavities and blowholes → Circular dark areas

Cracks appears as darkened areas of variable depth i.e. defects appear as dark on the negative of the film.



Production of a Radiograph

The piezoelectric effect occurs in materials where the atomic bonds are ionic- that is where the atoms are arranged in positive negative pairs called dipoles. Pressure applied to the material distorts these dipoles, causing separation of the positive-negative pair and creating an electric field.

Application

Piezoelectric materials are used wherever mechanical and electrical energy interchanged. It is used in transducers which converts mechanical stress into electrical signals.

Couplant

Regardless of the techniques being used it is usually necessary to use a couplant material between the transducer and the test object, because air is a relatively poor transmitter of sound waves. There is a great impedance mismatch between air and most materials to be tested. As a result, very little of the sound generated by the transducer is able to enter the test object through a layer of air, even that layer is very thin. Use of a couplant reduces the impedance mismatch by eliminating air and substituting a material with impedance nearer to that of the test object. Most couplants are liquid such as water or oils, or semi liquids such that gels or grease.

In addition to impedance matching, couplants should also

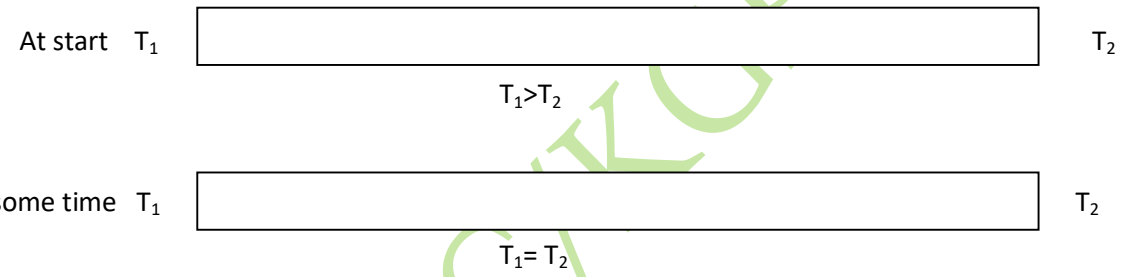
1) Conform closely to the test surface
2) Be stable under test conditions

3) Be non corrosive – it should not react with the object in bulk , or in crevices (narrow gap) of the test object and

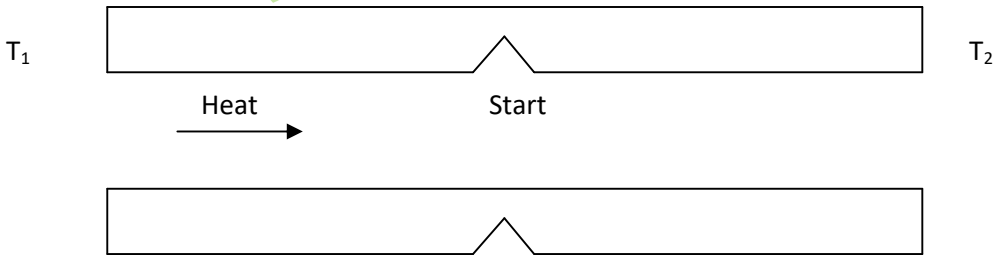
4) Be easy to remove after testing

Thermal Test:

Metals and alloys are the conductors of heat. When a metallic object is heated at one end, the heat is conducted from this portion to the other portions. The tendency is to attain a uniform heat distribution in the body. After some time, the body attains a uniform temperature throughout. If the temperature at the end where the heat is applied is T_1 and at the farthest end is T_2, the flow of heat takes place and continues as long as T1 is greater than T_2.



If there is a crack of discontinuity in the metal, the heat travel will not be fascilated. The region of discontinuity offers resistance to the heat flow.



After some time Heat ⟶ T_3 T_4

Consequently, the heat distribution in the object will not be uniform.

In such a case,

$T_1 \neq T_2$

$T_1 = T_3$, $T_2 = T_4$

$T_3 \neq T_4$

So if the heat is supplied to the object under test and the temperature distribution is studied, a fair idea of its uniformity is found. This is the basic principle behind the thermal testing procedure.

1) Requirement quickly heating the object under test by anyone of the following means : -

a) Direct thermal contact with a heat source

b) An electric current

c) Induction heating

d) Infra red heat source

2) A good and accurate method of studying the temperature distribution.

The accuracy of the test depends upon the accurate measure of temperature distribution. There are various means of studying the temperature distribution.

i) Wax coating

ii) Frosting

iii) Tempilstik

iv) Tempi laq

v) Temp sensitive phosphors

Frosting the test surface

Spraying the mirror finished metal and alloy surface with a solution of 40% Diphenyl in carbon tetrachloride leaves a frosted or dull surface. When the object under test is induction heated, the region of the defect gets quickly heated, the region of the defect gets quickly heated up and the frosted area clears out.

Tampilstiks and temilaqs

Tempilstiks are patented crayons which are sensitive to temperature. There are about a hundred types of tempitstiks in the market. These cover the temperature range of 60° and 1300°. Each of them is sufficiently sensitive to indicate a specified temperature with ±1% error.

The tempilstiks are used like chalk crayons to make the surface of the specimen under test. Heat is applied later and the mark liquefies.

Temperature sensitive pigments:

These are a recent development in the field of thermal testing. Branded and patented pigments are manufactured in West Germany. These are known by the name 'Thermocolors'. These pigments characteristically change their original color at certain temperatures. This colour change is very marked and quite permanent for a few hours.

Advantages

These methods of testing are cheap, reasonably simple and easy to interpret. The only drawbacks may be their inability to detect deep seated flaws.

There appears to be good scope for research and development in these testing techniques.

ACOUSTIC METHODS

Acoustic testing is performed using the sound energy.

Testing of a part by audible sound energy is called sonic testing and by making use of the ultrasonic sound waves, supersonic testing or ultrasonic testing.

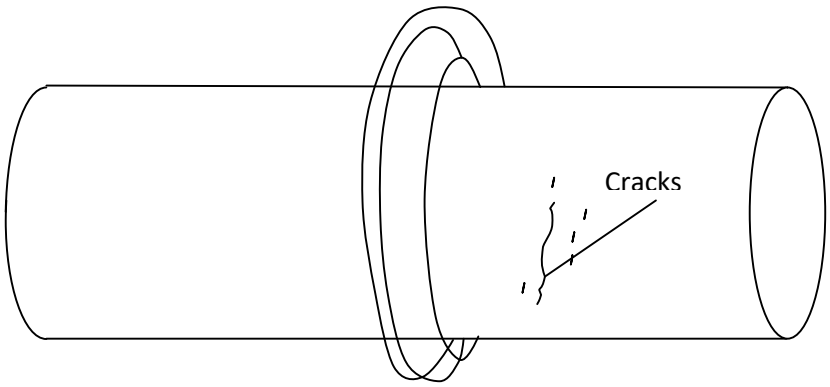
Magna flux machines

The machine is manufactured by the Magnaflux Corporation, Chicago, USA is a patent and the one used most commonly. It consists of the heavy copper contact plates mounted on two heads. The left hand side is fixed and the right hand side movable. The whole set up is mounted on a heavy body like an ordinary lathe machine. A low voltage current usually ranging from 4000A to 10000A passed through the part under test, the duration of the flow is controlled by a time relay switch.

The equipment has also a provision for a magnetizing coil to affect longitudinal magnetization of the part. The coil which is about 50 cm diameter is mounted on the machine bed and moves on two sets of wheels. Below the bed a tank of magnetic particle suspension is kept.

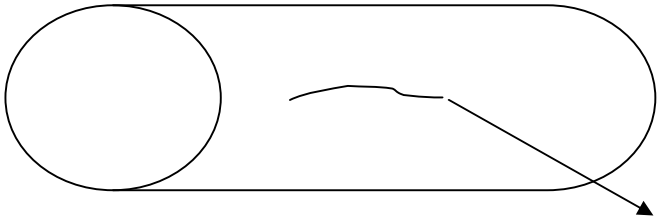
The process

Longitudinal magnetization of the part is used by employing the magnetizing coil to detect any flaws which are transverse.



Magnaflux indication of a transverse crack in a cylindrical part

Circular magnetization of the part is done by passing the current through the part itself. It detects the cracks which run along the path.

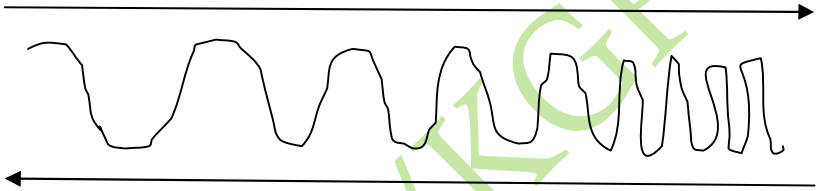


Longitudinal cracks

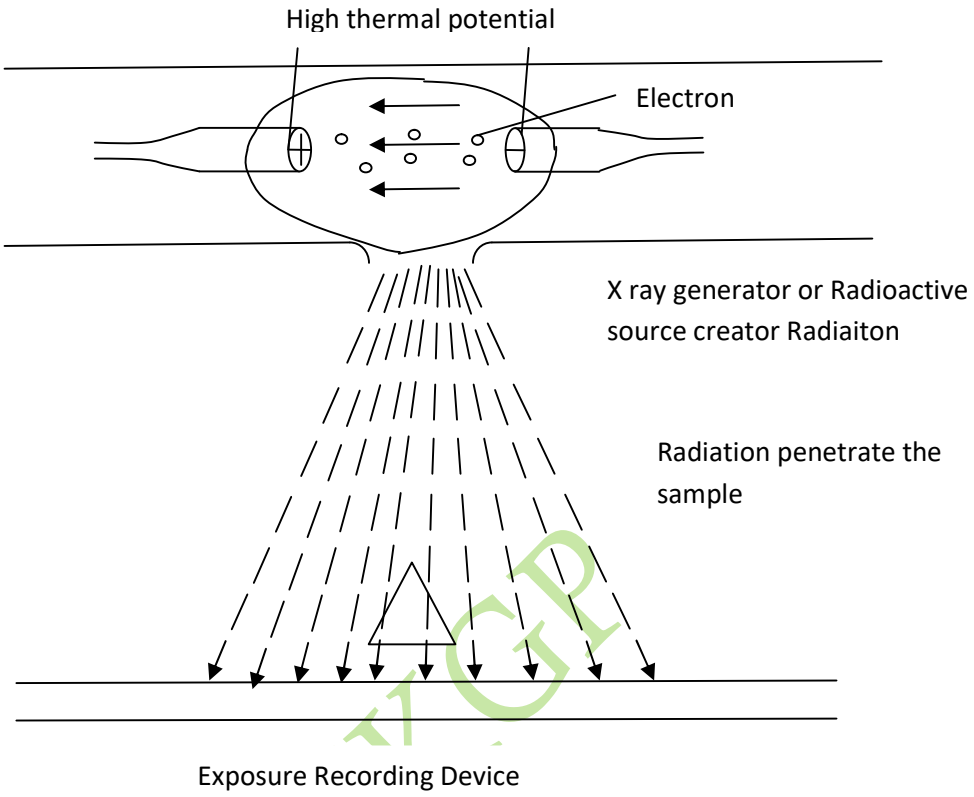
Radiography

The radiation used in radiography testing is a higher energy (shorter wavelength) version of the electromagnetic waves of visible light. The radiation can come from an X-ray generator or a radioactive source.

Low frequency High frequency

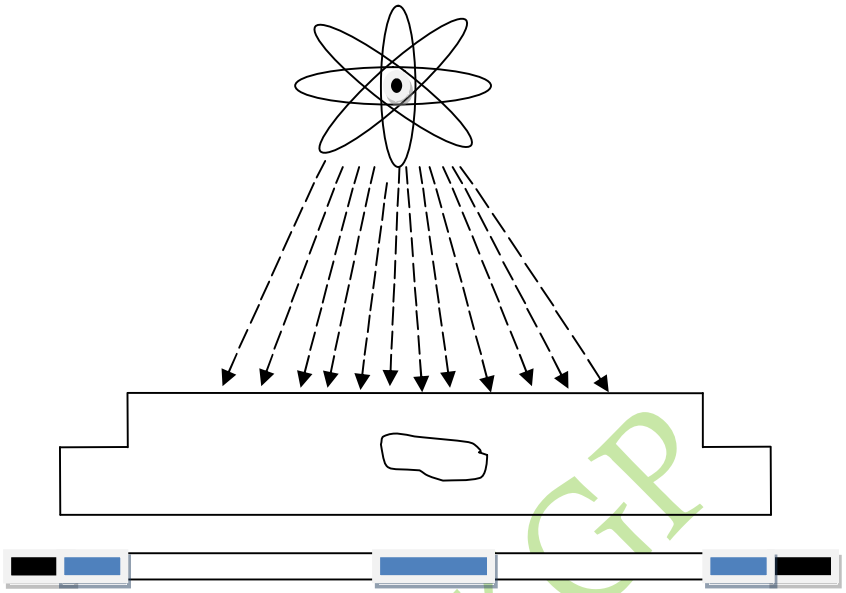


Long wavelength Short wavelength


High thermal potential
Electron
X ray generator or Radioactive source creator Radiaiton
Radiation penetrate the sample
Exposure Recording Device

Film Radiography

The part is placed between the radiation source and more dense area will stop more of the radiation.



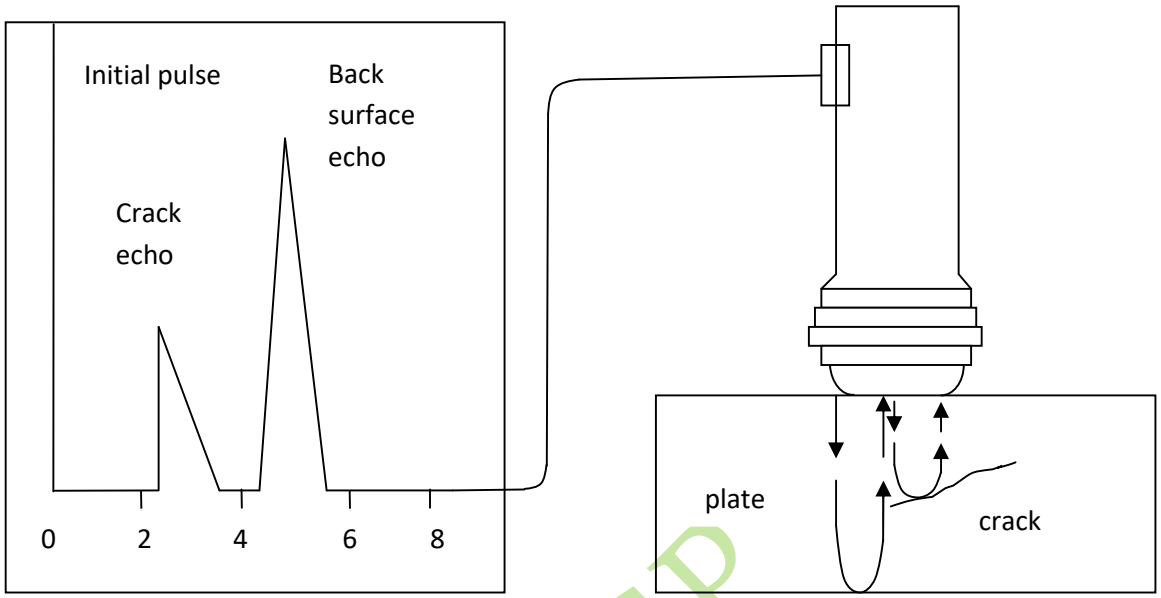
X Ray film

Top view of developed film

The film darkness (density) will vary with the amount of radiation reaching the film through the test object.

 = less exposure

 = more exposure



Oscilloscope, or flaw detector screen

High frequency sound waves are introduced into the material and they are reflected back from surfaces or flaws.

Reflected sound energy is displayed verses time, and inspector can visualize a cross section of the specimen showing the depth of features

FUNTIONS OF CMT LAB:-

Material Testing:

- Chemical and Physical Testing of Ferrous/ Non-Ferrous metals, Rubber, Plastics, Plywood,
- Composites, FRP materials, Electrical cables, Adhesives, Sealants & all other materials used in
  - Railways.
- Testing of Welding Consumables, Trials on Welding processes for coaches, bridges, tracks etc.
- Radiographic testing of Welds (Critical joints) *(100% of EMU Bogie Frames)*, Castings, Forgings etc.
- 100% Ultrasonic Testing of Wheel & Axle during manufacture & running in Railway Coaches
- 100% Magnetic Particle Inspection (MPI) of Spring Steel bars & Springs for detection of defects.
- Testing of Paints & surface coatings used for corrosion prevention on Railway coaches & other useful assets.
- Testing of Oil, Grease, Coolants & other Lubricants in Production Units/Diesel Sheds for proper running of Locomotives.

Process Control:

- Process control of welding of Bogie frames, Under-frames, Shell etc. at Shop Floor for Conventional,
- Export and LHB coaches.
- Welder approval for SAW, MIG, TIG, Spot welding processes
- Process control in heat-treatments of Annealing, Normalizing of Forged Components.
- Process control in heat-treatments of Hardening and Tempering of Coiled Springs.
- Process control in Corrosion prevention & Phosphating.
- Process control in Paint shop.

Additional jobs:

- Standardization of new materials used for rolling stock.
- Consultancy to Design Wings of all Engineering Departments of Indian Railways for selection of
- proper raw material, process etc.
- Carrying out failure analysis of components used in Rolling stock and advising the necessary
- corrective and preventive action to avoid such premature failure.
- Inspection and certification of materials at Firm's premises.

Quality Management System (ISO-9001/ 2000):

- Calibration of Measuring & Testing Equipments.
- Updating of Quality Manuals and related documents.
- Co-ordination for Process Qualification Requirements.
- Co-ordination for Process Validation Requirements.
- Periodical Internal Audits and Subject to External Audits.

Environment Management System (ISO-14001/2004):

- Measuring and Monitoring environment around the factory as per the stipulations of Pollution control Board
- Measuring & Monitoring of Ambient Noise level
- Measuring & Monitoring of Quality of stock of Gases
- Measuring & Monitoring of Ambient Air Quality
- Measuring & Monitoring of Water quality.