Performance Analysis and Function Simulation of Protective Clothing Exposed to Electromagnetic Radiation

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Abstract: Based on performance analysis of clothing exposed to electromagnetic radiation, a electromagnetic model for abdominal cavity of human body is established using electromagnetic simulation software (Ansoft HFSS). This can be applied to simulate the specific absorption rate (SAR) of the abdominal cavity under irradiation of electromagnetic waves. The SAR of the abdominal cavity with or without protective clothing and with different clothing has been compared. The differences in electromagnetic protective performance between clothing made of these materials are also discussed. The results show that the SAR of the abdominal cavity is larger when the radiation source frequency increases over a range of 300MHz to 900MHz .While at the same frequency of radiation sources, the protective performance of different clothing materials is related to their electrical characteristic parameters and protection patterns. Also simply using the shielding effectiveness (SE) of clothing materials to illustrate the protective performance of clothing is relatively unilateral. Visualization of the electromagnetic protective performance of clothing can be preliminary achieved. The results of this research can also be applied to improve the electromagnetic protective performance of clothing in the process of design and manufacture to ensure health and safety of the people.

Keywords: Electromagnetic radiation; clothing, protective performance, SE, SAR, HFSS.

1. Introduction

Mobile phones, computers, microwave ovens and other electronic products have become increasingly popular, which have not only brought convenience to the people's lives and work, but also a certain degree of damage to mankind. The electromagnetic radiation generated by these electronic products is invisible, colorless and tasteless, which can penetrate the human body. If the human body is exposed to the electromagnetic radiation beyond the safe radiation dose for long time, human cells will be destructed or killed in large amounts and consequently affect the health of people. When having contact with these electronic products, shielding measures should be taken to decrease the effect of electromagnetic radiation. For a human body in motion, the best way is to wear electromagnetic shielding clothing. Thus, the research and developmentof fabrics and clothing for protection from electromagnetic radiation has become an increasingly important topic. However, there is still not any standard method to evaluate the protective performance of clothing for electromagnetic radiation. The shielding effectiveness of clothing materials is usually used to simply evaluate the protective effectiveness of clothing made of these materials, which is relatively one-sided. So based on protective performance analysis of clothing for electromagnetic radiation, the electromagnetic simulation software is used to analyze the damage due to electromagnetic radiation at different frequencies on the human body. Thus simulate the protective performance of clothing when exposed to electromagnetic radiation.

2. Performance analysis and description of clothing for electromagnetic radiation

2.1 Performance analysis of clothing for electromagnetic radiation

Performance analysis of protective clothing when exposed to electromagnetic radiation is mainly based on the fact that the electromagnetic waves generate reflection, absorption and multiple reflections inside the clothing when passing through them, eventually leading to the energy attenuation of electromagnetic waves, as shown in Figure 1. The electromagnetic wave will produce reflection when reaching the surface of clothing. This is because the wave impedance of electromagnetic wave Z_1 (the ratio of the electric field intensity and magnetic field intensity at a certain point) and that of clothing Z_2 (the resistance of clothing) are

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not equal. If the difference between Z_1 and Z_2 is greater, the energy loss of electromagnetic wave will be larger. Actually, clothing has a certain thickness, so the multiple reflections had occurred after electromagnetic wave enters into the clothing [1].

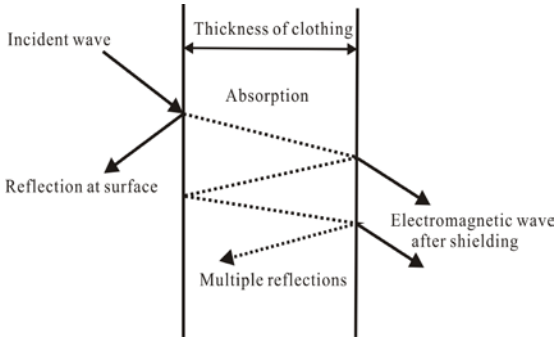

Figure 1 Attenuation of the incident electromagnetic wave by the clothing.

According to the theory of radiation in physics, the electromagnetic field intensity decays exponentially with the depth of the distance (the thickness of clothing) when the electromagnetic wave enters into a medium, as it can induce the eddy current into the medium, and the eddy current produces heat loss through the resistance of the medium, as shown in Figure 2.

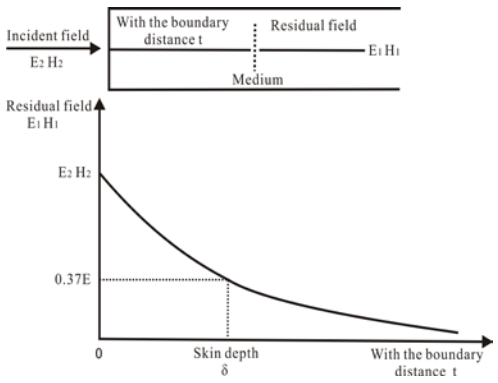

Figure 2 Exponential decay of the electromagnetic wave in clothing.

This is the absorption loss of electromagnetic wave while penetrating into the clothing. The electromagnetic field strength after attenuation can be expressed as $E_1 = E_2 e^{-t/\delta}$, $H_1 = H_2 e^{-t/\delta}$ where t is the thickness of clothing, and δ is the skin depth.

Whether the protective performance of clothing when exposed to electromagnetic radiation is good or bad, is mainly reflected by the factors such as clothing materials and structures. The metal types and content of clothing materials, as well as the distribution of metals in materials affect the shielding effectiveness of materials. Thus directly affect the shielding effectiveness of clothing made of these materials. In addition, clothing materials when being made into clothing also need to meet the wearing needs of human body, so there are a lot of openings and gaps in clothing. These gaps such as zippers and seams will cause electromagnetic radiation leakage, resulting in the decrease of protective performance of clothing, especially in case of pregnant women who wear relatively large clothing. Because of the large bottom opening, the electromagnetic wave can easily enter the human body throughit, which will greatly affect the overall shielding effectiveness of protective clothing. Based on the above analysis, the electromagnetic simulation software is applied to simulate the electromagnetic protective performance of clothing made of different clothing materials.

2.2 Description of the electromagnetic shielding effectiveness

The specific absorption rate and shielding effectiveness are usually used to measure the electromagnetic shielding effectiveness. The definitions of these two parameters are described as follows:

1) The specific absorption rate

The specific absorption rate (SAR) is defined as the electromagnetic power absorbed by human tissues per unit mass [W / kg].

$$\mathrm{SAR} = \frac{\mathrm{P}}{\mathrm{M}},\ \mathrm{P} = \mathrm{A} \times \mathrm{S} \tag{1}$$

Where M is the quality of human tissues under irradiation of the electromagnetic wave [kg]; P is the electromagnetic power absorbed by M kg human tissues [W]; A is the effective cross-sectional area of electromagnetic radiation absorbed by human body [m^2]; S is the power density of incident electromagnetic field [W/m^2].

2) The shielding effectiveness

The shielding effectiveness (SE) is defined as the ratio of power received with and without a material present for the same incident power, and it is calculated by the following equation:

$$\begin{aligned} SE &= 20Lg(E_2 / E_1) = 20Lg(H_2 / H_1) \\ &= 10Lg(W_2 / W_1), [decibels, dB] \end{aligned} \tag{2}$$