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MAGNETIC WOVEN FABRICS - PHYSICAL AND MAGNETIC PROPERTIES

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***Abstract*:** *A coated material is a composite structure that consists of at least two components: base material and coating layer. The purpose of coating is to provide special properties to base material, with potential to be applied in EMI shielding and diverse smart technical fields. This paper reports the results of a study about some physical and magnetic properties of coated woven fabrics made from cotton yarns with fineness of 17 metric count. For this aim, a plain woven fabric was coated with a solution hard magnetic polymer based. As hard magnetic powder, barium hexaferrite ($BaFe_{12}O_{19}$) was selected. The plain woven fabric used as base has been coated with five solutions having different amounts of hard magnetic powder (15% - 45%) in order to obtain five different magnetic woven fabrics. A comparison of physical properties regarding weight (g/m^2), thickness (mm), degree of charging (%) and magnetic properties of magnetic woven samples were presented. Saturation magnetizing (emu/g), residual magnetizing (emu/g) and coercive force (kA/m) of pure hard magnetic powder and woven fabrics have been studied as hysteresis characteristics. The magnetic properties of the woven fabrics depend on the mass percentage of magnetic powder from coating solution. Also, the residual magnetism and coercive field of woven fabrics represents only a part of bulk barium hexafferite residual magnetism and coercive field.*

Key words: *coated woven fabric, magnetic solutions, weight, thickness,barium hexaferrite, hysteresis loop.*

1. INTRODUCTION

The advanced industrial technologies progress is reflecting directly or indirectly influence on economic and social aspects of life and therefore these fields are seeking harmonization of development within a common benefit. In terms of social and economic, the textile industry is a major user of technologies and the need to respond positively to a larger number of challenges is obviously.

The main advantages of low weight, high flexibility, human and nature friendly of some textile material represent a good reason to add new function and to improve the potential use of them. Thus, the frequency of functionalized textile that ensure conductivity, photo-luminescence, UV protection, catalytic and antistatic effects, antimicrobial effects, self-cleaning properties, rejection and limiting the spread of fire, magnetic properties is growing.

The link between textile materials, considered as dielectric and diamagnetic ones and different fillers and functionalizing materials lead to grow and improve of smart textile sector [1], with potential in electromagnetic shielding sector [2-4].

Most technological solutions of this kind involve the using by inserton into a woven, knitted or nonwoven structure of electroconductive [5] or amorphous yarns [6]. Modern technologies have led to obtain micro or nano fibers containg magnetic powder through extrusion [7], electrospinning [8, 9] or co-precipitation "in situ" [10].

For yarns, the magnetic properties can be obtained as a result of using electroconductive fibers in yarn structure, of introduction magnetic powder into fiber matter during fiber production or coating with solution having magnetic properties [11]. Manufacturing of textile structures with magnetic properties involves the combining of traditional or nonconventional technologies with finishing and coating technologies by direct or indirect methods [12, 13].

In this paper we present several physical and magnetic relevant properties of coated, magnetic cotton woven fabrics obtained by direct coating with hard magnetic powder solutions. Five mixtures containing barium hexaferrite powder, as hard filler particles have been used.

2. MATERIALS AND METHOD

2.1 Materials

A plain woven fabric made from 100% cotton yarns (fineness 17 metric count) have been selected as base due to the compatibility with thermoplastic polymers included in coating solutions.

We selected five coating solutions with various mass percentages of hard ferrimagnetic powder (izotropic barium hexaferrite $BaFe_{12}O_{19}$, particularly used for permanent magnets, microwave absorber devices and recording media, two polymers in liquid state (polyvinyl acetate and polyurethane adhesive) and a glycerol ($C_3H_8O_3$) based plasticizer. The mass percentage of barium hexaferitte was varied between 15% and 45% while the amount of glycerol plasticizer was kept constant at 5%. The solution was performed by stirring for 24 h in a standard conditioning atmosphere (20^0C temperature and 65% relative humidity). After coating, five different magnetic woven fabric samples F1-F5 have been obtained.

The izotropic barium hexaferrite ($BaFe_{12}O_{19}$) - BF is a ferrimagnetic material, obtained from iron oxide (Fe_2O_3) and barium carbonate ($BaCO_3$) having the following estimated magnetic characteristics at room temperatures: saturation magnetization (M_s) of aproximatelly 54 emu/g, residual magnetization (M_r) of about 31 emu/g, and coercive field (H_c) of about 100 kA/m [13,14,15]

The polyvinyl acetate ($(C_4H_6O_2)n$) - PVAc is a rubbery synthetic polymer in the thermoplastic class of polymers. PVA is an excelent polymer emloyed in the textile, paper and chemical industry due to its good adhesion on materials with cellulosic content.

Polyurethane adhesive (no applicable formula) - PUR is a polymer, not soluble in water, composed of a chain of organic units joined by carbamate (urethane) links. It is widely used in a wide range of fields owing to its superior physical and chemical properties, including good adherence on porous celulozic materials, good abrasion resistence and good elasticity without cracking [16].

Glycerol ($C_3H_8O_3$) -GLYC is a trihydric alcohol widely used in the food, cosmetic and pharmaceutical industries because it can serve many functions such as a humectant (moisture absorbing), plasticizer (softening), bodying agent, flavoring, denaturant, emollient (smoothing), antimicrobial, thickener and solvent. For our purpose GLYC is used as plasticizer of magnetic solutions.

2.2 Method

The technique for applying in-depth of solution (6) at the woven structure surface (5) was by scraper or knife coating which is shown in Fig. 1. A scraper steel knife (1) is placed above the horizontal woven fabric. The coating was performed in a multi-polar magnetizing field generated by permanent magnets (7) based on NdFeB and having an induction of 0.7 T. After solution application, the sample was passed through a device having a pair of rollers.

Top pressing roller (2) has a rubber sheath (for not damaging the coated surface) while the lower roller (3) has a metal surface. Before and after coating, the woven fabric is driven by guidance rollers (4).

In order to investigate woven fabrics structural modifications and magnetic properties, the coated woven fabrics were conditioned in a standard atmosphere of 65%±2% R.H. and a temperature of $20^0 \pm 2^0$C. To highlight the coated surface unevenness of woven fabrics was used an Olympus SZX 10 microscope equipped with Olympus DF PL 1, 5 X -4 and Olympus DF PLAPO 1 X -4 lens to a 6.3 magnification degree.

The woven fabric weight was measured (according to SR 6142:2007, Romanian Standard) in g/m^2 by using a Radwag Radon RS 232C weighing scale. The fabric thickness was measured (according to PN-EN 29073-2:1994, Polish Standard) in mm by using a Tilmet 73-Grubosciomierz under a pressure of 2kPa.

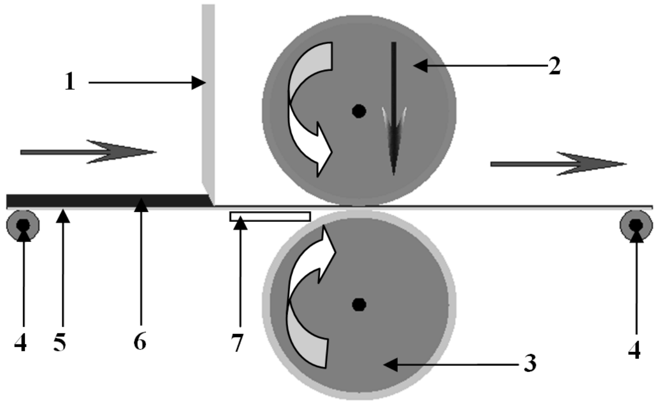


Fig.1:*Schematic drawing of scraper coating; 1) scraper knife; 2) top roller; 3) lower roller; 4) guidance rollers; 6) magnetic solution; 7) permanent magnets*

The degree of charging was calculated according to relation:

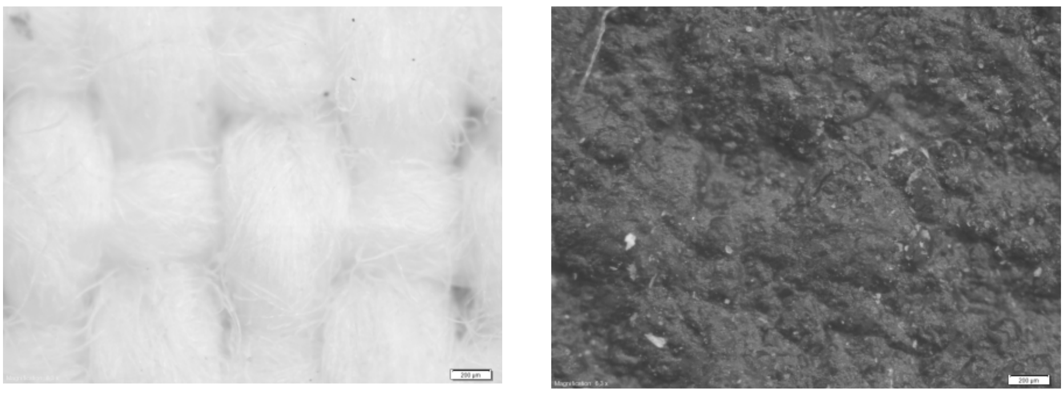
$$D_c = \frac{W_c - W_0}{W_0} \cdot 100(\%) \qquad (1)$$

where: W_C – coated woven fabric weight in g/m^2;
W_0 – uncoated woven fabric weight in g/m^2.

In order to estimate the magnetic characteristics of bulk barium hexaferrite (FB) and coated woven fabrics (F_1 - F_5), a VSM Lake Shore 7300 magnetometer has been used. Magnetic measurements with VSM have been made in accordance with ASTM A894/A894M-00(2011) e1, „Standard Test Method for Saturation Magnetization or Induction of Nonmetallic Magnetic Materials”.

3. RESULTS AND DISCUSSION

Two optical images of the uncoated woven fabric (F) and coated woven fabric (sample F3 with 30% hard magnetic powder in solution), respectively are given in Fig. 2.



a) b)

Fig.2: *a) Microscope images: a) uncoated cotton woven fabric F and b) coated woven fabric-sample F3*

On surface of uncoated woven fabric can be seen fiber ends free, out of yarn structure. Depending on the content of ferrimagnetic powder from coating solution, the surface of coated woven fabrics has various shades of brown. Fig. 2.b highlights the presence of hexaferrite grains on the sample F3 surface and also the coating unevenness. The coating solution enters even the spaces between those two yarns systems (warp and weft yarn system) due to the rollers device.

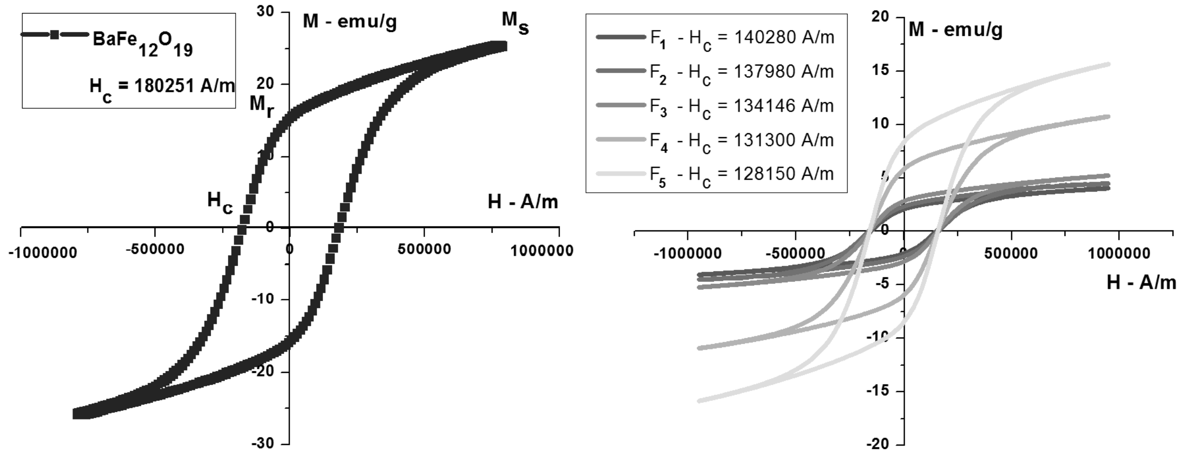
Table 1 shows the experimental average physical characteristics of weight, thickness and degree of charging for uncoated sample and for five coated samples depending on barium hexaferiite percent from solutions.

Table 1: *Physical characteristics of uncoated and coated samples*

Characteristics	F	F_1	F_2	F_3	F_4	F_5
Magnetic solution	-	R_1	R_2	R_3	R_4	R_5
Percent of barium hexaferrite, wt.%	-	15	20	30	40	45
Average weight, g/m^2	290	396	401	429	550	629
Variation coefficient of weight (%)	0.152	0.053	0.059	0.043	0.035	0.034
Average thickness, mm	1.01	1.23	1.27	1.3	1.34	1.37
Variation coefficient of thickness (%)	2.034	2.255	4.165	5.616	5.775	7.38
Degree of charging, %	0.00	34.60	35.41	39.63	52.91	58.82

It is observed from Table 1 that the weight of coated samples depends on the amount of hard magnetic powder from solutions compared to uncoated woven sample weight which is characterized by a value of 290g/m^2. For example, 30% increase of magnetic powder content from coating solution between sample F1 and F5 is resulting in an increase of weight woven sample from 396 g/m^2 to 629 g/m^2. The weight unevenness of woven samples decrease with the increasing of hard magnetic powder from 0.053% to 0.033%. Instead, the unevenness of thikness increases with the increasing of hard magnetic powder from 2.25% to 7.38% (see Table 1) because the hexaferrite grains may adhere in different amounts on the different parts of woven fabric surface. Therefore, the thickness is within range from 1.23 mm to 1.37 mm compared to uncoated woven fabric thickness of 1.01 mm.

The hysteresis loops of the barium hexaferrite and magnetic woven fabrics obtained are shown in Fig. 3. Experiments carried out indicated that for a maximum saturation magnezation of bulk magnetic powder, the value of maximum field H was 600kA/m and for the coated woven samples saturation magnetization was 1000 kA/m.



a) b)

Fig. 3: *Hysteresis loops of: a) pure $BaFe_{12}O_{19}$ and b) F_1-F_5 woven samples*

Applying the magnetic grains onto the diamagnetic woven fabrics resulted in obtaining of composite woven fabrics with magnetic properties according to Table 2.

The higher degree of charging (see Table 1), the higher are the values of coated woven samples magnetic characteristics (see Table 2).

Table 2: *Magnetic characteristics of coated samples*

Characteristics	$BaFe_{12}O_{19}$	F_1	F_2	F_3	F_4	F_5
Saturation magnetisation, M_s – emu/g	25.5	4.05	449	5.23	10.76	15.65
Residual magnetisation M_r – emu/g	15.43	2.07	2.35	2.84	5.81	8.34
Coercive field, H_c kA/m	180.2	128.1	131.3	134.1	137.9	140.2

Penetration depth of solution in the woven fabric pores depends on the solution amount and the pressure applied on rollers device. Since the solution amount and the pressure were kept constant for all woven samples, the magnetic properties of woven fabrics depends only the magnetic powder content from each solution. The magnetic woven samples, whose hysteresis loops are presented in Fig. 3.b, are characterized by smaller values of magnetic properties than magnetic hard powder. This behaviour may be testified by the lower (by 38%) value of the sample F5 residual magnetization in comparison with the pure magnetic powder, which has a value of 25.5 emu/g Also, the value of the field intensity of coated woven samples coercive force is lower (140.2 kA/m for sample F5) compared to coercive field of pure magnetic powder of 180.2 kA/m (see Table 2).

4. CONCLUSIONS

Five coating solutions with various mass percentages of hard ferrimagnetic powder, two polymers in liquid state and a glycerol have been proposed in order to obtain composite woven fabrics. The technique for applying of magnetic solution at the cotton woven sample surface was by scraper or knife coating.

Depending on mass percentage of hard magnetic powder, the surface of coated woven fabrics has various shades of brown.

Experiments carried out indicated that the coated woven fabrics physical properties depend on the hexaferrite percentage content from solution. Therefore, the higher the magnetic powder percentage content, the higher are the weight and thickness of the coated cotton woven fabrics. Magnetic grains from coating solution may adhere on different parts of woven fabric surface in different amounts and therefore the unevenness of thickness is higher than of the weight unevenness.

Nevertheless, the magnetic properties depend on the kind of magnetic filler and its percentage content by mass on the woven fabric surface. Also, the higher degree of charging, the higher are the values of coated woven samples magnetic characteristics.

The cotton coated woven samples are characterized by smaller values of magnetic properties than pure magnetic hard powder.

Improving of woven fabrics magnetic properties can be possible by using magnetic materials with smaller grain diameter (like nano magnetic grains), which would enable to increase of filling degree.

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