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A Research on the Use of Copper Core Yarns in Electromagnetic Shielding Application

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Abstract

In this work, possibilities for producing textile materials with copper core cotton yarns for the purpose of electromagnetic shielding were studied. Cu/Co core yarns were produced by using copper filaments as core material with two different diameters (0.05 and 0.07mm) and cotton as sheath material. All core yarns are produced in Ne 8 yarn count. Conductive Cu/Co yarns were integrated in to 3/1 twill woven fabric structure in the weft direction with 5 different weft densities (8, 13, 18, 23 and 28 per cm). According to the TS EN 50147-1 standard, the shielding effectiveness of these fabrics was measured in the frequency range 1 GHz – 6 GHz. The results have shown that EMSE of fabrics can be tailored by changing the weft density, core filament fineness and wave frequency parameters.

Keywords: Electromagnetic shielding textiles, Copper core yarns, Conductive woven fabrics.

1. Introduction

With technological progresses, electrical and electronic devices have reached a more important position in our daily life. The use of these devices makes our life easier but at same time they cause an important environmental pollution since they emit electromagnetic waves to their surroundings while they are working. Electromagnetic waves have harmful effects for both sensitive electronic equipment and also for human health. Electrical devices interfere with other electrical and electronic devices in that they generate the electromagnetic field. This interference may cause malfunctioning of other sensitive electronic devices, when specific limit is exceeded [1].

If an electromagnetic wave gets into an organism, it vibrates molecules to spread heat. In the same way, when an electromagnetic wave enters the human body, it will hinder a cell’s regeneration of DNA and RNA. Moreover, it causes abnormal chemical activities to produce cancer cells [2].
Protection from electromagnetic waves is very significant because of these reasons. Shielding is one of the most efficient solutions for protection from electromagnetic waves. Electromagnetic shielding can be defined as prevention of electromagnetic radiation transmission by a material [1].

There are some previous studies conducted on this topic. Su and Chern, (2004), used stainless steel as a conductive filler to produce core, cover and plied yarns to make different types of woven fabrics. The electromagnetic shielding effectiveness (EMSE) of these fabrics was measured by coaxial transmission equipment. Electromagnetic frequencies range from 9KHz to 3GHz. The experimental results showed that a denser fabric structure had a higher EMSE. In respect to the influence of yarn structure, a fabric made from the core yarn has a higher EMSE than fabrics made from cover or plied yarn [2].

Cheng et al., (2006), produced twill copper fabrics (3/1) and studied the effects of varying weft density, warp density, wire diameter and lay-up angle on EMSE. They used a coaxial transmission line holder in the frequency range of 144- 3000 MHz. With an increase in the number of conductive fabric layers, warp and weft density, an increase in shielding effectiveness was observed, while with an increase in wire diameter, a decrease in shielding effectiveness occurred [3].

Das et al., (2009), studied the effect of material type, yarn count, pick density, type of mordant and layers of fabrics on the EMS properties of textile materials. The shielding effectiveness of the fabric was measured by estimating the insertion loss incurred to the signal when the sample is placed in the path of the signal at the frequency range 100 MHz- 3 GHz inside the coaxial transmission holder. They stated that there are some effects of type of material, yarn count, number of fabric layers and type of mordant on EMSE whereas, the number of apertures and thread density do not have significant effect on EMSE, particularly in case of metallic sheets [4].

Duran and Kadoglu, (2015), studied woven fabrics, produced with two different types of conductive yarns, namely silver containing (Ag/PA,Co) core yarns and silver-containing (Ag/PA-Co) blended yarns. The effect of various yarn and fabric properties on EMSE was investigated. They obtained results that the shielding effectiveness can be tailored by changing the yarn and fabric parameters and also there are significant differences between the electromagnetic shielding characteristics and performances of the fabrics produced with different types of yarns. Such fabrics are convenient for both daily and professional uses, since they have both high EMSE performance and comfort properties [5].

2. Material and Method

2.1. Production

Yarn production was carried out on a ring spinning machine. Copper core cotton yarns (Cu/Co) were produced by using copper filaments as core material and cotton as sheath material. A core yarn apparatus was used in the machine for feed the conductive filament into the centre of the cotton
sheath before twistings [1]. 0.05 mm and 0.07 mm copper wires were used as core material. All of copper core cotton yarns were produced in Ne 8 yarn count [6].

After the yarn production, copper core cotton yarns were integrated to the 3/1 twill woven fabric structure in the weft, with five different weft densities, namely 8, 13, 18, 23, 28 wefts/cm, for the evaluation of their electromagnetic shielding effectiveness (EMSE) properties [1]. Ne 20/2, 100% cotton yarns were used as warp yarns for all the fabrics. Fabric samples have been coded according to their wire diameters and weft densities [7]. For instance; Sample 5.28. has 0.05 mm copper core and 28 wires/cm weft density.

2.2. Tests
Electromagnetic shielding properties of the woven fabrics were tested by using unechoic chamber test system according to EN50147-1 standard in 1GHz-6GHz frequency range. The results were attained in decibels (dB) [5].

The system is consist of a signal generator which generates signals, an RF power amplifier which amplifies the signals before being sent to the sample, two antennas and two adjacent shielded rooms, each having one of the antennas inside (First antenna connected to the signal generator and second to the spectrum analyzer as signal receiver) and a spectrum analyzer which analyzes the signals obtained from the receiver antenna [1].

Fabric was placed the gap between two rooms (two antennas) during the measurements. Signals were produced and amplified and then sent onto the fabric by an antenna. The signals transmitted by the fabric were detected by the receiver antenna, situated on the other side of the fabric [1]. Results were read from spectrum analyzer. EMSE of the copper core conductive fabrics were measured at frequencies ranging from 1 GHz to 6 GHz [8]. Each fabric sample has been measured three times. So as to obtain the actual shielding effectiveness results, blank measurements (without fabrics/shielding materials) are regarded at all frequencies [7]. The results were analyzed by using Excel tables, diagrams and SPSS software program.

3. Results and Discussion
The effects of wave frequency, fineness of the core filament and weft density on the electromagnetic shielding effectiveness of fabrics were investigated.

3.1. Effects of Wave Frequency
According to the ANOVA and SNK tests, wave frequency had a statistically significant effect on the shielding effectiveness [1,5].

Change of EMSE of fabric samples with wave frequency are given in Figure 1.
Figure 1. Change of EMSE of fabric samples with wave frequency.

Figure 1 shows the electromagnetic shielding effectiveness changes of fabrics according to wave frequency. When the wave frequency rise, (despite deviations) EMSE of three samples have 28, 23 and 18 wires/cm weft densities indicate slight increasing tendency but the samples have 13 and 8 wires/cm indicate slight decreasing tendency.

3.2. Effects of Core Fineness

According to the Paired Samples T Test, the core fineness has a statistically significant influence on the shielding effectiveness of the fabrics [3].

Figure 2 presents the variations of average EMSE for the fabrics with different core fineness in the frequency range 1 GHz – 6 GHz [9].

Figure 2. Variation of EMSE of samples with core fineness and weft density.

With an increase in wire diameter (wire becomes thick), a decrease in shielding effectiveness has been observed [3]. The reason of this, as copper filament becomes thick, its rigidity soars. Increased rigidity of the copper filament, makes it difficult to bent and take the form of copper. This can cause apertures on the fabric structure [1,8]. Therefore, EMSE of fabrics decrease. According to Figure 2, fabrics have 0,05 mm core fineness indicate higher EMSE than 0,07 mm at all frequencies.
3.3. Effects of Weft Density

In accordance with the results of ANOVA and SNK tests, weft density had a statistically important effect on the shielding effectiveness.

Figure 2 shows the changes in average EMSE of samples with different weft densities. As the weft density increase, the fabric comprises more conductive materials so EMSE values of the fabrics increase, as well. The highest average EMSE value obtained from the fabrics have 28 wires/cm weft density.

4. Conclusion

In this work, textile materials were developed for protecting from electromagnetic waves and their usage areas were investigated. For this purpose, Cu/Co core yarns were produced by using copper filaments as core material and cotton as sheath material on a ring spinning frame. Copper monofilaments of 0.05 mm and 0.07 mm were used as core materials. All core yarns are produced in Ne 8 yarn count. Conductive Cu/Co yarns were integrated into 3/1 twill woven fabric structure in the weft direction with 5 different weft densities (8, 13, 18, 23 and 28 per cm).

The effects of wave frequency, core filament count and weft density on the EMSE were investigated. The shielding effectiveness of these fabrics were measured between 1GHz and 6GHz using the TS EN 50147-1 standard [10].

The results have shown that there are significant effects of fineness of the core filament and weft density on the EMSE. The fabrics that was produced with 0.05 mm core filament have represented higher EMSE than 0.07mm core fineness. EMSE values of the fabrics increased with increasing weft density [11]. Since the fabric comprises more conductive materials.

The highest results were obtained from the fabric that was produced with 0,05 mm core filament and 28 wefts/ cm weft density (sample 5.28) at 2 GHz. Average EMSE value of the sample 5.28 is 31.98 dB (Figure 2).

In conclusion, since satisfactory results were received, the fabrics produced in this research can be used for electromagnetic shielding. Especially against devices which emit between 1 and 6 GHz frequency as cell phones, computers, tablets, radios and household electrical appliances. For this purpose, the produced fabrics are thought to be used in various applications in both professional and daily life such as curtain, mosquito netting, apron, tent, awning and protective clothing.
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