X-ray diffraction & Bragg's law:

X-ray diffraction is mainly used to determine the crystal 'structures. X-ray diffraction means the bending of X-rays around the obstacle so that the meeting of any two scattered X-ray produces maximum intensity or minimum intensity on the screen based on Bragg's law.

W.L. Bragg discovered that X-rays can be scattered or diffracted by cleavage planes of crystals when the X-rays are incident on their surface nearly at glancing angles. Glancing angle or Bragg angle is the angle b/w incident ray and crystal plane. Thus Bragg's Law aims at devising the condition for X-rays diffracted by the crystal plane to cause constructive interference.

X-ray diffraction methods to determine crystal structures:

X-ray diffraction procedure will reveal the details about

a) Grain size or crystal size

b) Orientation of the crystals

c) Cold worked, distorted and internally stressed crystals

d) Recrystallization

e) Preferred orientation etc.

There are three main X-ray diffraction methods by which the crystal structures can be analysed,

a) The Laws method

b) Interstitialcies

c) Impurities

Crystal Imperfections:

1. Point defects

a) Vacancies

b) Interrstitialcies

c) Impurities

d) Electronic defects

2. Line defects

a) Edge dislocation

b) Screw dislocation

3. Surface defects

a) Grain boundaries

b) Tilt boundaries

c) Twin boundaries

d) Stacking faults

e) Ferromagnetic domain walls

4. Volume defects

a) Cracks

b) Large voids or holes

Non-Destructive Testing:

The primary purpose of a non-destructive inspection is to determine the existing state or quality of a material, with a view to acceptance or rejection without impaving its future usefulness.

The benefits which can be derived from non-destructive tests include the following:

i) increased productivity and protect

ii) increased serviceability and assurance of quality of product

iii) safety and identification.

There are five essential steps in any non destructive test.

They are

a) Application of a testing or inspection medium.

b) Modification of the testing or inspection medium by defects or variations in the structure or properties of the material.

c) Defection of this change by a suitable detector.

d) Conversion of this Change into a suitable form for interpretation and
e) Interpretation of the information obtained.

Defects in the produced components may be divided into two types:
i) External defects
ii) internal defects
External defects:
i) Machining marks
ii) Hardening cracks
iii) Blow, holes in casting.
iv) Forging defects (laps).
v) Metallic inclusions on surfaces
vi) Stress corrosion
vii) Surface finish
viii) Surface damage

Internal defects:
i) Pipe or axial segregation
ii) Fish tail
iii) Overstressed parts
iv) Fatigue blow holes
v) Porosity in casting
vi) Large grain size
vii) Hydrogen embrittlement
viii) Micro Segregation
The above, defects-pr faults can be identified by different, NDT techniques such as radiography and ultrasonics.

Radiographic methods:
Radiography is a non-destructive testing method and is defined by the formation of images on fluorescent screens or photographic material by short wavelength radiation such as X-rays and Gamma rays or by Nefuron beams or Electron beams.

X-rays are produced by the Coolidge X-ray tubes. The penetrating power of X-rays is mainly depending on the anode voltage of-the X-ray tube. X-rays are obtained when the fast moving electrons are suddenly stopped by the metallic target (anode). A part of their kinetic energy is converted into X-rays. The gamma rays are obtained from the radioactive substances such as Radium,' Caesium-137 and Cobalt-60. Depending upon the radioactive source, their penetrating power varies. Neutrons are obtained from the fissioning of fissionable materials such as U-235 and PU-239. The direct photographic effect of Neutrons is negligible. So a thin layer of iridium or dysprosium is used as a converter of neutrons to alpha particles. The alpha particles impinge on a fluorescent screen and light from which affects the photographic film.
Generally neutron radiography is useful for inspection of light materials such as plastics and rubber components where X-ray radiography and gamma radiography can not be used.

Principle of X-ray or Gamma ray Radiographic techniques:
X-ray, radiations or' gamma ray radiations penetrate through the material under testing. The intensity of the penetrating radiation is modified by passage through the material and by defects in the material. The transmitted radiation are exposed' on the photographic film. The contrast (difference in density) on the developed film between the image of an area containing a defect and the image of a defect free area of the material permits the observer to distinguish the flaw. Thus the phenomenon of

differential absorption is the basis for the use of radiography.

Law of absorption of X-rays or Gamma rays:
When X-rays or gamma rays pass through the material, the decrease in intensity *dl' has been found to be proportional to the intensity T of the incident radiation and penetrated distance 'dt' through the material.

∴ dI = -μIdt

where μ is a constant of proportionality and the negative sign is used to indicate a decrease in intensity with respect to increase of penetrated distance.

Thus $\frac{dI}{I} = -\mu dt$

Integrating the above equation, we get

$\log \frac{I}{I_0} = -\mu t$

Changing this equation into exponential form, we get

$\frac{I}{I_0} = e^{-\mu t}$ or

$I = I_0 e^{-\mu t}$

where I_0 = initial radiation intensity

I = Emergent radiation intensity after passing through the material of thickness 't'

μ = Linear absorption coefficient or attenuation coefficient of the material

Absorption coefficient and Anode voltage of X-ray tubes:
In the case of X-rays, the value of the linear absorption coefficient 'p' increases with atomic number and density of specimen. Further it also increases with increasing image contrast and decreasing penetrability. Lead has a greater absorption coefficient than steel. At 200 kV of anode voltage in X-ray tube, 2.54 mm thickness of lead absorbs as much radiation as 30.48 mm thickness of steel. Depending upon the thickness and nature of the specimens, the anode voltage of X-ray tube is varied For example copper has greater attenuation of X-rays than aluminium. Therefore for a given thickness higher voltage is required in the X-ray tube to copper than Aluminium. Higher the anode voltage, higher will be the penetrating power of X-rays.

Determination of defect location:
The position of a flow within the volume of a test piece cannot be determined exactly with a single exposure of X-rays on a film. However the location of the defect within the volume of the specimen is determined by the 1 tube shift method. A shot is taken at halt the normal exposure time with the X-ray tube and then again on the same film with the X-ray tube displaced through a distance t. The distance b/w the images of the flaw on the film 's' is measured on the developed film and the location of the flaw 'd' from the bottom surface of the • specimen is given by the similarity law:

$d = \frac{FFD \times S}{(S+t)}$

Here FFD means Film Focus Distance which is the distance b/w the focal spot of the X-ray beam and film.

Exposure factor:
In X-ray radiography, the exposure rule (reciprocity law) states that for a given source to film distance the exposure time is inversely proportional to the X-ray tube current.

Generally the tube current 'i' is expressed in milliamperes. and the exposure time 'it' is expressed in minutes. Thus by exposure rule i×t =c, constant for a given source to film distance i.e.

$i_1t_1 = i_2i_2$ = constant

To get a satisfactory image on the photographic film the exposure lime (t), the source to film distance (L) and X-ray tube current (i) should be adjusted to get a constant called exposure factor and is given as exposure factor = $\frac{it}{L^2}$ = constant, for a given specimen.

Image Quality Indicator (IQI) or Penetrameter:

An IQI is used only to demonstrate the quality of a radiographic techhique, it cannot indicate the minimum size of detectable defect. It is designed to give an indication of radiographic quality by demonstrating the component parts of sensitivity, the definition and. contrast.

Sensitivity % = $\frac{\text{Smallest hole (or thinnest wire diameter) discernible on radiograph}}{\text{Thickness of metal under test}} \times$ 100

Fluoroscopy:

Fluoroscopy is similar to industrial radiography. Instead of photographing the transmitted X-ray image, here it is projected on a fluorescent screen. Fluoroscopy is widely used in industry for ready inspection of manufactured articles before final approval. Thus it is used for inspection of fruits before packing, cannel foods, transmitting tubes and other assembled articles. X-ray radiography on the other hand is usually employed for inspection of .larger objects such as metal castings, welded assemblies, etc.

Appearance of X-ray Radiographs:

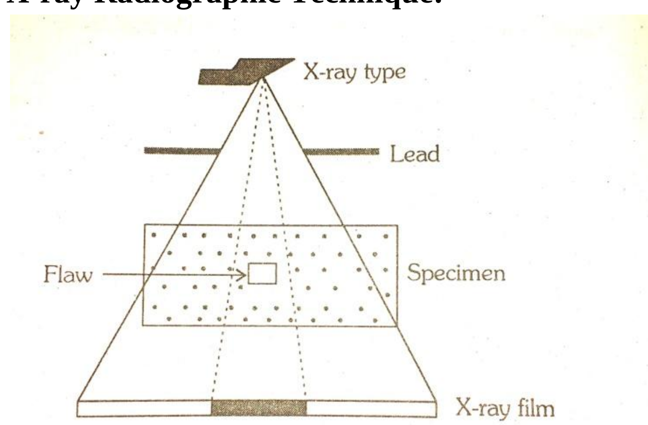
Nature of Defect	Appearance of radiograph
Micro Shrinkage	Dark feathery streaks
Gas porosity	Round or elongated smooth, dark spots
Tears	Ragged dark lines bf variable width
Cold Cracks	Single, straight sharp dark line
Inclusions	Small, higher or darker areas
Cracks	Fine dark lines

Exposure time in Gamma ray radiographic technique:

Exposure time = $\frac{\text{Exposure factor}}{\text{Source strength at present}}$

Exposure factor is expressed in curie – hours

X-ray Radiographic Technique:



Above diagram shows the principle of X-ray radiographic technique. There are three basic elements. X-ray tube (probing medium), the specimen (test piece)-and a recording medium (photographic film) to produce a radiograph. The specimen is a plate of uniform thickness containing an internal flaw that has absorption characteristics different from those of the surrounding material. X-rays from the X-ray tube, is absorbed by the test piece as the radiation passes through it. The flaw and its surrounding material absorb different amounts of radiation. Thus the amount of radiation that impinges on the film in the area beneath the flaw is different from the amount that impinges on adjacent areas. This produces on the film a latent image of the flaw. When the film is developed the latent image of the flaw can be seen as a 'shadow' of different photographic density I from that of the image of surroundings material. A solid portion of the casting absorbs greater percentage of X-raps than a defect like blow hole.