SNS COLLEGE OF ALLIED HEALTH SCIENCES

SNS Kalvi Nagar, Coimbatore - 35

Affiliated to Dr MGR Medical University, Chennai

DEPARTMENT OF RADIOGRAPHY AND IMAGING TECHNOLOGY

I YEAR

TOPIC – X-RAY PRODUCTION AND X-RAY TUBE DESIGN

INTRODUCTION

DISCOVERY OF X-RAYS:

- X-rays were discovered by WC Roentgen, the german physicist in 1895 on November 8,when he was investigating the conduction of electricity through gases at low pressure in glass tubes.
- He noticed that the positive electrodes in the tubes gave off invisible rays that caused fluorescent screen to glow and that fogged photographic plates too.
- As their nature was not known, he called them x-rays.

PROPERTIES OF X-RAYS

- X-rays are electromagnetic radiation of shorter wavelength.
- They travel in straight line with the velocity equal to light.
- X-rays are not influenced by electric and magnetic fields.
- X-rays penetrate through substances that are opaque to visible light.
- X-rays produce fluorescence on materials like CaWO4 and ZnCds.
- X-rays affect photographic film and form latent image.
- X-rays produce ionization and excitation in the medium.
- X-produce chemical changes in certain substances.
- X-rays can have biological changes in living organisms.

PRODUCTION OF X-RAYS

- X-rays are produced when fast moving electrons are stopped by means of a target material.
- The moving electron possesses kinetic energy.
- When the electron is suddenly stopped by the target, its kinetic energy is converted into heat and x-rays.
- This conversion is taking place in the target material. Therefore,the interaction of electron with the target is the basis of x-ray production.

CHARACTERISTIC X-RAYS

- This is an interaction between the incident electron and the electron in the K shell.
- In this process,the incident electron directly hit the K shell,transfers sufficient energy and removes the K shell electron.
- The vacancy in the K shell is filled by an electron moving towards from the outer shell.
- During this transition,the difference in binding energies of the two shells is given out as x-ray photon.
- This photon is known as the characteristic x-ray.

BREMSSTRAHLUNG X-RAYS

- The incident electron occasionally reaches nearer to nucleus of an atom in the target.
- Since the electron is a negative particle,it is attracted by the positive nucleus.
- It is made to orbit partially around the nucleus,decelerates and goes out with reduced energy.
- The loss of energy appears in the form of x-ray photons, known as bremsstrahlung x-rays.

X-RAY TUBE DESIGN

The production of x-ray needs the following;

- Electron source(cathode)
- Target to stop the electron (anode)
- High voltage supply to accelerate electrons
- Vacuum
- Tube insert(glass envelope)

X-RAY TUBE DESIGN

The production of x-ray needs the following;

- Electron source(cathode)
- Target to stop the electron (anode)
- High voltage supply to accelerate electrons
- Vacuum
- Tube insert(glass envelope)

CATHODE

- The cathode is made up of tungsten wire in the form of helical filament,surrounded by a focusing cup.
- Tungsten is used as filament material because of its high melting point,low vapor pressure,good ductility and low work function.
- The focusing cup controls the width of the electron distribution,and directs the electron towards the target.

SPACE CHARGE EFFECT

- When the applied Kv is zero or small,the electrons surrounding the filament forms a cloud,resulting in space charge effect.
- These electrons tend to repel the electron back into the filament and hence,the tube current is very small.
- As the kVp is increased (0 to 40 kVp),the effect of space charge reduces gradually and the tube current also increases.
- This is called space charge limited region.

ANODE

- The anode is the target electrode, which is maintained at a positive potential.
- Tungsten(W) is the metal widely used as target.Because of its,
- high melting point to withstand high temperature.
- High atomic number to increase the x-ray production efficiency.
- High thermal conductivity to dissipate heat quickly.
- Low vapor pressure at high temperature to prevent the evaporation of target material.
- Easily machined to make smooth surface.

FOCAL SPOT SIZE

- The area of target within which the electrons are absorbed and x-rays are produced is called focal spot or focal area.
- If the focal area is very small,penumbra will be lesser,and the picture sharpness will be good,but heat removal is difficult.
- On the other hand,if the focal area is large,heat will be removed very quickly,penumbra is larger and the picture sharpness is bad.
- This is compromised by careful design of the tube with line focus principle.

FOCAL SPOT SIZE

- Usually,focal spot is defined in two ways,namely actual and effective focal spots.
- The actual focal spot size is the area on the anode that is struck by electrons.
- The effective focal spot size is the length and width of the emitted x-ray beam as projected down,along the central axis of the x-ray tube.
- The effective focal spot length is always smaller than the actual focal spot.

LINE FOCUS PRINCIPLE

- X-ray tube requires a specialized focal area in the target,which is larger in size to spread the heat easily and smaller in size to act as a point source.
- The point source reduces penumbra effect resulting in sharp images.
- Hence,the target of an x-ray tube is mounted at a very steep angle with respect to the motion of the incident electrons.
- The x-rays will appear to come from a small focal area(effective focus),whereas the electrons bombard relatively a larger focal area(actual focus).therefore,heat is removed very quickly and also the image sharpness is preserved.
- This is known as line focus principle.

ANODE ANGLE

- Anode angle is defined as the angle of the target surface with respect to central ray in the x-ray field.
- It has strong relationship with focal spot size and usable x-ray field size.
- A small anode angle gives smaller effective focal spot,but its usable x-ray field is limited.
- Large anode angle gives larger usable x-ray field,but the effective focal spot is larger.
- To optimize the design,larger anode angle with small filament length is used.
- This will provide smaller effective focal size,with wide field coverage.

ASSESSMENT

1)Who discovered x-rays ?

2)Mention any five properties of x-rays.

3)Mention the function of focusing cup.

4)What is line focus principle?

5) What is space charge effect?

TUBE INSERT,HOUSING AND VACUUM

- The tube insert or envelope is made up of borosilicate glass(pyrex).The pyrex glass can withstand high temperature and also acts as an electrical insulator.
- It contains vacuum,which support the electrodes.

The tube insert serves the following purpose:

- Absorbs the x-rays emerging in undesired directions.
- Maintains the required vacuum.
- Acts as an electrical insulator.
- Contains cooling systems,which removes the heat from the target.

- Glass is also susceptible to damage from electron bombardment.Hence,metal envelope have been developed with low attenuation beryllium window,for x-ray transmission.
- However,metal may short circuit cathode and anode,due to its conductivity.
- To eliminate this,ceramic or glass insulations are done at the end of the tube.This type of envelope is called meta-ceramic or metal glass design.

- A high vacuum is maintained between the anode and cathode.This is necessary to carry out the following,
- To avoid the collision between electrons and gas molecules,which gives raise to ionization,that reduces the kinetic energy of the electrons.
- To prevent oxidation of electrodes.
- Act as an electrical insulator.

TUBE COOLING

- In x-ray tube,only less than 1% of the electrical power supplied is converted to x-rays.
- The remaining electrical power (over 99%) is converted into heat.
- This large amount of heat can melt the target and therefore heat should be removed very quickly from the target.
- Hence,efficient cooling systems are necessary for the x-ray tube.


Thank
you!