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Influence of Silver Coated Yarn Distribution on Electrical and Shielding Properties of Flax Woven Fabrics

Abstract
The aim of the research was to investigate the influence of silver coated yarns incorporated into fabric on the electrical and shielding properties of textile materials designed to ensure protection against the risk of harmful electromagnetic fields as well as thermophysiological comfort in a warm climate. The wearing comfort of conductive textiles is poor due to the chemical nature of synthetic fibres and coatings usually used in their production. In order to solve the problem, natural flax fibres that have good antistatic, hygienic and wearing comfort properties were used as a base for electroconductive textiles. This paper presents the research of these newly developed conductive textile materials. The content of the experimental investigations consisted of determination of the electrical conductivity, electromagnetic interference (EMI) shielding of the materials designed, and an analysis of measurement results. From the results obtained, it can be concluded that not only the amount of conductive additive (in this case –silver) but also the distribution of conductive yarns in woven flax fabric influence the electrical properties, such as electromagnetic wave shielding and electrical conductivity. Correlations between the shielding effectiveness and electrostatic properties are also discussed.

Key words: *electro-conductive textile, flax, EM shielding properties.*

Introduction

Fibres and coatings with unique optical, magnetic and electrical properties are being widely researched for both military and commercial use. Conductive woven or knitted fabrics, because of their structural order and ability to flex and conform to most shapes desired, offer an opportunity to develop multifunctional and interactive textiles.

Various techniques have been used to increase the electrical conductivity of yarns or fabrics:

- adding conductive fillers such as carbon fibres, metal fibres (stainless steel, aluminium) or metal powders and flakes (Al, Cu, Ag) to yarns [15];
- incorporating conductive fibres and yarns into fabric [6, 7];
- laminating conductive layers onto the surface of fabric using conductive coatings [8, 9];
- incorporating inherently conducting polymers (ICP) into textile [10 – 13].

Textiles with different levels of electrical conductivity could be used for a number of applications: electromagnetic (EM) shielding, electrostatic dissipation, for use in heating devices or for the production of clothing where physical changes in the textile cause variations in electrical resistance, which can be monitored [14 - 16].

Although fabrics with conductive fibres or yarns inserted are mostly used for electrostatic dissipating protective clothing, their application for EM shielding is becoming more and more numerous. The reduction of the electromagnetic radiation impact is very important protection for the survivability of people frequently using electrical equipment, which exposes humans to different frequencies of electromagnetic waves. Electrical and electronic devices, used in modern society at an ever increasing rate, are capable of emitting electromagnetic waves with frequencies that are potential hazards to health [5, 17].

Unwanted reception of EM radiation may lead to electromagnetic interference (EMI). The most common type of EMI occurs in the radio frequency of the EM spectrum, from 10^4 to 10^{12} Hz. This energy can be radiated by computer circuits, radio transmitters, fluorescent lamps, electric motors, over-head power lines, lightning and many other sources [5]. Another downside of electromagnetic radiation is that it can also be used by malevolent individuals or criminal organizations and is a security threat for the civilian population, especially for those people who use certain electronic devices during work and everyday life or are working near power lines. To counter this threat, special protective clothing produced from electro conductive textile materials with particular EM shielding properties can be used.

Metals or metal-coated materials generally show very high EMI shielding. High conductivity makes them shield mostly by surface reflection [1 – 5]. The filaments of yarns can be coated by the vacuum spray method or using a galvanic coating, as well as by the use of plasma treatment. It is possible to control the thickness of coating using these methods, but adhesion between fibre and metal remains a problem [14, 15].

Some studies [1] have shown that among the coating materials Ag, Cu, Al and Ti, silver possessed the highest electrical conductivity. Therefore at present silver coated fibres and yarns are widely used for technical textiles, as besides high conductivity they also provide good antibacterial properties [4, 15].

Thus conductive additives not only change the electrostatic properties of the fabric (surface resistance, half decay time, shielding factor) [7] but also have an influence on the optical properties

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of fabric. These properties of a material are major factors influencing their EM shielding properties.

Effective protection against electromagnetic radiation can be provided by its reflection or absorption. When an EM field is passed through an object, there are three phenomena that determine how the field strength is lost as it interacts with the object's absorption attenuation, attenuation due to reflection, and that due to successive internal reflections (usually neglected) [5].

In thin shields, such as metal-coated or metal incorporated textile, the shielding mechanism can be explained by means of the phenomenon of multiple EM wave reflection. Metalised textile fabrics have very high reflection coefficients (up to 100 dB) and consequently their shielding efficiency mainly derives from energy reflection, and not from its absorption [10, 18].

A parameter that characterises any shield is the effectiveness of shielding (SE), defined as the ratio of the electromagnetic field strength (E_0) measured with and without the material tested (E_1) when it separates the field source and receptor [10, 18, 19]:

$$SE = E_0/E_1 \qquad (1)$$

or, in decibels,

$$SE_{dB} = 20\log(E_0/E_1) \qquad (2)$$

The same relationships are valid in relation to the conjugated field (far field – where the distance from the EM radiation source is higher than $\lambda/2\pi$) or electric component (near the field) [18].

There are several methods used for evaluating the shielding effectiveness of flat shielding structures [9, 20, 21]. There are particular methods of electromagnetic shielding investigation developed for far-field and near-field measurements [22, 23]. Currently known methods differ in frequency range, sample dimensions, measurement conditions, and the geometry of the test setup. Therefore it is not possible to compare the results of shielding effectiveness obtained by such diverse test methods. There is also a lack of generally accepted standardised methods for measuring shielding effectiveness [9].

At the developing stage of new textile materials intended to have EM shielding properties it is more importantly to have a simple measurement method to afford ground for reliable comparisons of small samples of designed fabrics. It is important to use the same testing conditions – test setup geometry, the size of the test samples, atmosphere for testing, parameters of the source of EM radiation.

***Table 1.** Description of fabrics used for investigation.*

Code of fabric	Surface density, g/m^2	The distance between conductive yarns in the fabric, cm		Grid area, mm^2	Count of yarn with silver additives, %
		Warp	Weft		
Sample 1 (control)	162.4	-	-	not formed	-
Sample 2	159.6	1	-		0.87
Sample 3	160.5	2	-		0.48
Sample 4	162.3	-	1		0.87
Sample 5	159.1	-	2		0.48
Sample 6	159.8	1	1	100	2.08
Sample 7	159.9	1	2	200	1.36
Sample 8	157.8	2	1	200	1.36
Sample 9	160.6	2	2	400	1.13

In this paper a description of a simple measuring method used for the determination of relative EM shielding effectiveness in particular frequency ranges is presented. The method is based on the measurement of the electric (E)/magnetic (H) field strength of the EM radiation source (in a particular frequency range) with and without the test fabric when it separates the EM field source and receptor – an E/H field meter.

The purpose of this study was to investigate the influence of silver coated yarns incorporated into fabric on the electrical and shielding properties of textile materials designed to ensure protection against the risk of harmful electromagnetic fields as well as−thermophysiological comfort We chose flax as the substrate because of its high moisture absorbing nature, which is important for thermophysiological comfort, and due to the fact that flax fabrics, unlike polyester, do not collect electrostatic charges on the surface [24]. Besides, interest in flax fibres for protective application in textile has increased as a result of the search for new renewable materials. As a natural resource, flax has a number of unique properties such as non-toxicity, biocompatibility and biodegradability. As a conductive additive, silver coated yarns were used as they can provide high electrical conductivity. Silver has very low emissivity and besides that has powerful antimicrobial properties, which are very important for clothing worn near the skin.

Experimental

Nine plain weave woven fabrics differing in the quantity and distribution of conductive yarns inserted were manufactured for this research work at the Textile Institute of the SRI Center for Physical Sciences and Technology. All fabrics were manufactured using 24.3 tex × 2, S 300 m^{-1} flax spun yarns (both in the warp and weft directions). The set of warp of all fabrics investigated was 18 cm^{-1} and that of the weft also 18 cm^{-1}, and the thickness of all fabrics investigated was 0.7 ± 0.01 mm. The thickness of individual fabric was determined with DM-teks thickness apparatus, following the guidelines of EN ISO 5084 [25].

The conductive yarns were inserted in eight woven fabrics at specified intervals – some samples have conductive yarns only in one direction (warp or weft), in others the conductive yarns form a grid of certain area. One fabric was manufactured as a control fabric, i.e. no conductive yarns were inserted in the fabric (sample 1). A detailed description of the fabrics tested is presented in ***Table 1***.

The conductive yarn used was silver-coated yarn (T = 15.7 tex; Z 300 m^{-1}), consisting of two twisted components:

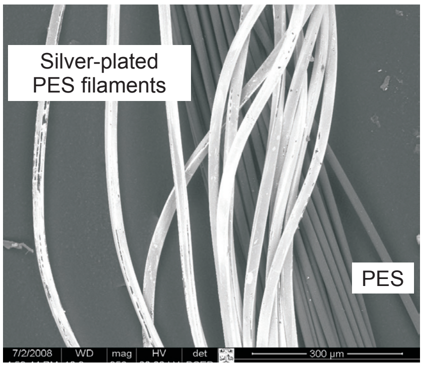

***Figure 1.** Microscopic view of conductive yarn.*

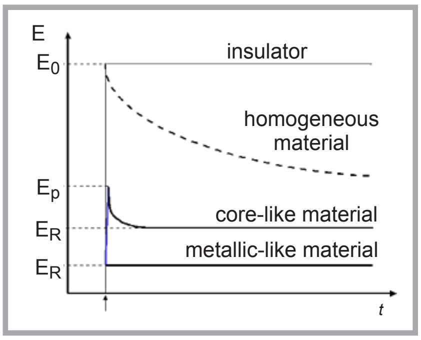

***Figure 2.** Principle view of charge decay curve obtained using apparatus ICM-1 [30].*

polyester 11.3 tex (f 32) and polyester silver-coated 4.4 tex (f 12). A microscopic view of this yarn is presented in ***Figure 1***.

The count of yarns with silver additives was established according to Standard EN ISO 1833-1, Annex B [26], where the method of quantitative analysis by manual separation is indicated.

In this research work two testing methods evaluating the shielding efficiency were used. Firstly electrostatic properties, such as the shielding factor and half decay time were determined according to EN 1149-3, 2nd method (induction charging) [27] with an electric charge meter - ICM-1 (produced by STFI, Germany), where charging of the test specimen was carried out by an induction effect. Immediately under the test material, which was horizontally arranged, a field-electrode was positioned without contacting the specimen. A high voltage of 1200 ± 50 V was rapidly applied to the field-electrode. The instrument was controlled by a microprocessor and makes measurements with automatic calculations and display of the data measured.

The shielding factor S is expressed as:

$$S = 1 - \frac{E_R}{E_{\max}}, \tag{3}$$

where E_R is the maximum electric field strength indicated on the recording device with the test specimen in the measuring position, and $E_{\max}$ is the electric field strength in kV/m indicated on the device with no test specimen present.

The half decay time t_{50} is the time taken for the indicated field strength to decay to $E_{\max}/2$, expressed in seconds. A principle view of the charge decay curve of the fabrics tested using apparatus ICM-1 is presented in ***Figure 2***.

The coefficient of variation of values of the half decay time t_{50} was less than 3 %, and for the shielding factor S – less than 1%.

As was presented in our previous study [28], the EMI shielding effectiveness of textile fabrics can be suitably assessed by measuring the variation in the strength of the electric field near the particular electromagnetic radiation source. Although it can be noticed that an electromagnetic wave consists of an electric component and magnetic component perpendicular to each other [5], in this study for evaluation of EMI shielding effectiveness only data of the electric field strength alternation were used, as measurements of the magnetic field did not showed any significant change in it. The relative effectiveness of EMI shielding was investigated by evaluating the change in strength of the electric field (ΔE) of electromagnetic radiation sources that work in 0.02 ÷ 0.05 MHz and 2.45 GHz frequency diapasons, using manufactured fabrics as shields. ΔE was calculated using the following equations:

$$\Delta E = \left(\frac{E_0 - E_i}{E_0} \right) \cdot 100\%, \tag{4}$$

where E_0 is the electric field strength without a shield, and E_i the electric field strength with the specimen used as a shield in V/m.

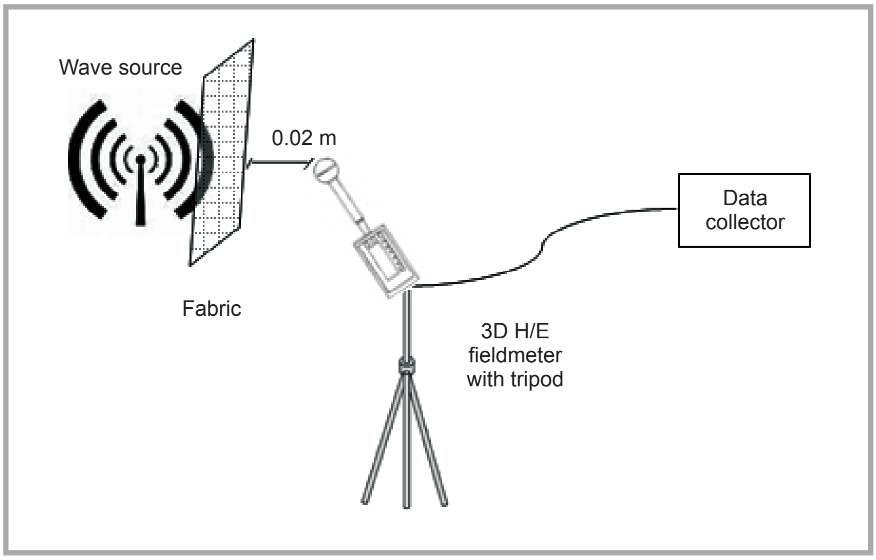

***Figure 3.** Protection from electromagnetic disturbances effectiveness measuring scheme.*

The measuring of the electric and magnetic field strength was made using a 3D H/E fieldmeter ESM-100 (Maschek, Germany), presented in ***Figure 3***. The measuring range of the apparatus is 100 mV/m – 100 kV/m, with a precision of ± 5%, and it is suitable for simultaneous isotropic measurement of electric and magnetic fields. The measuring was performed with a test fabric of 1 × 1 m that was set on a chosen electromagnetic radiation source. The measurements were made at a fixed distance of 0.02 m between the fieldmeter and material tested. To ensure the stability of measurement conditions, the fieldmeter was fixed on a tripod. The measurement time applied was 2 min, and readings were taken twice in a second.

That is to say, firstly the initial E in V/m of the source was measured, then the source was covered with the fabric tested and the electric field strength was measured again with the measuring device. The distance between the source and measuring device was kept as in a real personal workplace. The experiments were carried out in a standard atmosphere – temperature 20 ± 2 °C and relative humidity 65 ± 4%. The coefficient of variation of the electrostatic field strength does not exceed 5%.

Results and discussions

To evaluate the effect of the conductive yarns used (see ***Figure 1***) on the electrical conductivity of the fabrics designed, their electrostatic properties were measured. Usually, to determine the conductivity $(\Omega m)^{-1}$ of a material, its resistivity in Ωm was measured [14]. To determine the surface resistivity of textile materials, test method EN 1149-1 [29] was applied. However, surface resistance measurements are not meaningful for special materials, e.g. for fabrics with core or surface conducting fibres [27]. For assessment of such inhomogeneous materials, a different test like the charge decay test is more reliable. In this study, to measure the dissipation of electrostatic charge from the surface of the fabric, the inductive charging test method [27] was used. According to this method the shielding factor S and half decay time t_{50} were determined. Results of the shielding factor of all fabrics tested are presented in ***Figure 4***.

Together with the shielding factor, the half decay time was measured for the fabrics investigated. Results for the half decay time of all fabrics tested are presented in ***Table 2***. It can be remarked that according to [30, 31] and the shape of the curve of the test fabrics, with specially designed and manufactured conductive yarns, they represent core-like materials (see ***Figure 2***), i.e. the conductive yarns may be assigned as steel core conductive yarns. Comparing the results presented in ***Figure 4*** and ***Table 2,*** it can be seen that shielding factor S is a more informative parameter than the half decay time t_{50}, particularly when evaluating electrical conductivity properties of samples with differing quantities and distributions of conductive yarns inserted. Thus, as seen in ***Figure 4***, the values of S increased greatly with conductive yarn incorporation, depending on the content of conductive yarns used. The shielding factor is the best for woven fabric which has the biggest count of yarn with silver additives (sample 6), and its value of half decay time is less than 0.01 s, i.e. charges do not accumulate on the fabrics (see ***Table 2***). Similar results showing that the insertion of conductive yarns results in a shorter half decay time, i.e. the half decay time is less than 0.01 s, were determined in previous papers [32, 33]. The control fabric (sample 1) has no shielding effect; it is equal to zero and the half decay time is very long. Hence decreasing the distances between conductive yarns, the shielding factor increases. Analogous investigations were presented by other authors, who stated that the best shielding effect is of fabrics with conductive yarns in both the weft and warp directions [5, 28].

The dependence between the content of conductive yarns and S is presented in ***Figure 5.*** As is seen from ***Figure 5,*** a high correlation coefficient between the conductive yarn content and shielding factor exists. When the count of the conductive yarn is increased, the shielding of the material also increases. Samples with the same content of conductive yarns and geometrical distribution, differing only in the position of conductive yarns in the warp and weft directions (pairs of these investigated samples: 2 and 4, 3 and 5 & 7 and 8), have almost the same shielding factor S values. Consequently for further investigations only one sample from each afore-mentioned pair was selected (samples 4, 5 and 7). Also it was found out that samples with a very similar content of conductive yarn, but with different geometric distribution – that is samples 2 & 4, with conductive yarn only in one direction, compared with sample 9, which has conductive yarn in both directions, i.e. it forms a grid, – have similar S values, which means similar surface electric conductivity. Thus in light of these results it could be stated that the geometric distribution of conductive yarns in the samples tested has no meaningful influence on their conductivity, with this parameter of the fabric being governed by the content of such yarns.

Table 2. *The half decay time* t_{50} *of tested fabrics.*

Code of sample	Half decay time, s
Sample 1	1.48
Sample 2	<0.01
Sample 3	0.07
Sample 4	<0.01
Sample 5	0.02
Sample 6	<0.01
Sample 7	<0.01
Sample 8	<0.01
Sample 9	<0.01

In order to evaluate the effectiveness of EMI shielding in the ranges stated (0.02 - 0.05 MHz and 2.45 GHz), the electrostatic field strength of the electromagnetic field sources chosen was measured before and after inserting the test fabrics as shields between the source and fieldmeter (see ***Figure 3***). Results of the electric field strength distribution of the samples investigated are presented in ***Figure 6*** (see page 88)**.**

The experiments using both electromagnetic field sources showed (see ***Figure 6***) that the electrostatic field strength near the EM source used can be decreased significantly using fabrics with conductive yarns as shields. Pure flax fabric (sample 1) has practically no influence on electrostatic field strength change; when using certain fabric with conductive yarn it can be decreased till 70% or 80% (sample 6), respectively, for electromagnetic field sources with 0.02 - 0.05 MHz and 2.45 GHz frequency ranges.

During the investigation, it was concluded that the influence of the materials used on the electrical field strength is obvious (***Figure 6***) and has practically no influence on the magnetic field strength. Therefore for evaluation of the effective-

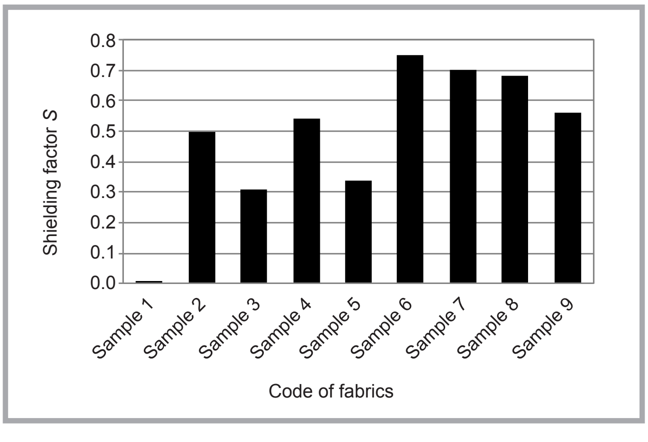

Figure 4. *Shielding factor S of fabrics investigated.*

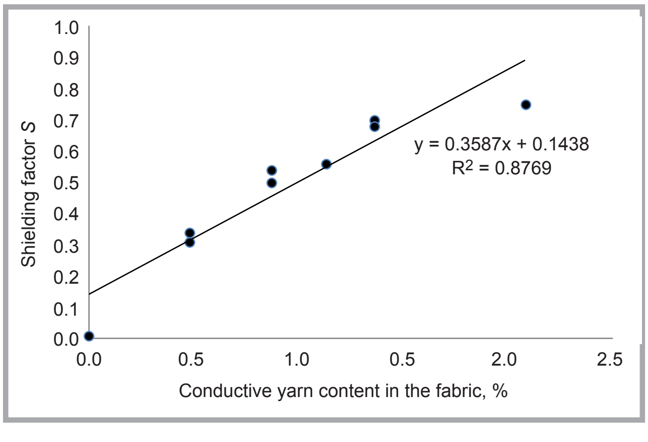

Figure 5. *Dependence of conductive yarn content in fabrics investigated on shielding factor S.*

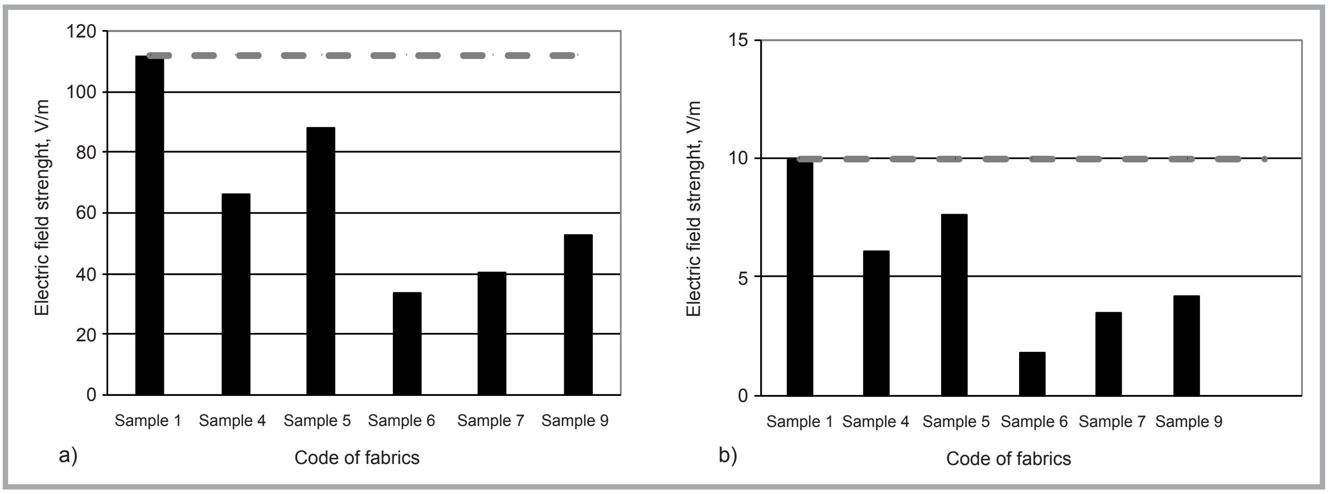

__Figure 6.__ Alternation of electric field strength of EM source using tested samples as shields (- - - - - – electric field strength of device which works in a) 0.02 - 0.05 MHz frequency diapason; b) 2.45 GHz frequency range).

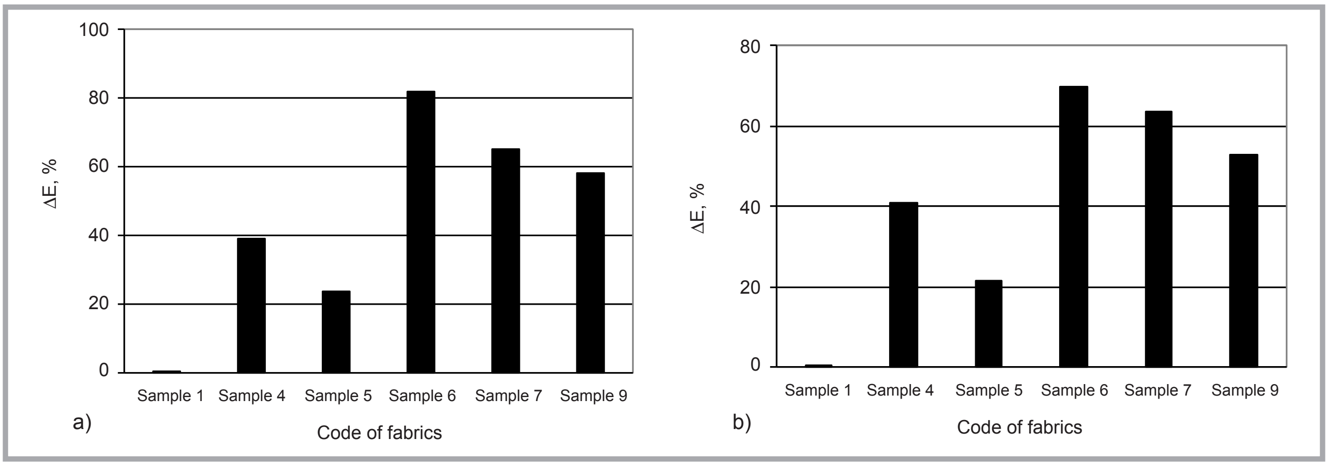

__Figure 7.__ Effect of samples tested on EMI shielding in a) 0.02 - 0.05 MHz frequency range; b) 2.45 GHz frequency range.

ness of electromagnetic disturbances, one parameter – difference in electrical field strength ΔE, % – was used. The difference in electrical field strength ΔE, %, was calculated according to ***Equation 2***. The results of this evaluation are presented in ***Figure 7.***

The results of investigations showed that the insertion of conductive yarns distinctly increases the EMI shielding effectiveness of fabrics. We can make such a conclusion by comparing the values of ΔE of sample 1 – fabric without any conductive yarn in the structure, to other test fabrics with conductive yarns inserted (see ***Figure*** *7*). It is also clear from ***Figure*** *7* that the EMI shielding effectiveness of the samples tested increased with an increase in the content of conductive yarns inserted into fabric, with a resulting rise in their electrical conductivity (however, not measured directly). The EMI shielding effectiveness of sample 6 is the highest (see ***Figure*** *7*) compared to the other fabrics tested; it is also distinguished for the best dissipation of electrostatic charge and protection against incendiary discharges (see ***Figure 4***).

In the next stage, the influence of conductive yarn content on the EMI shielding effectiveness was investigated. Results of the dependence of conductive yarn content on EMI shielding effectiveness are presented in ***Figure 8***.

Based on the results estimated, it can be stated that EMI effectiveness depends on the content of conductive yarns in the material (see ***Figure*** *8*), similar to that determined in the case of investigation of electrostatic properties (see ***Figure*** *5*). However, in addition we also found that the geometrical distribution of conductive yarns has more influence on ΔE than on electrostatic properties. This is especially noticeable comparing different types of conductive yarn distributions, i.e. comparing fabrics with conductive yarns inserted only in one direction (warp or weft) to those with conductive yarn forming a grid of certain area. For example, samples 4 and 9 have a very similar content of conductive yarns and electrostatic properties (see ***Figure*** *4*), but their EMI shielding effectiveness is visibly different (see ***Figure*** *7*), as they have a different type of distribution of conductive yarns. Sample 9, which has conductive yarn in both directions, i.e. it forms the biggest grid, has a considerably higher ΔE value than sample 4, with conductive yarns only in one direction (see ***Figure*** *7*). This can be explained by the fact that electromagnetic waves propagate in multiple directions. Therefore it may be better to insert conductive yarns in different directions so that they would form an electrical conducting net. Analogous findings are presented by other authors who investigated the EMI shielding effectiveness of metal composite fabrics [1, 16]. Comparing test results of the samples with conductive yarn grids

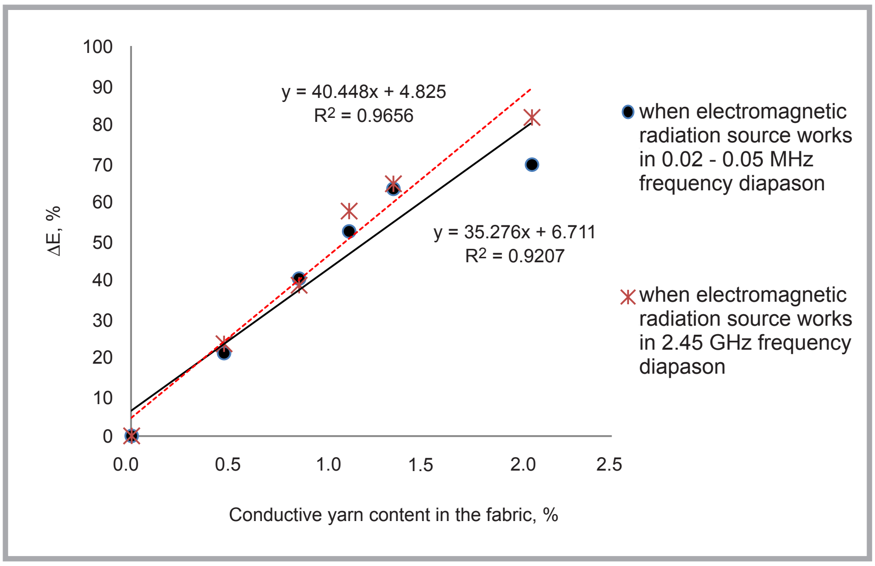

Figure 8. *Dependence of conductive yarn content on EMI shielding effectiveness.*

(samples 6, 7 and 9), it was found that the EMI shielding effectiveness increased with the content of conductive additives and with a reduction in the grid area (see ***Figure*** *7*). However, the results showed that the grid area affected ΔE values more considerably than the content of conductive additives. In particular, when the grid area was reduced from 400 mm^2 to 200 mm^2 (samples 9 and 7, respectively), but with content of conductive yarns being similar (1.36% and 1.13%), ΔE values rose to a great extent. This suggest that choosing an appropriate content of conductive yarns and their geometrical distribution , optimal EMI shielding properties of fabrics with conductive yarns incorporated could be obtained. The further investigations to determine optimal parameters to achieve desirable EMI shielding effectiveness will follow.

Conclusions

Multifunctional metal composite woven fabrics from flax with different contents and distributions of incorporated silver coated yarns were developed and explored. From the results of experiments it can be clearly seen that electrical properties such as electromagnetic wave shielding and electrostatic properties are improved with the incorporation of silver coated yarns. Parameters influencing the above-mentioned properties of the test fabrics were investigated. It was found that electrostatic properties, which were measured to evaluate the dissipation of electrostatic charge from the surface of the material and protection from incendiary discharge of the fabrics tested, depend on the content of conductive yarns used, whereas EMI shielding properties depend on both the content of conductive yarns and their distribution in the fabric. Among the fabrics tested with a similar content of conductive yarns, those with a conductive yarn grid showed higher EMI shielding effectiveness compared to those with conductive yarns only in one direction. It was shown that the EMI shielding of fabrics could be tailored by modifying the content and distribution of silver coated yarns. On the basis of this study, it was determined that even fine texture fabric with metal coated yarns can provide multifunction EMI shielding. Further investigations to determine optimal parameters to achieve desirable EMI and thermal shielding effectiveness will follow.

Acknowledgements

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References

1. Chen MY, Wu H, Zha AX. Electromagnetic Shielding Effectiveness of Fabrics with Metalized Polyester Filaments. *Textil Res J* 2007; 77, 4: 242-246
2. Su ChI, Chern JT. Effect of Stainless Steel-Containing Fabrics on Electromagnetic Shielding Effectiveness. *Textile Research Journal* 2004; 74, 1: 51-54.
3. Cheng KB, Cheng TW, Nadaraj RN, Giri Dev VR, Neelakand R. Electromagnetic Shielding Effectiveness of the Twill Copper Woven Fabrics. *Journal of Reinforced Plastics and Composites* 2006; 25, 7: 699–709.
4. Nurmi S, Lintukorpi A, Saamanen A, Luoma T, Soinnen M, Suikkanen VP. Human, Protective Cloths and Surgical Drapes as a Source of Particles in an Operating Theatre. *Autex Research Journal* 2003; 3: 394-399.
5. Roh JS, Chi YS, Kang TJ, Nam SW. Electromagnetic Shielding Effectiveness of Multifunctional Metal Composite Fabrics. *Textile Research Journa*l 2008; 78, 9: 825-835.
6. Lemaire P. Estimation of Static Dissipation Through Corona Discharges in Protective Garments Using Core Conductive Fibres. In: *Electrostatics 2005 Conference,* 2005; 15-17.
7. Varnaitė S, Katunskis J. Influence of Washing on Electric Charge Decay of Fabrics with Conductive Yarns. *Fibres & Textiles in Eastern Europe* 2009; 17, 5: 69-75.
8. Holme I, McIntyre JE, Shen ZJ. Electrostatic Charging of Textiles. *Textile Progress* 1998; 28, 1: 1-90.
9. Wieckowski TW, Janukiewicz JM. Methods for Evaluating the Shielding Effectiveness of Textiles. *Fibres & Textiles in Eastern Europe* 2006; 14, 5: 18-22.
10. Avloni J, Ouyang M, Florio L, Henn AR, Sparavigna A. Shielding Effectiveness Evaluation of Metalized and Polypyrrole-Coated Fabrics. *Journal of Thermoplastic Composite Materials* 2007; 20, 3: 241-254.
11. *Military Textiles*. Ed. Wiluz E. Woodhead Publishing in Textiles, 2008: 384.
12. Xue P, Tao XM, Kwok KWY, Leung MY, Yu TX. Electromechanical Behaviour of Fibres Coated with an Electrically Conductive Polymer. *Textile Research Journal* 2004; 74, 10: 929-936.
13. Kaynak A. Characterization of conducting polymer coated fabrics at microwave frequencies. *International Journal of Clothing Science and Technology* 2009; 21, 2-3: 117-126.
14. *Intelegent Textiles and Clothing*. Ed. Mattila HR. Woodhead Publishing in Textiles, 2006: 528.
15. Textiles for Protection, edited by Scott RA. Woodhead Publishing in Textiles, 2005: 784.
16. Brzeziński S, Rybicki T, Karbownik I, Malinowska G, Rybicki E, Szugajew L, Lao M, Śledzińska K. Textile Multi-layer Systems for Protection against Electromagnetic Radiation. *Fibres & Textiles in Eastern Europe* 2009; 17, 2: 66-71.
17. Zamanian A, Hardiman C. Electromagnetic radiation and Human Health: A Review of Sources and Effects. *High Frequency Electronics in Summit Technical Media* 2005: 16-26.
18. Brzezinski S, Rybicki T, Malinowska G, Karbownik I, Rybicki E, Szugajew L. Effectiveness of Shielding Electromagnetic Radiation, and Assumptions for Designing the Multi-layer Structures of Textile Shielding Materials. *Fibres & Textiles in Eastern Europe* 2009; 17, 1: 60-65.

19. Koprowska J, Pietranik M, Stawski W. New Type of Textiles with Shielding Properties. *Fibres & Textiles in Eastern Europe* 2004; 12, 3: 39-42.
20. ASTM D4935-10 Standard Test Method for Measuring the Electromagnetic Shielding Effectiveness of Planar Materials.
21. Wieckowski TW, Janukiewicz JM. Methods for Evaluating the Shielding Effectiveness of Textiles. *Fibres & Textiles in Eastern Europe* 2006; 14, 5: 18-22.
22. Wilson PF. Techniques for Measuring the Electromagnetic Shielding Effectiveness of Materials: Part I: – Far-Field Source Simulation. *IEEE Transactions on Electromagnetic Compatibility* 1988; 30, 3: 239-250.
23. Wilson PF. Techniques for Measuring the Electromagnetic Shielding Effectiveness of Materials: Part II: – Near-Field Source Simulation. *IEEE Transactions on Electromagnetic Compatibility* 1988; 30, 3: 251-259.
24. Zimniewska M, Michalak M, Krucinska I, Wiecek B. Electrostatic and Thermal Properties of the Surface of Clothing Made from Flax and Polyester Fibres. *Fibres & Textiles in Eastern Europe* 2003; 11, 2: 55-57.
25. EN ISO 5084:1996. Textiles – Determination of thickness of textiles and textile products.
26. EN ISO 1833-1:2010. Textiles – Quantitative chemical analysis – Part 1: General principles of testing.
27. EN 1149-3:2004. Protective clothing – Electrostatic properties – Part 3: Test methods for measurement of charge decay.
28. Varnaitė S. The Use of Conductive Yarns in Woven Fabric for Protection Against Electrostatic Field. *Materials Science (Medžiagotyra)* 2010; 16, 2: 133-137.
29. EN 1149-1:2006. Protective clothing – Electrostatic properties – Part 1: Test method for measurement of surface resistivity.
30. Evaluation of Excisting Test Methods for ESD Garments, [looked: 2007 05 25]. Access in internet: http://estat.vtt.fi/publications/vtt_btuo45-041224.pdf.]
31. Pinar A, Michalak L. Influence of Structural Parameters of Wale-Knitted Fabrics on their Electrostatic Properties *Fibres & Textiles in Eastern Europe* 2006; 14(5): 69-74.
32. Vogel Ch, Beier H, Erth H. Research and Development in the Field of Special Protective Clothing; Requirements for Selected Methods and Products. *Fibres & Textiles in Eastern Europe* 2006; 14(5): 29-34.
33. Cieślak M, Wróbel S, Kamińska I, Lao M. Functional Upholstery Materials for Protection Against Electrostatic Risk. *Fibres & Textiles in Eastern Europe* 2009; 17(4): 52-58.

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TOWAROZNAWSTWO
KIERUNEK MIĘDZYWYDZIAŁOWY

Commodity Science

At the Technical University of Łódź a **college of interfaculty studies 'Commodity Science'** was created under the management of **Prof. Izabella Krucińska PhD, DSc, Eng.** It is constituted of four faculties:

- Organisation and Management,
- Material Technologies and Textile Design,
- Biotechnology and Food Sciences, and
- Chemistry.

The creation of such studies was in response to marketdemand, as in Łódź no other university has a similar offer, and specialists in the field of commodity science are sought more and more often.

The surplus of commodities present on the market should be properly checked and subject to censorious quality assessment so that consumers would have a chance to select a proper product from the many offers; one that is safe to use, fulfilling his/her needs completely.

That is why the aim of the College is the preparation of the student in such a way that his/her knowledge and abilities are adequate to the needs of employers. Thanks to the utilisation of the huge scientific potential of as many as four faculties of the Technical University of Łódź, it is possible to dedicate the last semester of studies to professional internships.

One of many important forms of education are laboratories ensuring the undergraduate obtains unique professional qualifications.

The programme of studies prepared has an interdisciplinary dimension as it combines knowledge from a range of engineering-technical subjects, as well as from the economic, management and social sciences.

The intention of the creators of the programme is to prepare undergraduates so that they would have the knowledge and abilities to **assess the quality of commodities** from the point of view of **human-product** interaction.

The innovativeness of the programme is based on offering such specialisations, which refer to products which directly influence the health of consumers: **food, textiles, clothes, pharmaceutical & chemical products, as well as medical and hygienic products.**

All these can have a negative influence on human health or life, and that is why the abilities of quality assessment gained in the aspect f the pro-health properties of products have fundamental importance.

In the offer of commodity science studies there are four specialisations:
1. Innovative biomedical products,
2. Innovative textile products,
3. Food commodity science,
4. Modern chemical and pharmaceutical products.

The complete offer of the 'Commodity Science' studies is presented on the following webpage: www.towaroznawstwo.o.lodz.pl