MULTIVARIATE ANALYSIS OF THE PARAMETERS THAT INFLUENCE THE EMR ABSORPTION/SHIELDING OF THE TEXTILE SURFACE COATED USING NICKEL/GRAPHITE/COPPER MICROPARTICLE

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REZUMAT. În cadrul acestei lucrari sunt prezentate mai multe aspecte referitoare la potentialul de utilizare a textilelor acoperite cu nichel, grafit sau cupru pentru absorbția radiațiilor electromagnetice (EMR), ecranarea EMF (câmp electromagnetic), ecranarea EMI (inferență electromagnetică). Materialele textile acoperite cu nichel-cupru sunt materiale care confera protecție RFID si sunt utilizate pentru realizarea huselor pentru notebook-uri, smartphone-uri, portofele pentru carduri de credit si perdele. Studiile asupra materialelor cu capacitate de ecranare / absorbție reprezinta inca o provocare, deoarece interferențele electromagnetice (EMI) pot perturba dispozitivele electronice (în special dispozitivele electronice medicale), echipamentele și sistemele utilizate în aplicații critice specifice domeniului medical, militar, de securitate și aerospațiale, cum ar fi sisteme de transport in comun, ecrane tactile industriale, senzori, sisteme de navigație și control vehicul (avionica). Inferențele electromagnetice pot fi produse din numeroase surse, cum ar fi naturale sau datorită activităților umane. Efectul inferențelor electromagnetice asupra dispozitivelor electronice menționate anterior poate fi de la tulburări temporare și pierderi de date până la defectarea sistemului și chiar pierderea vieții. Prin intermediul proiectarii electronicelor se pot ecrane de protectie electromagnetica care costă mai puțin, dar asigură o ecranare electromagnetică activă. Ecranele EMI alternative, realizate de obicei din fire de argint și argint-aluminiu, argint-cupru și argint-sticlă, pot rezolva probleme legate de ecranare electromagnetica dacă sunt integrate în materiale de ambalare flexibile pentru a acoperi dispozitivele electronice. Se cunoste faptul că un ecran electromagnetic pe baza de silicon si grafit si/sau nichel are performanțe de ecranare la nivelul unui ecran din argintului-aluminiu, dar cost este mai mic. In general, materialele pe baza de silicon si nichel-grafit îndeplinesc cerințele de eficiență de ecranare din specificațiile de apărare MIL-DTL-83528, care solicită o eficiență de ecranare minimă de 100 dB la frecvențe RF cuprinse între 20 și 10 GHz.

Cuvinte cheie: EMR, EMI, absorbtie, ecranare electromagnetica, textil, nichel, grafit, cupru

ABSTRACT. In this paper are presented several aspects concerning the potential use of the nickel/graphite/copper coatings for textile surfaces designed for electromagnetic radiation (EMR) absorption or EMF (electromagnetic field), EMI (electromagnetic inference) shielding. Materials coated with nickel-copper are RFID shielding fabric used for notebook bags, credit card wallets, curtains, and smartphones. Studies about materials with shielding/absorption capacity are still challenging because electromagnetic interference (EMI) can disrupt electronic devices (in particular medical electronic devices), equipment, and systems used in critical applications specific to medical, military, security, and aerospace electronics such as mass transit systems, industrial touch screens, sensors, navigation, and vehicular control systems (avionics). The electromagnetic inferences can be produced from numerous sources such as natural or due to human activities. The effect of the electromagnetic inferences on the electronic devices previously mentioned can be from temporary disturbances and data losses to system failure and even loss of life. The electronic design can provide a specified particle fills that cost less but still provide active electromagnetic shielding. The alternative EMI shields, usually made from silver and silver-aluminum, silver-copper, and silver-glass materials, can solve this problem if they are integrated into flexible packaging materials in order to cover the electronic devices. It is already known that a shield based on nickel-graphite silicone performs at the shielding level of silver-aluminum but a lower cost. The nickel-graphite silicones meet the shielding effectiveness requirements of defense specifications MIL-DTL-83528, which request a minimum shielding effectiveness of 100 dB at RF frequencies between 20 and 10 GHz.

Keywords: EMR, EMI, absorption, shielding, textile, nickel, graphite, copper

1. INTRODUCTION

The study of textile materials for electromagnetic radiation shielding presents an increased interest for the protection of the electronics devices for medical, military, security, avionics domain and civil application (ceiling or walls shielding in the public building, phones, notebooks, TVs) involving mobile telephony aerials and Wifi/WLAN networks. Overal, for the attenuation of electromagnetic radiation in the home can use curtains, window blinds, or carpets made of fabric, knitted or non-woven materials, with conductive wires or polymeric films with electroconductive properties. The electromagnetic

The electromagnetic (EM) atetnuation by screens is done by:

➔EM attenuation by reflection

The wave that represents the electromagnetic field incident and that propagates in the direction of the screen, suffers the first reflection from contact with the screen, and then repeated internal reflections within it, a part of the wave being transmitted and in the protected space.

Magnetic materials may route the low frequencies magnetic fields in a particular area of the space, producing such a strengthening of the field only in certain areas and it decreases outside the areas concerned.

➔EM attenuation by absorption

The impact of electromagnetic waves with a surface of separating the two environments with different electrical properties - the first being free space, and the second - the screen (textile surface with conductive or magnetic properties), the two components, the electric field and magnetic field, transmitted in the screen, undergo modifications that can be appreciated by comparing the Z_s impedantelor surface (1) of the two environments.

$$Z_s=E/H \quad (1)$$

Where H is the magnetic field strength, and E is the electric field strength.

Concerning the absorbtion of the electromagnetic radiation, this depends on the material type that can transform electromagnetic energy into internal energy (e. q. termal energy). An efficient absortion material is a composite metal foam, "high-Z steel-steel," against all three forms of radiation and is made of high percecent of stainless steel and a percent of tungsten. Also anosisotropic crystal, nichel, silver,SYCO composite [1, 2], based on PVDF (polyvinylideni fluoride) as matrix polymer and carbon black and Strontium-Yttrium-Cobalt-oxide fillers, and composites based conducting epoxy resins filled with polyaniline (PANI) and polypyrrole (PPy) [3], can be used as electromagtic waves absorbers. Overall, radio waves can travel through brick and glass, but not well through a metal cage [4],and using flexible shields [5] made from textiles with conductive yarns or conductive coating by thin film layers deposition or screen printing method with polymeric paste based on nichel, carbon [6], graphite, graphene or silver.

Conductive parts or magnetic materials are used for the achievement of the screens of electric, magnetic, and electromagnetic fields. An electromagnetic screen is a tire lead which separates the space in 2 regions, one containing the electromagnetic waves and others which does not contain such waves.

To achieve the electromagnetic attenuation screens [7] will use the special treatment of textile surfaces with materials having different degrees of magnetism [8]:

-Diamagnetic materials such as micro/nanoparticle C (graphite), Ag, Cu, Pb and Zn having $\chi_m<0$, $\mu_r<0$;

-Paramagnetic materials properties such as micro/nanoparticle such as Al, Cr having $\chi_m>0$ and $\mu_r>\mu_0$

-Ferromagnetic materials such as micro/nanoparticle of Fe and Ni, having $\chi_m\approx106$. Magnetic susceptibility of the material is inversely proportional to the temperature, depends on the frequency of the magnetic field. If the temperature exceeds the critical temperature (Curie), ferromagnetic material becomes paramagnetic;

-ferrimagnetic materials such as ferrites based on Fe, Mn, Zn, Ni, or Mg having $\chi_m\approx104$.

-antiferromagnetic materials such as manganese oxide, ferrous chloride, chromium, copper(I) chloride, and iron oxide II.

At the same time, for the manufacture of advanced materials to be used for electromagnetic shielding will take into account the characteristics to be satisfied by the material such as:

-The thickness of the composite screen made of textile materials and magnetic material/non-magnetic (δ [mm]);

-The conductivity composite material (σ [$S\cdot m^{-1}$]);

-Electrical resistivity of composite material (ρ [$\Omega\cdot m$]);

-The magnetic permeability of the composite material (μr [H/m]);

-Magnetic susceptibility (χ_m), electric susceptibility (χ_e)

-The geometry of the screen (deposits of micro/magnetic nanoparticle/non-magnetic grid type or continuous).

2. EXPERIMENTAL PART

In the framework of our experiments has been used a woven made of 100% cotton with mass 401g/m^2 on which have been applied with conductive paste coverage polymeric with content of polivinilic alcohol (PVA), polietilen glycol (PEG) and micro/nanoparticles (Ni (< 50 µm), Cu (14-45 µm), Ag (< 150 nm) and Graphite (50-100 µm) by direct scraping on textile surface (samples no. 1, 2, 3), by screen printing (sample no. 4) and thin film deposition using doctor blade coating method (sample no. 5).

In our laboratory were investigated for all samples, the weight, thickness, air permeability using FX 3300 Air Permeability tester, and surface resistance using Surface Resistance Tester, which measures the electrical resistance of the surface between 2 parallel electrodes.

In Table 1 are presented the samples and physico-mechanical and electrical properties.

In case of the sample no. 1 treated by conductive paste based on Nichel microparticle can be observed that the air permeability measured by (Fig. 2.1) has a lower value, and also the surface resistance is lower, which mean that the conductivity is increased.

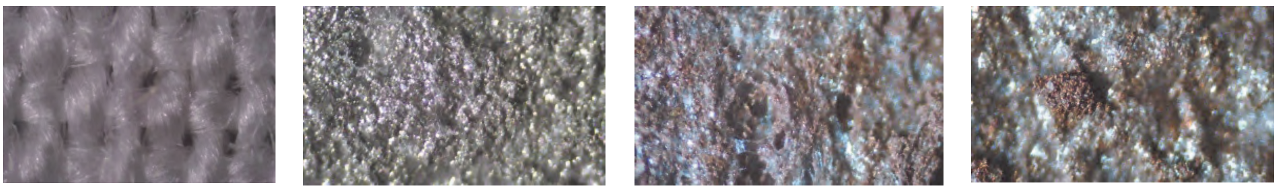
In Figure 2.2 are presented, based on electronics microscopy analysis, the surface of the original fabric (without metal microparticle content, Fig. 2.1. a), and the surfaces of the fabrics with microparticles (Fig. 2.2.b-2.2.d) submitted.

Even if the sample treated using Ag has an excellent surface resistance, the Ag is very expensive and will generate a higher cost for the electromagnetic shield obtained.

Fig. 2.1. Air permeability test – Ni sample no. 1

Table 1. **Fabrics functionalised with conductive paste – physico-mechanical and electrical properties**

Sample	**Ni**	**Cu$_1$**	**Cu$_2$**	**Graphite**	**Ag**	**Mass M [g/m^2]**	**Thickness δ [mm]**	**Air permeability Pa [l/m2/s]**	**Surface resistance Rs [Ω]**
1	X					1159	2.13	7.06	1x10^5
2		X				1587	4.48	33.9	1x10^7
3			X			1431	3.34	31.7	1.1X10^7
4				X		1114	2.07	33.4	1.2X10^7
5					X	596.5	0.821	16.8	6.6X10^5



a.Fabric without metal microparticles

b. Fabric with Ni microparticles

c.Fabric with Cu microparticles (14-25 µm)

d.Fabric with Cu microparticles (<45 µm)

Fig.2.1. Electronic microscopy analysis

3. RESULTS AND DISCUSSIONS

In figure 3.1 is presented the representation of the 3D surface resistance of the samples obtained by screen rinting, doctor blade coating and direct scraping methods in the function of the air permeability (Pa) and thickness (δ) using Matlab software and multivariate analysis of the surface resistance (Rs) in the function of the air permeability (Pa) and thickness (δ).

By using Pearson's correlation coefficient (6) was analysed the correlation between Rs, Pa, δ, m (3, 4, 5, 6, 7, 8). Based on analysis of the correlation between air permeability (Pa), the surface resistance (Rs), and the thickness (δ) was demonstrated that between the Rs and Pa is a positive linear relationship, and between the Rs and δ it cannot be considered a positive linear relationship.

By analysing the correlation coeficients, $R_{1,2}(Rs,Pa) = R_{2,1}(Rs,Pa) = 0.9584$, $R_{1,2}(Rs,\delta) = R_{2,1}(Rs, \delta) = 0.6201$, $R_{1,2}(Rs,m) = R_{2,1}(Rs,m) = 0.6352$, $R_{1,2}(Pa, \delta) = R_{2,1}(Pa, \delta) = 0.5982$, $R_{1,2}(Pa,m) = R_{2,1}(Pa,m) = 0.5416$, $R_{1,2}(\delta,m) = R_{2,1}(\delta,m) = 0.9646$ we can conclude that between Rs and Pa, respective δ and m it is a positive linear relationship which means that the increase of values for Pa will generate the increasing of the Rs values and this will generate the reducing of the surface conductivity, because Rs is inverse proportional with surface conductivity, and as result this will generate the reducing of the electromagnetic attenuation (dB).

$$R=\rho(X,Y)=\frac{cov(x,y)}{\sigma_x\sigma_y} \qquad (2)$$

where:

cov is the covariance;

σ_x is the standard deviation of X;

σ_y is the standard deviation of Y.

$$R(Rs,Pa)=\begin{vmatrix} 1.000 & 0.9584 \\ 0.9584 & 1.0000 \end{vmatrix} \qquad (3)$$

$$R(Rs,\delta)=\begin{vmatrix} 1.0000 & 0.6201 \\ 0.6201 & 1.0000 \end{vmatrix} \qquad (4)$$

$$R(Rs,m)=\begin{vmatrix} 1.0000 & 0.6352 \\ 0.6352 & 1.0000 \end{vmatrix} \qquad (5)$$

$$R(Pa,\delta)=\begin{vmatrix} 1.0000 & 0.5982 \\ 0.5982 & 1.0000 \end{vmatrix} \qquad (6)$$

$$R(Pa,m)=\begin{vmatrix} 1.0000 & 0.5416 \\ 0.5416 & 1.0000 \end{vmatrix} \qquad (7)$$

$$R(\delta,m)=\begin{vmatrix} 1.0000 & 0.9646 \\ 0.9646 & 1.0000 \end{vmatrix} \qquad (8)$$

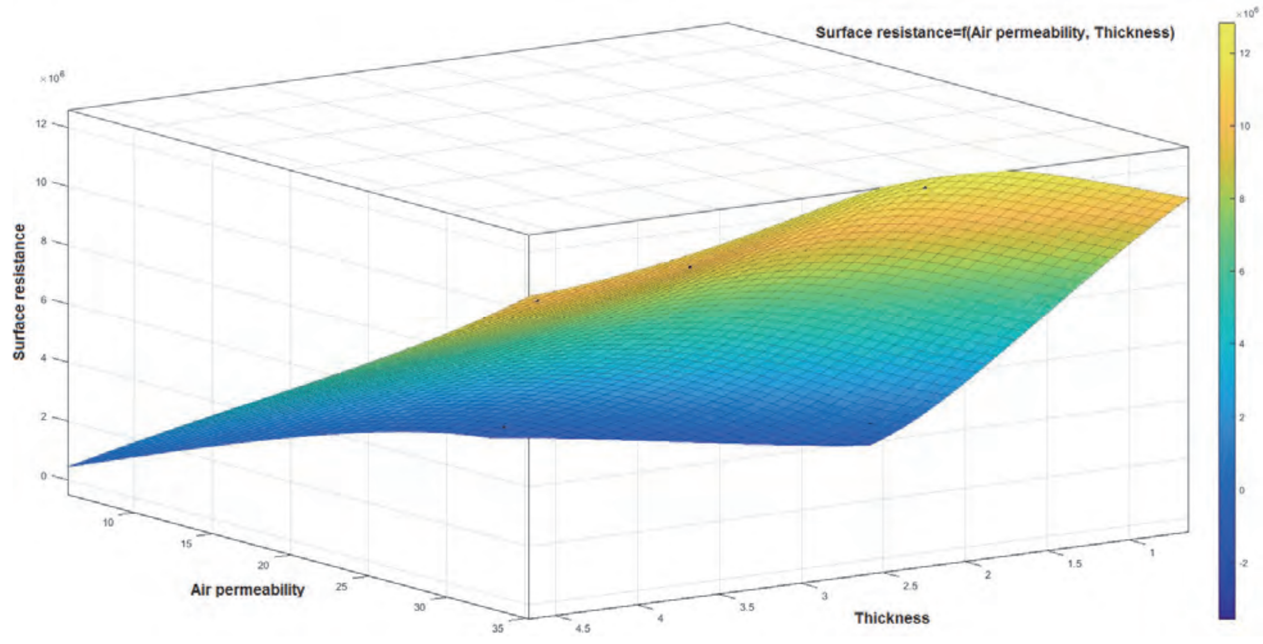


Fig. 3.1. 3D representation of the surface resistance in the function of air permeability and fabric thickness (Rs = f(Pa, δ)

4. CONCLUSIONS

In conclusion, it can be specified that:

The use of materials with higher electrical conductivity results in the attenuation of the electromagnetic field. The effectiveness of the screen for quasistationary electromagnetic fields tends to infinity with increasing frequency.

The value of the attenuation factor in the quasistationary electromagnetic field depends on the frequency, the thickness of the screen, electrical conductivity, magnetic permeability of the fabric and the geometry of the screen.

Besides, the losses by reflection do not depend on the thickness of the shielding material, and the losses by absorption depend on the thickness of the screen.

The shielding of the magnetic fields is generally difficult and can be achieved with magnetic screens made by surface treatment of textiles with dispersion based on ferromagnetic particles, such as Nichel, Iron.

The developement of the screens with the effectivess of the electromagnetic attenuation (EM) involves the design, construction, and EM attenuation analysis [9] and electromagnetic screen connection to the earth.

However, the parameters such as thickness and air permeability are important for electromagnetic attenuation by absorbtion.

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