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RECENT DEVELOPMENTS IN EMI SHIELDING BASED ON TEXTILE AND FLEXIBLE MATERIALS

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Abstract: *In today's interconnected, world we use many electronic devices. In order to provide dependable and functional devices, electromagnetic shielding devices are crucial. Electromagnetic interference (EMI) has become a major issue, leading to circuit issues caused by signal noise, data loss, malfunctions, and even potential health dangers. The current advancements in electromagnetic shielding devices are the main topic of this essay, with an emphasis on new solutions. An overview of EMI shielding screens with an emphasis on domain development is given in this paper. The creation of bending EMI shielding is one way that textile materials affect the EMI properties.*

Key words: *screens, interference, efficiency, fabrics, coefficients*

1. INTRODUCTION

With the rapid development of wireless communication technology and the continuous development of smart exchange products, it has been found that the increase in electromagnetic waves can reach up to 10% in limited frequencies and spaces. The health effects are numerous including high blood pressure, heart disease, pregnancy complications, increased risk of immune deficiencies, headaches, physiological disorders and other health problems. Electromagnetic radiation is an important perturbation factor. It is known that electromagnetic waves propagate from the radiation source, the electric and magnetic fields interconnecting perpendicular in space, creating waves of particles coupled for propagation. Protection against electromagnetic radiation can be addressed through shielding, remote protection and control of the radiation source.

Shielding instruments and people against electromagnetic interference (EMI) has become increasingly important in recent decades, due to the growing number of electric cars and devices that radiate electromagnetic waves. Textile fabrics as a general category, can have these properties, combined with potentially good mechanical properties, depending on the textile structure and the material chosen. On the other hand, the necessary electrical properties, especially conductivity and magnetic properties, cannot be taken for granted in ordinary textile fabrics.

Electromagnetic interference (EMI) shielding materials are known to be able to protect people, instruments, etc. from electromagnetic radiation (EM) by absorbing or reflecting radiation, often combining both. EM shielding is used to minimize exposure to electromagnetic radiation.

EMI shielding must be distinct from magnetic shielding. Magnetic shielding refers to low frequencies (50 or 60 Hz). Radio waves and microwaves emitted by electronic devices operate in radio and mobile wave frequencies. Since today there are many electronic devices that interfere, the research of EMI shielding materials has increased greatly in recent times [1].

2. GENERAL INFORMATION

By either absorbing or reflecting radiation—often a combination of both—electromagnetic interference (EMI) shielding materials are known to be able to protect people, equipment, etc. from electromagnetic (EM) radiation shielding

The investigation of electromagnetic interference shielding, EMI, for different materials is done according to Figure 1: open field methods, coaxial transmission line methods (according to the ASTM D4935 standard, can be applied in different frequency ranges and require different amounts of time and equipment), armored box methods and armored camera methods.

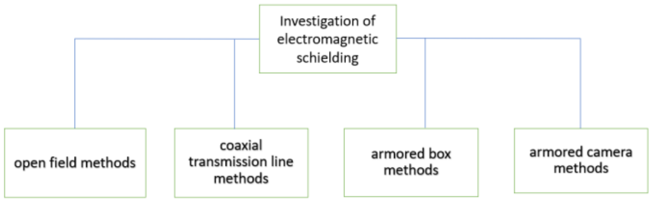

Figure 1. Methods for investigating electromagnetic schielding

By measuring the radiated emissions which emanates from a final product, the open-field or free-space approach assesses the practical efficacy of shielding a whole electronic assembly. Due to changes in how each finished product is assembled, the test is highly variable and does not assess the performance of any particular material.

Another method used is the shielded box method. This method is comparative and is used in measurement on different shielding materials. The test essentially consists of a metal case and an electrically sealed joint. The joint has a receiving antenna placed on the outside of the box that is used to measure the strength of the received signals, both through the open hole and through a sample mounted over the hole.

The disadvantage of this method is that it is difficult to achieve adequate electrical contact between the test samples and the shielded box. The other problem is the limited frequency range of about 500 MHz. Currently, the results obtained experimentally with this method show a weak correlation. The method of the coaxial chamber is similar from an ideal/principled point of view to the shielding box method. The coaxial transmission line method for measuring shielding effectiveness is a preferred method to be used nowadays, being more efficient than the previous two. The main advantage of this technique is that the results obtained in different laboratories are comparable. In addition, the coaxial transmission line can also be used to break down data into reflected, absorbed and transmitted components.

In particular, coaxial transmission line methods can be applied in different frequency ranges and require different amounts of time and equipment. A more detailed discussion of the effect of these physical properties on EMI protection and measurements can be found in [2].

EMI protection is one of the deeply investigated topics in the field of smart textiles. The necessary physical properties, such as electrical and/or magnetic conductivity, can be added to common textile fabrics through layers with conductive polymers, carbon-based or metal-based layers. As it results from the review of the papers published in the article, it is found that several approaches can be used to achieve a high efficiency of EMI shielding, measured both in the X-band, technologically relevant and in other frequency ranges.

The calculation of the electromagnetic efficiency of screens is based in the above article on Skelkunoff's theory [3]. Textiles, as low-cost substrates, are known to offer advantages such as cutability, comfort, breathability and ease of processing, making them suitable for flexible wearable electromagnetic protection. In the progress of research on textile-based electromagnetic protective materials is analyzed, providing references for their application.

Electromagnetic waves are known to propagate from the radiation source, with electric and magnetic fields interconnecting perpendicularly in space, creating waves of particles coupled for propagation. Electromagnetic shielding mechanisms can be divided into electromagnetic field shielding, magnetic field shielding, and electrostatic field shielding. In practice, electromagnetic shielding mainly refers to shielding the electromagnetic field.

Metallic or non-metallic materials with electromagnetic protection properties generally have a high initial modulus and stiffness, which makes them difficult to use in this field. By converting these materials into fibers and mixing them with conventional textile fibers, it is possible to meet the efficiency requirements of the electromagnetic screen while improving textile substrates. The conductive network formed by the mutual conduction of the electromagnetic protection fibers inside the fabric improves its shielding performance.

The efficiency of shielding increases with the content of stainless-steel fibers per unit area up to a certain point, beyond which it decreases. Two theories — small pore coupling and pore transmission — try to explain this, but no consensus has been reached. Some researchers conclude that when the fiber content of stainless steel is between 20% and 30%, the blended material achieves a protective efficacy of 30-40 dB, balancing the protection and the fabric [4].

Today, the commercialization of electromagnetic protective fabrics made of stainless-steel fibers has had some success, with positive feedback in the market. In [5] shielding effectiveness is defined as the ratio of impact to energy to residual energy. When an electromagnetic wave passes through a screen, absorption and reflection occurs. The residual energy is part of the remaining energy, which is neither reflected nor absorbed by the shield, but is removed from the shield. All electromagnetic waves are made up of two essential components, a magnetic field (H) and an electric field (E) as shown in Figure 4. These two fields are perpendicular to each other, and the direction of propagation of the wave is perpendicular to the plane containing the two components.

The efficiency of shielding is defined using the terms before and after attenuation is given in equations (1) and (2), with transversal and incident/longitudinal components.

$$SE = 20\lg\left(\frac{E_t}{E_i}\right) \tag{1}$$

$$SE = 20\lg\left(\frac{H_t}{H_i}\right) \tag{2}$$

The paper [6] also presents a literature study on EMI shielding on graphite fibers, thermoplastics, intrinsically conductive polymers, etc. The paper concludes that polymers based on polyaniline, polypyrol are important candidates for shielding electromagnetic interference due to their lightweight, non-corrosive nature and commercial viability.

The attenuation of an electromagnetic wave is achieved by: Absorption (A), Reflection (R), Multiple reflections (B) and the shielding effectiveness is calculated with equation (3):

$$SE = \frac{1}{4}A + \frac{3}{4}R + \frac{3}{4}B \quad (3)$$

where SE – shielding efficiency
A – absorption coefficient
R – coefficient of reflection
B – coefficient of multiple reflections

Several materials used for electromagnetic screens are reviewed. Carbon-based shielding materials suffer from limited mechanical flexibility. Metal-based shielding materials face high weight, corrosion, and difficulties in adjusting shielding efficiency. Therefore, the organic polymers represent the most attractive candidates for EMI shielding due to their ease, non-corrosive nature, and commercial viability.

3. DEVELOPMENTS IN EMI SHIELDING

In [7], the shielding of the electromagnetic field is done to protect human health and ensure the immunity of electronic equipment, in the context of the accelerated development of telecommunications. The shielding solutions offered by textile materials were studied, in order to support economic agents in the production of competitive products. A mathematical model was used to predict the electromagnetic attenuation of an enclosure covered in fabric, which is characterized according to its geometric and electrical parameters. Thus, according to the principles of electromagnetic compatibility (EMC), radiation shielding is one of the solutions for ensuring the health of living beings and the immunity of electronic equipment. Adolf Schwab concludes that conductive textiles can be used as protective curtains, screens, tents and other construction elements, to shield electromagnetic radiation and ensure the maintenance of human health along with ensuring the electromagnetic compatibility of the operation of electronic equipment.

Using a shielding efficiency approximation relationship proposed by Heinreich Kaiden [8], it has been processed according to the circuit method to describe the shielding produced by conductive lattice structures, and is therefore applicable to structures woven with conductive wires. It represents a "mechanical" mathematical model, unlike previous research carried out with phenomenological mathematical models. In order to obtain the desired shielding properties for textile fabrics, conductive wires made of ferromagnetic (stainless steel – Fe) and diamagnetic (Ag) materials were introduced into the weft system of the fabrics.

The shielding effectiveness of a housing for the near-field electromagnetic spectrum is studied [9]. An analytical relationship for the effectiveness of shielding, taking into account both the geometric and electrical aspects in which the parameters of the conductive fabric were simplified by the authors was proposed, and a validation study was also carried out. Calculations based on the proposed simplified relationship are possible to obtain an optimization between the fabric processing capacity, costs and targeted shielding effectiveness. The frequency range proposed for testing is limited by the near electromagnetic field conditions, on the one hand, and by the resonance conditions specified by the IEEE 299.1 standard, at 1 MHz - 20 MHz. The experimental results show lower values for shielding effectiveness than the analytical values, which depends on: because the electrical continuity at the edges of the cube is only partially ensured, and the analytical relationship represents an ideal model, very difficult to reproduce with physical equipment. The experimental arrangement and the applied procedure are useful primarily to compare the characteristics of different fabrics. The simplified analytical relationship provides a good approximation for the analytical relationship in the literature for the specified frequency range and supports the calculation of the distance between the conductive wires in relation to the targeted shielding effectiveness. Thus, an important question

regarding the necessary distance between the conductive grid for textile fabrics and its raw material could be answered. A parametric study for the distance between conductive weft wires shows that the denser the conductive wires, the better the shielding effectiveness of the near electromagnetic field. Calculations based on the proposed simplified relationship are possible, in order to achieve an optimization between the fabric processing capacity, costs and the targeted shielding effectiveness.
Conductive polymers are a solution for textiles to shield against electromagnetic interference. Such compounds may have metallic conductivity or can be semiconductors.

In [10] textiles for electromagnetic shielding (EMI) made with conductive polymers are treated. These materials are important for the protection of humans and electronic devices against electromagnetic radiation. It is known that most textiles should have protective properties, properties of reflecting incident electromagnetic radiation (EMR), without being able to absorb it. Normally, natural fibers do not have shielding properties against electromagnetic radiation. To allow the shielding of the electromagnetic field, textiles must have conductive properties. This can be implemented if the textiles have electroconductive properties and are achieved by: surface changes of the fibers or textiles made of such fibers and by changes in the volume of the fibers themselves (in the case of artificial fibers) in their formation stage (spinning).

As the development of miniature electronics is constantly expanding, there is also a need for transparent and flexible materials that provide EMI protection, especially for: windows, touch screens, displays, aerospace and military applications. In [11] 4 major classes of materials are analyzed: thin films (oxides, metals, metal-dielectric structures) with example of TiO_2-Ag, nanocarbon-based materials with example of graphene multilayer structures, conductive polymers with example of polyaniline and metallic nanowires with example of nanowire networks deposited on metallic structures. The paper concludes that most current solutions rely on increased conductivity, which leads to reflection shielding. In the current context, a major challenge remains the balance between transparency, flexibility and shielding efficiency.

The increase in the use of wireless technologies (including 4G, more recently 5G) has led to an increase in electromagnetic radiation, which can affect both the operation of electronic equipment and human health. Textiles are investigated as lightweight, flexible and cost-effective solutions for EMI (Electromagnetic Interference) protection.

Like electromagnetic shielding mechanisms there are three main mechanisms: loss by reflection – waves are reflected due to the conductivity of the material; dielectric loss – electromagnetic energy is transformed into heat by polarization processes; Magnetic loss – magnetic materials absorb wave energy through magnetic resonances. Schelkunoff's theory, used to characterize shielding efficiency, is also discussed [12].

3. CONCLUSIONS

EMI-protected fabrics need a certain set of characteristics. These are required in many scientific domains as well as in the defense sector. The intended shielding in a variety of applications will result from new advancements and ongoing research in this area. In order to promote the development of the area, this study provides a thorough but non-exhaustive survey of materials for EMI shielding. Due to the need for wearable devices and 4G/5G, textiles for EMI shielding are changing quickly. Therefore, the main trends are enhanced production processes, hybrid materials, and nanocomposites. Long-term durability, washing stability, and environmental impact are still unknowns. Multifunctional fabrics that can combine EMI shielding with additional features (thermoregulation, sensors, energy capture) are anticipated to be the way of the future. The coupling of signals from one system to another is known as electromagnetic interference (EMI). It is an issue for the majority of electronics because it can lower circuit performance or even lead to circuit failure. Specific shielding efficiency (SSE), which is defined as shielding efficacy per unit weight/thickness, is becoming the focus of modern materials. The electronics could malfunction due to interference. Shielding materials for radiation sources and electronics are becoming more and more necessary as radio and microwave wave devices proliferate. As a result, during the past 20 years, research into the creation of EMI shielding materials has grown significantly.

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