Unit VII : Non Destructive Testing & Nanotechnology.

An industrial product is manufactured with an aim to perform a certain function & user expects that it perform the required function well.
But if there are some imperfections or defects in product, its performance efficiency will be lowered.
To check ~~whether~~ if there are some imperfections in the product, testing is done after manufacture.
Defects in a product can arise during manufacturing stage, or during assembly, installation etc.
These defects can be external defects (micro cracks, surface finish etc) or internal defects (micro-segregation, overstressed parts etc)
These defects can be detected by mainly two types of methods :

(I) Destructive Testing –
In this method, external stress / forces applied on ~~pr~~ testing components of product which can damage the product.
Hence after destructive testing components can not be resused.
Internal defects can not be found using this method

(II) Non-Destructive Testing :-
Testing / Analysing specimen using different techniques without destroying serviceability of component or the system.
Also called as – NDI : Non Destructive Inspection
NDA - Non Destructive Analysis ; NDE - Non Destructive Examination / Evaluation

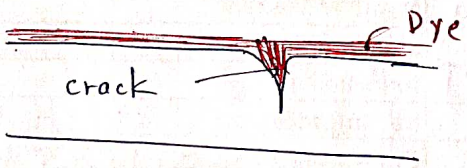
* Methods in NDT :

① Visual Inspection :-

- For examination & detection of surface defects.
- Component is cleaned & then light is incident on it, then examined by naked eyes or with use of optical instruments.

⑪ Liquid / Dye Penetrant Testing :

- For examination & detection of minute discontinuties like cracks & surface openings.
- Surface is cleaned & dried. Then dye is spread over the surface uniformly. If there are cracks / openings on surface, dye will penetrate in it, ~~postion~~ position & deapth of crack can be found easily.



Crack of ~150 nm narrow can be detected using this method.

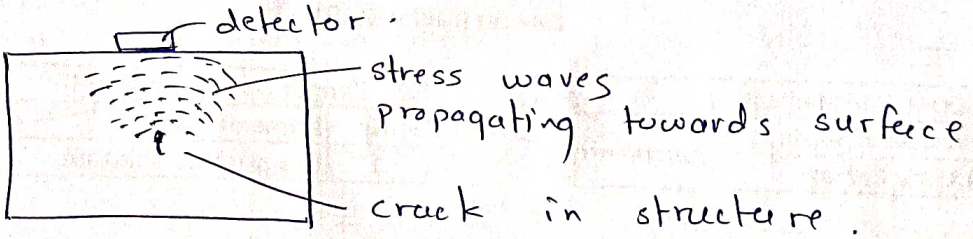
⑪⑪ Magnetic particle Testing :

- For detection of cracks / discontinuties on the surface of ferromagnetic materials as Fe & steel.
- Not applicable for non-magnetic materials.
- Small magnetic particles are spread over surface, if there are discontinuties, particles will be crowded there.

* Mainly 3 methods :

① Acoustic Emission Testing :

- An advance method to detect & locate hidden defects.
- When an external stress is applied to any structure / product, area / region having cracks / imperfection get more deformed than the ~~surroung~~ surrounding & it generate stress waves.
- These stress waves propagate through structure & ~~reached~~ reaches the surface, which can be ~~dected~~ detected using different sensors. (piezoelectric ~~cr~~ crystals)
- Distance of crack from the surface can be found.
- used for detecting defects in bridges, dams & aerospace structures.



Advantages :

- Highly accurate results.
- Early detection of flaws.
- Possible to test equipment during operation.
- Sensitive, Economical. (less cost)

Disadvantage :

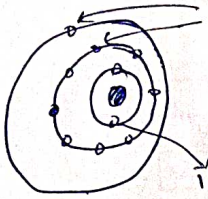
- Loading required is high to produce detectable signal.

(11) Radiography Testing :-

↳ X-rays & γ-rays are used for testing.

→ What are X-rays ?

- When an electron make transition from one of the outer shell — visible light emitted.

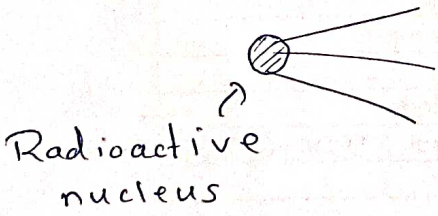


When we give external energy in such a way than inner shell electrons make transition to higher level., while going back to initial inner level, → X-rays are emitted

- High energy / high frequency, low wavelength EM radiation.

→ What are γ-rays ?

- γ-rays are produced from a radioactive nucleus.
- When a radioactive element is in high nuclear energy state, while coming to lower (stable) state — γ-rays are emitted.



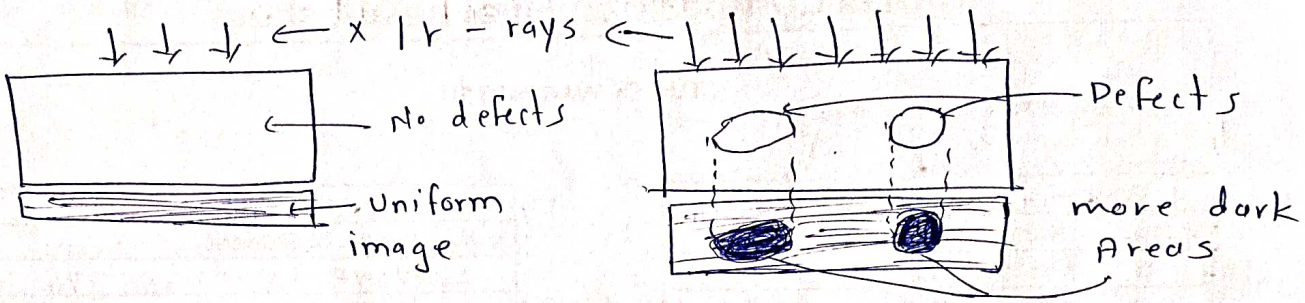
} Nuclear ~~Radioactive~~ radiations.

↳ When these X-rays / γ-rays are passed through sample to be analysed, components will absorb these radiation.

- Absorption of X-rays / γ-rays depends on absorbing power of that material & density in that region.
- If there are some defects like a void / hole in the sample, density will be less in that ared

because of which x-rays / r-rays can easily pass through it.

- If a photographic plate is used to get image, the region where defects are their will be dark (As more x-rays / r-rays will incident there)



- Advantages:
  - Hidden flaws can be detected
  - Wide variety of materials can be tested
  - Very little time required for inspection.

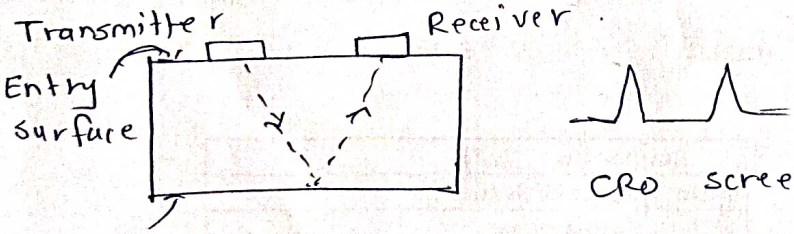
- Disadvantages:
  - Expensive (As special systems are required for generation of x-rays & r-rays)
  - As r-rays are radioactive rad^n harmful for human beings, testing need to be done in isolated spaces.

(III) Ultrasonic Testing method:

↳ Ultrasonic waves?
Sound waves with frequency 20 KHz to 20 mHz. (or greater than 20 KHz)
Principle of ultrasonic testing is based on fact that solid materials are good conductors of sound waves.
Waves are reflected by surface of material & ~~fata~~ flaws also.

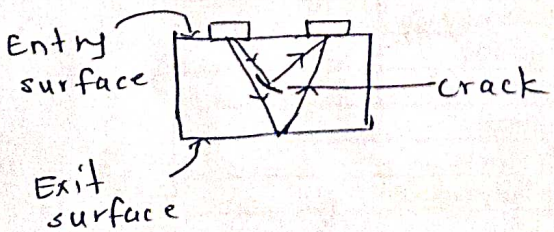
- System consists of several functional units pulse transmitter, transducer & display devices
- Ultrasonic waves are generated using piezoelectric crystals. Transmitter produce high electrical voltage pulse.
When these AC pulse is applied to transducer, it converts signal into high frequency ultrasonic waves. These waves are transmitted through specimen to be tested, it is reflected from other ~~sur~~ (opposite) surface of specimen.
If there are cracks present, part of energy is reflected from crack region. Signal transmitted & converted into electrical signal by a transducer.
This signal is displayed on CRT.

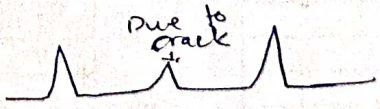
↳ When there is no any flaw, CRO will show two peaks (echo) - one due to transmitted pulse & other for reflected pulse.



CRO screen.

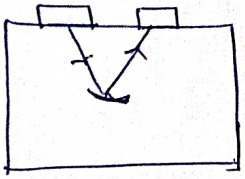
↳ If there is crack / flaw present then, there will be pulses due to cracks.





CRO screen.

↳ If velocity of ultrasonic waves ~~are~~ is known for that medium, we can find distance of flaw from the surface:



we know,

$$V = \frac{d}{t}$$

V : velocity of wave
d : distance of flaw from surface

t : time required for pulse to reach surface after reflecting from flaw.

But, t will be time required to cover 2d.

$$\therefore \boxed{d = \frac{Vt}{2}}$$

- Distance of flaw can be found.

Advantages:
- Very fast
- Highly reliable method
- Low cost.

Disadvantages:
- Not suitable for complex shapes
- Surface must be cleaned before use

* Nanotechnology :-

- Word nanotechnology was used for the first time in 1974 by Prof. ,

* Nanotechnology :

- As the technology is advancing, there is continuous miniaturization of technical devices & components. Result is development of various micro-technological processes.
- Nanotechnology : use of nanoscale machines to build complex products including other nanomachines.

Nanoscale :-

- Nano derived from Greek word meaning dwarf or extremely small & means a billionth (10^{-9}) part of a unit.
- $1\ nm = 10^{-9}\ m = 10^{-3}\ \mu m = 10\ \text{Å}$
- 1 nm ≈ 3 to 5 atoms lined up in a row.

Size(nm)	Example	Terminology
0.1 - 0.5	Individual chemical bond	Molecular / atomic
0.5 - 1.0	Small molecules	Molecular
1 - 1000	Proteins, DNA, inorganic nanoparticles	Nano
$10^3 - 10^4$	Devices on a silicon chip, living cells. human hair (50dm)	Micro
$> 10^4$	Normal bulk matter	Macro.

* Significance of Nanoscale :-

- Many properties of solid depends on size of solid
- Properties of material can be different at nano-scale because :

(i) Nanomaterials have larger surface area. it makes them more reactive & affect their strength or electrical properties.

(ii) Quantum effects dominate at that scale which also affect their optical, electrical & magnetic behaviour.

o Nanotechnology :

term 1st coined in 1974 by Norio Taniguchi of Tokyo Science University

Nanotechonology is design, characterization, production & application of structures, devices & systems by controlling shape & size at nanometer scale.

o Nanoparticles :

- Aggregate of atoms or molecules bonded together with a radius of less than 100 nm.
- Bulk material should have constant physical properties regardless of its size, but at nano-scale size dependent properties are often observed.
- Increased surface areas & dominant quantum effects enhance the properties like ractivity, strength, electrical characteristics

o Quantum Confinement :

- Quantum confinement is change of electronic & optical properties when material sampled is of sufficiently small size ~ 10nm or less :

4) Band gap increases as size of nanoparticles decreases.

As length scales are so small (nanoscale) spatial extent of electronic wave fuc^{h} is comparable to the size of particle.

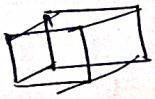
Density of states can ~~bechange~~ be changed if electrons are confined (restrict) in one or more directions by reducing dimensions of material.

Density of states:

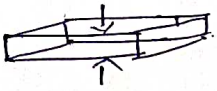
$$g(E) = \frac{4\pi}{h^3}(2m)^{3/2}\sqrt{E} \quad \ldots \text{ 3D}$$

$$g(E) = 2\sqrt{2}\,\frac{\sqrt{m}}{h^3}\,\frac{1}{\sqrt{E}} \quad - \text{2D}$$

$$g(E) = \frac{4\pi m}{h^2} \quad \ldots \quad - \text{1D}.$$



3-D material, no confinement



2-D material
1-D confinement

1-D material
2D confinement.

3-D confinement
Quantum dot.

Q-dots :- crystals so small that their properties are subjected to quantum effects.

zero dimensional object.

Smallest quantum dot - contains only 3 atoms of water.

* Surface to volume Ratio :-

↳ Surface area to volume ratio is important parameter for reactivity.

When size of particle size decreases, fraction of atoms available on the surface to collection of atoms increases which increases chemical reaction rate

* Properties of Nano particles :

(i) Hard & wear resistant

(ii) Ductile at high temp.

(iii) Very low wear & ~~fatr~~ tare

(iv) Active for chemical reactions.

(v) Less corrosion.

* Applications in Mechanical Engineering :

(i) Because of ~~hardr~~ properties that they are stronger, lighter, can be used to make hard metals.

(ii) Used in Giant Magneto Resistance (GMR) spin valves.

(iii) Nano MEMS (micro Electro Mechanical Systems) used in optimal switches, pressure sensors, mass sensors.

* Applications in Electrical, Electronic & Communication Engineering :

(i) Nano materials are used as quantum electronic devices.

(ii) Used as sensing elements used to design robots, assembler etc.

(iii) Used in energy storage devices (ionic batteries)

(iv) Magnetic recording devices.

* Applications in Computer science Engineering & IT

(i) To make CDs

- Smaller chips for information storage.
- In mobile phones, lap-tops etc.

* Applications in Bio-medical & Chemical Energy:

(i) Using nano materials bio sensor - nano robots can be manufactured, these nano robots can be used for surgries. They can go to specific part/organ in body & can do surgery

(ii) Nano materials are also used for targeted drug deliver.

(iii) Bio sensitive nano particles are used in prodn of DNA chips, bio sensors etc.

(iv) Also used in synthetic bones (ceramic nano materia

(v) Few nanomaterials are used in absorbents, self cleaning glass fuel additives, drugs, ferro fluids etc.