Bremsstrahlung and characteristic radiation pdf

Bremsstrahlung means braking radiation and is preserved from the original German to describe the radiation that is emitted when electrons are deceleration or braking when they are firing on a metal target. Accelerated charges emit electromagnetic radiation, and when the energy of the bombarding electrons is high enough, it's radiation in the X-ray area of the electromagnetic spectrum. It is characterized by continuous radiation distribution, which becomes more intense and shifts towards higher frequencies when the energy of bombarding electrons increases. The above curves are from data from 1918 on Ulrey, which bombarded tungsten targets with electrons of four different energies. Bombarding electrons can also explane electrons from the inner shells of metal target atoms, and the rapid filling of these free places by electrons that fall from higher levels leads to sharply defined characteristic X-rays. The content of X-radiation is created by energy from electrons and convert it into photons with suitable energies. This energy transformation takes place in an X-ray tube. The amount (exposure) and quality (spectrum) of radiation produced x can be regulated by adjusting the electrical quantities (KV, MA) and exposure time S applied to the pipe. In this chapter, we first became acquainted with the design and construction of X-ray pipes, then looked at the process of X-ray production and concluded by reviewing the quantitative aspects of X-ray production. CONTENT The X-ray tube is an energy converter. It receives electricity and converts it into two other forms: x-radiation and heat. Heat is an undesirable by-product. X-ray tubes are designed and manufactured to maximize X-ray production and duct heat as quickly as possible. X-ray tube is a fairly simple electrical device, which usually contains two basic elements: cathode and anode. As the electric current flows through the pipe from the cathode to the anode, electrons undergo a loss of energy, leading to the formation of X-rays. The following article shows the cross-section of a typical X-ray tube. The cross-section of the typical X-ray tube Anoda is the component in which X-rays are produced. This is a fairly large piece of metal that connects to the positive side of the electrical circuit. The ante has two basic functions: (1) convert electronic energy to x-rays, and (2) dissipate the heat generated in the process. The material for the anachm is selected to enhance these functions. The ideal situation would be if most electrons created X-ray photons rather than heat. The proportion of total electronic energy that is converted into x-radiation (efficiency) depends on two factors: the atomic number (Z) of the anode material and the energy of electrons. Most pipes use tungsten, which has atomic number 74, as an anachram material. In addition to the high atomic number, tungsten has several other properties that make it suitable for this purpose. Tungsten is almost unique in its ability to maintain its strength at high temperatures and has a high melting point and relatively low evaporation rate. For many years, pure tungsten was used as an anode material. In recent years, tungsten and rhenia alloys have been used as target material, but only for the surface of some anaes. Anode body under the surface of tungsten-rhenium on many tubes is made of a material that is relatively light and has a good heat storage capability. Two such materials are molybdenum and graphite. The use of molybdenum as an anach-based base material should not be confused with its use as an anode surface material. Most X-ray tubes used for mammography have anodes with a molybdenum surface. This material has an intermediate atomic number (Z = 42) that creates characteristic X-ray photons with energies suitable for this particular application. Some mammographic tubes also have a second anachron is made of rhodia, which has the atomic number 45. This creates higher energy and more penetrating radiation that can be used to display dense breasts. The use of rhenium-tungsten alloy improves the long-term radiation performance of pipes. For X-ray tubes with pure tungsten anaesdas, radiation performance is reduced when used due to thermal damage to the surface. Most anades are shaped as beaky discs and attached to the shaft of the electric motor, which rotates them at relatively high speeds during the X-ray manufacturing process. The purpose of turning the anada is to dissipate heat and is considered in detail in another chapter. Not all anodes are involved in X-ray production. Radiation is produced in a very small area on the surface of an anach virus known as a focal point. The dimensions of the focal point are determined by the dimensions of the electron beam coming from the cathode. In most X-ray tubes, the focus is approximately rectangular. The dimensions of focal points usually range from 0.1 mm to 2 mm. X-ray tubes are designed to have specific focal point sizes; small focal spots produce less blur and better visibility of details, and large focal spots have a greater ability to dissimite heat. The size of the focal point is one of the factors to consider when choosing an X-ray tube for a particular application. Tubes with small focal spots are used when high visibility of image details is important, and the amount of radiation required is relatively low due to small and thin body areas, as in mammography. Most X-ray tubes have two focal lengths (small and large) that can be selected by the operator according to the imaging procedure. The basic function of the cathode is the exclusion of from the electrical circuit and focus them on a well-defined anachal-focused beam. A typical cathode consists of a small coil of wire (fiber) embedded in the cup-shaped area, as shown below. Energy exchange within the x-Ray tube electrons, which flow through electrical circuits, can generally not escape from the material of the conductor and move to the open space. However, they can if they are given sufficient energy. In a process known as thermal emissions, thermal energy (or heat) is used to exclude electrons from the cathode. The cathode thread is heated in the same way as the bulb by passing through the current. This heating current is not the same as the current flowing through the X-ray tube (MA), which produces X-rays. During the operation of the tube, the cathode is heated to a blazing temperature and thermal energy displaces some electrons from the cathode. Anode and cathode are contained in an airtight cover or envelope. The envelope and its contents are often referred to as a tubular insert, which is part of a tube that has a limited service life and can be replaced in a housing. Most X-ray tubes have glass envelopes, although the tubes for some applications have metal and ceramic envelopes. The primary functions of the envelope are to provide support and electrical insulation for anode and cathode assemblies and maintain a vacuum in the tube. The presence of gases in the X-ray tube would allow free flow of electricity through the tube, not just in the electron beam. This would interfere with x-ray production and could damage the circuit. The X-ray tube housing provides several functions in addition to closing and supporting other components. It acts as a shield and absorbs radiation, except for radiation that passes through the window as a useful X-ray beam. Its relatively large outer surface dissipates most of the heat generated inside the pipe. The space between the housing and the liner is filled with oil, which provides electrical insulation and transfers heat from the liner to the surface of the housing. CONTENT The energy used by the X-ray tube to create X-rays is supplied by an electrical circuit, as shown below. The circuit connects the pipe with the power source, that in the x-ray room is often referred to as a generator. As described in another chapter, the generator receives electricity from the electrical system and converts it into a suitable form (direct current, which is applied to the X-ray tube). The generator also provides the ability to adjust certain electrical quantities that control the X-ray production process. The three principles of electrical quantities that can be set are: KV (voltage or electrical potential applied to the pipe) MA (current that flows through the tube) S (exposure time or exposure time, usually a fraction of a second) The circuit is actually a circulatory system for electrons. They pick up power as they pass through the generator and transfer their energy to the X-ray tube an anachon as described above. The energy that will be converted into X-rays (and heat) is transferred to the X-ray tube by a stream of flowing electrons, as mentioned above. As electrons pass through the X-ray tube, they undergo two energy conversions, as previously shown: Electricity potential energy is converted into kinetic (motion) energy, which in turn is converted into X-rays and heat. When electrons arrive in an X-ray tube, they transmit electrical potential energy. The amount of energy transmitted by each electron is determined by the voltage or KV between the anode and the cathode. For each kV voltage, each electron has 1 keV energy. By adjusting the KV, x-ray machine operator actually assigns a certain amount of energy for each electron. After the electrons are emitted from the cathode, they come under the influence of an electrical force that pulls them towards the anode. This force accelerates them, causing an increase in speed and kinetic energy. This increase in kinetic energy continues as electrons travel from cathode to anode. As the electron moves from the cathode to the anode, its electrical potential energy decreases because it is transformed into kinetic energy all the time. Just as an electron reaches the surface of an anachm, its potential energy is lost and all its energy is kinetic. At this point, the electron travels at a relatively high speed determined by its actual energy content. The 100-keV electron reaches an anachovie surface that moves at more than half the speed of light. When electrons hit the surface of an anody, they are slowed down very quickly and lose kinetic energy; kinetic energy is converted either to x-radiation or to heat. Electrons interact with individual atoms of material, as shown below. Two types of interactions produce radiation. Interaction with electron shells creates characteristic X-ray photons; interactions with the atomic nucleus produce Bremsstrahlung x-ray photons. Electron-Atom interactions that produce X-Ray photons CONTENT Electrons in an atom each has a certain amount of binding energy that depends on the size (atomic number, Z) of the atom and the shell in which the electron is located. As described in the previous chapter, binding energy is the energy that would be needed to remove an electron from an atom. In fact, it is an energy deficit rather than the amount of energy available. The binding energy of electrons in an atom plays an important role in the x-radiation as described later. The interaction that produces the most photons is the Bremsstrahlung process. Bremsstrahlung is the German word for braking radiation and is a good description of the process. Electrons that penetrate into the anachnial material and pass near the core are skeined and slowed down by attractive force from the core. The energy lost by the electron during this encounter appears in the form of an X-ray photon. Not all electrons create photons of the same energy. Only a few photons are produced, which have energy close to electrons; most of them have lower energy. Although the reason is complex, the simplified bremsstrahlung interaction model is listed below. First, suppose there is a space, or field, surrounding the nucleus in which electrons experience braking forces. This field can be divided into zones, as shown. This gives the nuclear field the appearance of a target with a real core located in the center. An electron that hits anywhere in the target experiences a certain braking effect and produces an X-ray photon. These electrons, which extend closest to the center, are exposed to the greatest force, and therefore lose the most energy and produce photons with the highest energy. Electrons, which are exuded in the outer zones, experience weaker interactions and produce photons with lower energy. Although zones are essentially the same width, they have different areas. The area of the zone depends on its distance from the core. Since the number of electrons that hit a given zone depends on the total area in the zone, it is clear that the outer zones capture more electrons and produce more photons. From this model, x-ray energy spectrum can be predicted, such as the following. Model for bremsstrahlung production and associated photon energy spectrum The basic spectrum of Bremsstrahlung has maximum photon energy that corresponds to the energy of incident electrons. This is 70 keV for the example above. Below this point, the number of photons produced increases with a decrease in photon energy. The spectrum of X-rays emerging from the tube generally looks quite different from the one shown here due to selective absorption in the filter. A significant number of lower energy photons are absorbed or filtered out when they attempt to pass through the anade surface, x-ray tube window or added filter material. X-ray filtering of the beam is discussed in more detail in a later chapter. The amount of filtration is generally dependent on the composition and thickness of the material through which the X-ray beam passes, and is generally what determines the shape of the low-energy end of the spectrum curve. The high-energy end of the spectrum is determined by the KV (kiloload) applied to the X-ray tube. This is because the GOV electron energy as soon as they reach the anachage, and no X-ray photon can be generated with energy greater than that of electrons. The maximum photon energy in keV is therefore numerically equal to the maximum potential used in kV (kilovolches). For some X-ray equipment, the voltage acting on the tube may vary during exposure due to the cycle of the nature of the AC electrical system. . The maximum photon energy is determined by the maximum or peak voltage during the voltage cycle. This value is commonly referred to as kilovolt peak (KVP) and is one of the adjustable factors of the X-ray device. In addition to determining the maximum X-ray photon energy, KVP has an important role to play in determining the amount of radiation produced for a given number of electrons, such as 1 mA, that interfere with the anachnode. Since the general efficiency of X-ray production by the Bremsstrahlung process is increased by increasing the energy of bombarding electrons and electronic energy is determined by the KVP, it follows that the KVP affects the efficiency of X-ray production. Changing the KVP generally changes the Bremsstrahlung spectrum, as shown below. The total area below the spectrum curve represents the number of photons or the amount of radiation produced. If filtration is not present where the spectrum is essentially a triangle, the amount of radiation produced is approximately proportional to the quadratic KV. However, with the presence of filtration, the increase in KV also increases the relative penetration of photons, and a smaller percentage is filtered out. This results in an even greater increase in radiation performance with KVP. Comparison of photon energy spectra Produced as different values of KVP The type of interaction that produces characteristic radiation, also illustrated above (in paragraph Kinetic), involves a collision between high-speed electrons and orbital electrons in an atom. Interaction can occur only if the incoming electron has kinetic energy greater than the binding energy of the electron in the atom. When this state exists and a collision occurs, the electron is released from the atom. When the orbital electron is removed, it leaves a free space that is filled with an electron from a higher energy level. As the filling electron moves down to fill the vacancy, it gives up the energy emitted in the form of an X-ray photon. It is known as characteristic radiation because the energy of the photon is characteristic of the chemical element that serves as an anode material. In the example given, the electron releases a tungsten k-shell electron that has a saging energy of 69.5 keV. The free space is occupied by an electron from the l shell, which has a saging energy of 10.2 keV. The characteristic X-ray photon therefore has an energy equal to the energy difference these two levels, or 59.3 keV. In fact, the given anode material leads to several characteristic X-ray energies. This is because electrons at different energy levels (K, L, etc.) can be released by bombarding electrons, and vacancies can be occupied from different energy levels. Electronic energy levels in tungsten are listed below, along with some energy changes that lead to characteristic photons. Although filling L-shell vacancies generates photons, their energies are too low for use in diagnostic imaging. Each characteristic energy is indicated by a marking that indicates the shell in which the free space occurred, with a lower index showing the origin of the filling electron. The lower alpha index (a) indicates the filling with the l-shell electron, and beta ((3) indicates filling from the M or N shell. The spectrum of significant characteristic radiation from tungsten is shown below. Characteristic radiation creates a liner spectrum with several discrete energies, while Bremsstrahlung produces a continuous spectrum of photon energies to a certain extent. The number of photons created at each characteristic energy varies because the probability of filling the free space of the K-shell varies from shell to shell. The energy levels of electrons in tungsten and the associated characteristic X-ray spectrum of molybdenum anachnode tubes used for mammography produce two fairly intense characteristic X-ray energies: K-alpha radiation, at 17.9 keV, and K-beta, at 19.5 keV. as shown below. The optimal spectrum for achieving the best balance between contrast sensitivity and radiation dose for the average breast size is one with most radiation with photon energies less than about 20 keV. However, there is considerable Bremsstrahlung over this energy. In a typical mammographic device, a molybdenum filter is used to remove this unwanted part of the spectrum. This is a filter application that operates on the K edge principle. It absorbs radiation that is above the energy of K-edge, which corresponds to the binding energy of electrons in the shell K of the molybdenum atom. CONTENT Rhodium has an atomic number (Z) of 45 compared to Z 42 for molybdenum. Therefore, the characteristic X-rays produced with anode rhodium will have energies that are slightly higher than those produced with molybdenum and are more penetrating. It has a value for displaying dense breasts. Anodes, which have dual surface areas, molybdenum and rhodium, allow the operator to select a spectrum that is optimized for different breast sizes and densities. The KV value also strongly affects the formation of characteristic radiation. No characteristic radiation will be produced if the KV is smaller (numerically) than the binding energy of k-shell electrons. When the GOV rises above this threshold the amount of characteristic radiation is generally proportional to the difference between the operating GOV and the GOV threshold. The X-ray beam that comes out of the tube has a spectrum of photon energies determined by several factors. The typical spectrum is shown below and consists of photons from both Bremsstrahlung and characteristic interactions. Typical photon energy spectrum from a machine operating at KV = 80 Relative composition of the X-ray spectrum with respect to Bremsstrahlung and characteristic radiation depends on the anachv material of the KV and filtration. No characteristic radiation is emitted in the tungsten anachnode tube if the KV is less than 69,5. With some higher KV values, which are usually used in diagnostic examinations, characteristic radiation can contribute up to 25% of total radiation. In the target tubes of molybdenum operated under certain KV conditions and filtration, characteristic radiation may be a major part of the total power. Only a small part of the energy supplied to the electron anada is converted into x-radiation; most are absorbed by the anachno and converted into heat. The efficiency of X-ray production is defined as the total X-ray energy expressed as a fraction of the total electricity overdosed to the anadode. The two factors that determine the production efficiency are the voltage applied to the pipe, KV and atomic number of the Z anada. Approximate relationship is Efficiency = KV x Z x 10-6. The relationship between the efficiency of X-ray production and KV has a specific effect on the practical use of X-ray equipment. As we will see in the later chapter, X-ray tubes have a certain limit on the amount of electricity that can dissipate due to the heat produced. This basically limits the amount of X-rays that can be produced by an X-ray tube. However, by increasing the GOV, the amount of radiation emitted per unit of heat increases significantly. The relationship of the effectiveness of X-ray production to an anode material is only academic, since most tubes use tungsten. An exception is molybdenum and rhodium used in mammography. The efficiency of X-ray production of these tubes is significantly lower than that of tungsten anachor tubes due to their lower atomic numbers. X-ray efficiency of the X-ray tube is defined as the amount of exposure in milliroentgens delivered to the point at the center of a useful X-ray at a distance of 1 m from the focus for 1 mA of electrons passing through the tube. The efficiency value indicates the tube's ability to convert electronic energy into X-ray exposure. Knowledge of the efficacy value for a given tube makes it possible to determine the patient's exposure to both image receptors by the methods described in later chapters. As well as X-ray energy performance, tube efficiency on many factors, including KV, stress course, anode material, filtration, tube age and anachic surface damage. The figure below shows typical efficiency values for tungsten anachal tubes with normal filtration. KV is very useful in controlling the radiation output of the X-ray tube. The following illustration shows a nonlinear relationship. It is usually assumed that the radiation output is proportional to the squares of the KV. Doubling the KV quadruples the exposure from the tube. Typical X-ray tube efficiency (Exposure output) for different KVP values The course describes how the KV changes with time during the X-ray production process due to the cyclic nature of the power supply. uses several different KV waveforms. The general principle is that the course with the smallest variation of KV during exposure is the most effective X-ray manufacturer. Most new X-ray equipment now uses generators that produce relatively constant KV throughout the exposure period. Further progressions are described in more detail in another chapter. Content