Monte-Carlo Simulation to Compare the Absorption Capacity of Different Substances for X-ray

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Abstract: A shield that effectively absorbs X-rays is used to avoid injuries caused by X-rays. The shielding principle of the shielding material against radiation is based on the absorption of ionizing radiation by the contained absorbing substance. The different absorption capacity of different substances for ionizing radiation mainly depends on the atomic number of the absorbing substance. The larger the atomic number of the substance, the better its ability to absorb radiation, so Pb is often used as a shielding protection material. In this paper, the MCNP5 Monte-Carlo is used to simulate the interaction between X-rays and different substances, and the shielding performance of different substances and the relationship between X-ray energy and the absorption capacity of the substance are compared.

Keywords: MCNP5X-,ray, Shielding Material

1.Introduction

In the medical X-ray radiological diagnosis and radiotherapy, in order to protect the health of the public and staff, according to different radiation protection purposes, X-ray shielding protective materials (referred to as protective materials for short) of different materials and different thicknesses are often used [1]. Therefore, research on X-ray shielding protective materials of different materials and different thicknesses becomes more and more important. Finding laws and methods through research has a huge effect on the development of new shielding materials. The Monte Carlo Method Calculation Program (MCNP) is a large-scale multifunctional Monte Carlo neutron, photon and electron coupling transport program developed by the Los Alamos laboratory in the United States. With the development of computer technology, the version of MCNP has also been improved and developed. Commonly used transport models are: only neutrons, only photons, only electrons, photon-neutrons (photons are generated by neutron interaction), neutron-photon, electron-photon [2]. This article is to establish a model through MCNP5 to study the absorption characteristics of substances with different atomic numbers to X-rays, and the shielding laws of shielding materials with different thicknesses to X-rays.

2.Materials and Methods

Figure 1, Three effects of the interaction between rays and matter
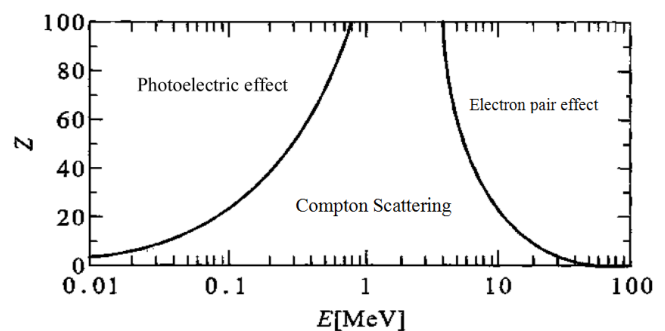
The interaction between matter and rays produces the three effects shown above: electron pair effect, Compton scattering, and photoelectric effect. The principle of radiation shielding is mainly based on these three effects. The main objects of radiation shielding are photons and neutrons. When the photon passes through the shield, it mainly passes through the photoelectric effect, Compton scattering, and electron pair formation to transfer energy to the shield and is reduced or absorbed. The photoelectric effect is that photons transfer all their energy to the orbital electrons, causing the electrons to detach from their shells and be released from the atoms. This plays a major role in the absorption of low-energy photons (photons with energy less than a few hundred keV). Compton scattering is the collision of photons and free electrons, transferring part of the energy to the electrons, while changing their direction and energy, which plays a major role in reducing the energy of intermediate-energy photons (energy between hundreds of keV and MeV). Electron pair formation is the action of the electric field between

the photon and the nucleus. The photon is completely obliterated. Its energy is converted into the mass and kinetic energy of a pair of positive and negative electrons and the kinetic energy of the recoil nucleus[3]. For different atomic numbers, the probability of electron pair effect, Compton scattering and photoelectric effect are different. The substance with larger atomic number interacts with the ray to produce electron pair effect and photoelectric effect, and the atomic number is smaller. The main matter is the Compton scattering.

The single energy X-ray intensity of I_0 X-rays is perpendicular to the flat absorber of thickness d,and its intensity decreases exponentially when passing through the absorber, namely:

$$I=I_0e^{-\mu_1 d}$$

Where μ_1 is the attenuation coefficient and I / I_0 is the X-ray transmittance. The transmittance increases with increasing X-ray energy and decreases with increasing absorber thickness. Experiments show that the absorption coefficient depends on the energy of the X-ray, the atomic number Z and the density p of the absorber material. For example, the atomic number Z of lead is large, the density p is high, and its ray transmittance is lower than steel and aluminum of the same thickness [4]. It can be seen that the attenuation coefficient of the shielding material to a certain energy ray reflects the shielding effect of this material on this energy ray.

Figure 2 Schematic diagram of Monte Carlo simulation

Establish the model according to the principle above, set the single energy X-ray source, absorption material and recording surface of the recording particles. Experiment 1: Set the photon energy to 200keV, and record the probability of the number of photons reaching the recording surface through different materials and different thicknesses. Experiment 2: Set different photon energies as 300keV, 250keV, 200keV, 180keV, 150keV, 120keV, 100keV, 90keV, 70keV, 50keV and 30keV, and the probability of photon number reaching the recording surface through different materials of 0.1mm.

3. Experimental data results and analysis

Figure 3 Probability relationship between different thickness materials and photon number
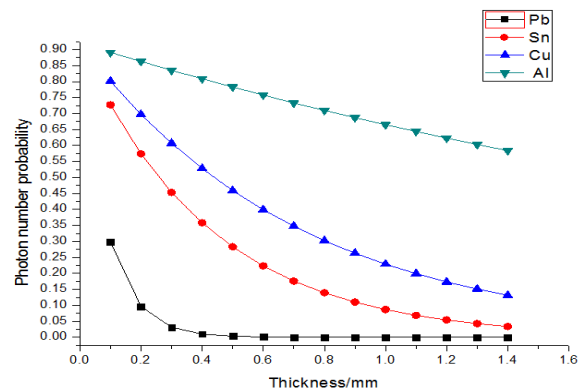
The above diagram is based on the photon energy of 200keV. As the thickness of different materials increases, the absorbed particles increase, and the probability of the number of photons reaching the recording surface decreases. From the figure, it is found that the Pb plate with the highest atomic number drops the fastest. For medium-energy photons, substances with a higher atomic number are more likely to suffer from Compton scattering and therefore absorb photons more easily. The larger the atomic number, the stronger the X-ray absorption capacity, Pb> Sn> Cu> Al.

Therefore, when choosing a shielding material, a material with a higher atomic number can be used as a good shielding material.

Figure 4 Probability relationship between photons of different energy and photon number
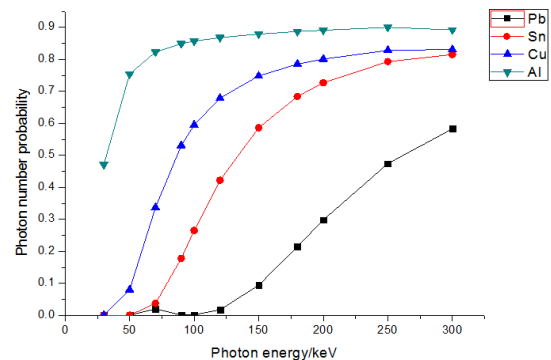
As the photon energy continues to increase, the photon transmittance also gradually increases. In the energy range of 50keV to 120KeV, the absorption capacity of the Pb material does not change much with the increase of X-ray energy, and other substances gradually increase with the increase of the photon energy. The main reason for the change is that the attenuation coefficient of the material changes with the photon energy.

Substance absorption of rays is essentially achieved by the interaction of rays and substances. Single-energy X-ray attenuation is not only closely related to atomic number and density, but also related to material thickness and X-ray energy. For the selection of shielding materials, many factors need to be considered, such as shielding functionality, thickness, weight, structural performance, solderability, thermal stability, etc. Radiation protection requires more and more comprehensive physical and mechanical properties of shielding materials, and the requirements for optimal design of shielding materials and integration of structure and function become more and more important.

References

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