ENVIRONMENT PROTECTION POTENTIAL THROUGH MAGNETICALLY TEXTILE SYSTEMS

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Abstract: As part of a multifunctional textile system, the magnetically textile products represent technical and technological solution with a big application potential in textronics, sensors and protection against radiation. In this paper are evidenced the result of physically and magnetically analyses of coated yarns with solutions heaving magnetic content. Analyses made after washing test presents the degree of degradation of the coatings. Also there are evidenced the BH hysteresis curves which presents the magnetic behavior of the yarns.

Key words: yarns, magnetic layers, wash test, microscopic analysis, magnetic measurements.

INTRODUCTION

The technological development has registered a progress unknown in the last 50 years, imposing new quality standards and the expectation of specialists has been exquisite in the various fields a lot once with implementation of these new available technologies. The world textile industry is not an exception, by providing new and various products with characteristics and functionalities hybrid, these being limited as needs but very required. Traditionally, many fields of science generally and engineering in particular have been separate and distinct. Recently, there has been considerable movement and convergence between these fields, there are endeavor for multidisciplinary research and the results have been astonishing. Smart technology for materials and structures is one of these results. Smart materials and structures can be defined as the materials and structures that sense and react to environmental conditions or stimuli, such as those from mechanical, thermal, chemical, electrical, magnetic or other sources [14].

One of the possibilities of obtaining of smart textiles is by coating. Today, coated fabrics are essentially polymer-coated textiles. Advances in polymer and textile technologies have led to phenomenal growth in the application of coated fabrics for many diverse end uses. Coated fabrics find an important place among technical textiles and are one of the most important technological processes in modern industry. Coating is the process of applying a viscous liquid (fluid) or formulated compound on a textile surface [7, 12]. Coating textiles techniques with magnetic blends represent alternatives of integrating of magnetic materials into polymeric matrices, rapid, chip and easy to realized techniques. As part of magnetic textile among of magnetic fibers [11], or magnetic coated fibers [9], the magnetic yarns represent a new direction of research with complex applications electronic technical textile field as magnetic cores of the textile coils [15, 16, 17]. Also, the most important application of these yarns should be for microwave absorption, due to the magnetic materials content [8] with impact in public health protection. The magnetic yarns can be included into composite yarns category where the reinforcement element is made of textile and together with magnetic matrix forms discontinuous phase [4, 5, 6]. Direct coating to the ambient temperature represents a new possibility of obtaining of magnetic yarns [3].

MATERIALS AND METHOD

Materials

This paper presents aspects regarding the researches performed at Faculty of Textile, Leather Engineering and Industrial Management, Technical University of Iasi, Romania and Faculty of Material Technology and Textile Design, Technical University of Lodz, Poland.

The producing of magnetic yarns implies testing and using of many different materials (components of blend recipes). After analyzes performed were presented some commonly blend recipes used for cover of yarns. The main blend element is magnetic powder, in first case barium hexaferrite (FB 1), a hexagonal hard magnetic ferrite with a magnetoplumbite structure. It is well known as the wide used ceramic permanent magnet [10, 13], bought from “Rofep” company of Urziceni, România. Another powder used in this research is Black Toner 6745 CP-313 produced by Lanier Worldwide Inc. company from U.S.A, a composite magnetic mixture powder (CMP) wide used as ink carrier during printing process. The main informations of powders collected from safety data sheets of manufacturers are presented in the Table 1.

Table 1. The main characteristics of barium ferrite [8, 10, 13] and black toner

No.	TECHNICAL DATA		
1.	**name**	isotropic barium hexaferrite 1	black toner
3.	**class**	hard ferrimagnetic material	soft ferromagnetic material
4.	**chemical formula**	$BaFe_{12}O_{19}$	mixture
5.	**components**	Fe_2O_3 and $BaCO_3$	Styrene acrylate resin (60-90%), c arbon black or black iron oxide (ferosoferic oxide, iron tetrahidrate) ($Fe_3H_8O_4$) (5-10 %), Polypropylene wax (1-5 %), Organic pigment (0,5-1%), Silica (<1 %)
6.	**medium diameter**	4-6 µm	1-2µm
7.	**measured density**	4458 kg/m^3	658 kg/m^3

In the case of blends are known components densities and proportions in recipe by mass and are calculated proportions by volume. Density values of components were determinate experimentally using pycnometer method. For the reason of coating yarns with magnetic materials was used binding adhesives mixed with magnetic powder. One of this is polyvinyl acetate (PVA) - a wide used thermoplastic adhesive used due of good adherence between cellulosic materials and for producing of latex paints. Another adhesive used is polyurethane adhesive (PU) with remarkable performance in adherence. As plasticizer agent for blends was selected the glycerin. Yarns used in this research are:

-a spun yarn (CY), (A10) with 35 tex, 100% cotton [1, 2] presented in the Figure 1a.

-a polifilamentar yarn (SSY) (A9), 120 tex, 100% stainless steel (SS), used for electro conductive and antistatic properties presented in the Figure 1b.

Fig 1a: SSY (A9)

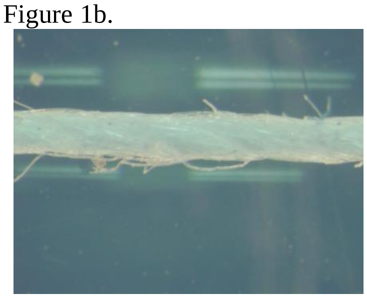


Fig 1b: CY (A10)

2.1. Coating method

The magnetic yarns made by adding a thin magnetic layer on its surface represents a very clever and simple but meticulous alternative for spun yarns obtained from fibers with content of magnetic material inside of it. The method consists of adding a thin magnetic layer on the yarn surface (3). Coated yarns were realized using own principle and own laboratory installation (figure 2), that allows the deposit of a magnetic composition, previously created, (by mechanical mixing of the magnetic powder, adhesive and plasticizer) on the yarn surface in a micrometer film by a process called core-sheath.

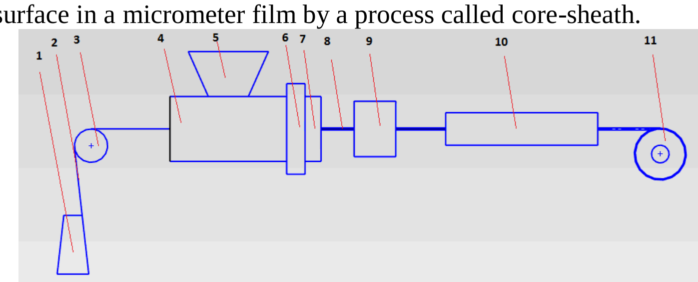


Figure 2: Schematic drawing of the installation for obtaining of the magnetic yarns 1) bobbin 2) matrix yarn, 3) yarn leader, 4) magnetic mixture feed room 5) feed hopper, 6) electromagnet, 7) spinneret 8) coated yarn, 9) multi-polar magnetizing device, 10) drying and fixation room, 11) winding reel of the coated magnetic yarn

Depositing of the magnetic layer on the yarn surface is done into electromagnetic field to orient the magnetic particles of its structure into a room (4), which has provided special filing calibration system, spinneret (7), for uniformity, deposited layer. After calibration, the coated wet yarn (8) is passed through another special concept of device (9) that magnetize the yarn in stripes on longitudinal direction [2]. The process finalize with the drying, thermo fixing (10) and winding on a reel. (11).

EXPERIMENTAL

After coating of cotton ans steel yarns with the seven blends (4 hard magnetic blends (named R1, R2, R4, R6) and 3 soft magnetic blends (R3, R5, R7), (table 2), has been selected 8 representative samples (generic named A1, A2, A3, A4, A5, A6, A7, A8. During coating, function of the magnetic micro powder content the magnetic yarn appear with a nuance of brown and varnished brick look. In the figure 3a and 3b are presented the photos of coated yarns A3 and A6. The coating of yarn present a high degree of homogeneity, easy highlighted in the S.E.M photo from Figure 3c.

Figure 3a: Stainless steel coated yarn (A6)

Figure 3b: Cotton coated yarn (A1)

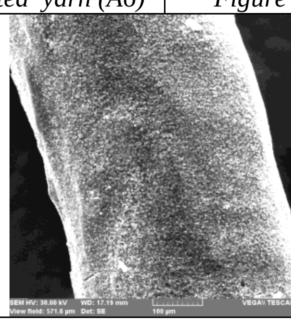


Figure 3.c: S.E.M of cotton coated yarn (A1)

Table 2: Description of the magnetic yarns used and the coatings of them

Yarn	Magentic recipe for coating	
	Coatings components (wt%)	Calculated density (g/cm^3)
A1: 100% CY, Nm 85/3	R1: 45 FB1, 52 PVA, 3 G	1,78
A2: 100% CY, Nm 85/3	R2: 33 FB1, 66 PVA, 1 G	1.57
A3: 100% CY, Nm 85/3	R3: 30 CMP, 45 PVA, 10 PU, 5 G	0,95
A4: 100% CY, Nm 85/3	R4: 40 FB1, 50 PVA, 10 PU	1,72
A5: 100% CY, Nm 85/3	R5: 40 CMP, 57 PVA, 3%G	0.90
A6: 100% SSY, 0,12g/m	R4: 40 FB1, 50 PVA, 10 PU	1,72
A7: 100% CY, Nm 85/3	R6: 50 FB1, 50 PU	2,14
A8: 100% CY, Nm 85/3	R7: 42,5 CMP, 54,5 PVA, 3G	0,89
A9: 100% SSY 0,12 g/m	-	-
A10: 100% CY, Nm 85/3	-	-

It were made 100 diameter measures for each of 10 samples on different position along the yarn randomly chosen and was obtained a average diameter and coated thickness layer value. The mass was measured using a digital scale ***Radwag Radom RS 232C,*** and was calculated the degree of charging value (table 3).

Washing test of coated magnetic yarns

The manual washing test of A1, A2, A3, A4, A5, A6, A7 and A8 with a length of 100 cm eachone was made under ISO-6330 with a SRM Tarnow UTU-4 device at 40^{0}C. by mixing 30 min. After washing, the samples were rinsed with cold clean water to remove traces of soap. The samples are dried into an Mera Lumer HUS-01 oven at 50^0 C for 25-30 min and after that weighted with a digital scale.

Magnetic measurements of coated yarns

To emphasize the phenomena occurring in the coated yarn with magnetic micro particles during the measuring of the magnetic characteristics were used standard samples of bundles of yarns fixed with epoxy resin. The apparatus used for magnetic analysis is a magnetic field meter system type MAG-ST100 with a maximum value ± 800 kA/m and the maximum induction value 3 T for cylindrical sample. Measurements were made at Technical University of Lodz, Poland.

RESULTS AND DISCUSSIONS

In the table 3 are presented the characteristics of coated samples A1-A8 and also of support yarns A9 and A10. It is observed that the charging degree vary direct way with the percent of magnetic powder from mixture and determine a different average diameter.

Table 3: The characteristics of yarns A1, A2, A3, A4, A5, A6, A7, A8, A9 and A10

Average characteristic	Sample									
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
Average mass, (g/m)	0,134	0,088	0,136	0,204	0,063	0,183	0,206	0,068	0,12	0,035
Average diameter, (µm)	332.92	312.48	333.56	335.45	305.98	305.39	344.17	313.83	292.6	256.45
Calculated density, (g/cm^3)	1,19	1,15	1,01	1,18	1	1,72	1,24	1,24	2,23	0,6
Average degree of charging(%)	79.104	68.181	79.411	86.274	55.555	84,69	86.407	58.823	-	-
Ttex, (g/km)	134	88	136	204	63	183	206	68	120	35
Average coated layer thickness (µm)	76,47	56,02	77,10	79	49,52	12,71	87,71	57,37	-	-

In the case of CY coated with hard magnetic layer (A1, A2, A4, A6 and A7) is noted that the use of the PVA determine a higher degree of charging than when using PU (figure 4a). In the case of SSY the degree of charging with magnetic mixture for the same percent of FB1 (40 wt%), is lower than CY because of the lower adherence of the mixture on yarn surface, This is confirmed also by the average diameter of coated SSY close to the average diameter of matrix SSY (figure 4b). For the yarns coated with soft magnetic layer (A3, A5, A8) PU has a proportional greater influence than PVA on charging degree (figure 5b).

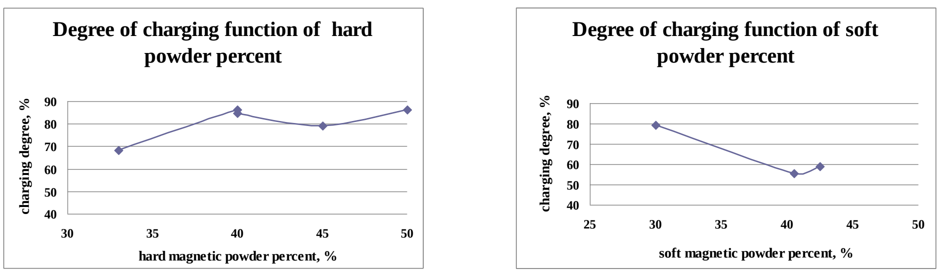


Figure 4: Degree of charging function of powder percent

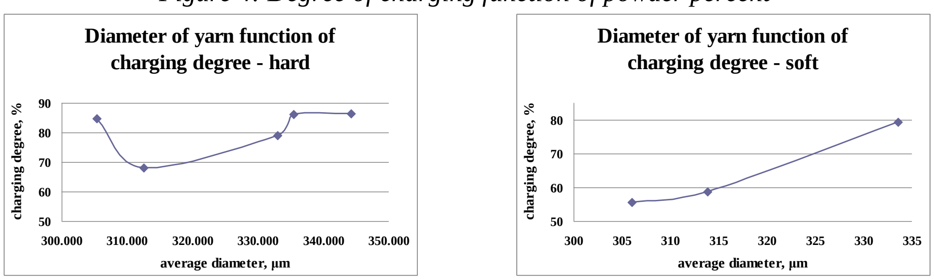


Figure 5: Average diameter function of degree of charging

The reason is given by the size of the hard magnetic particles that is higher than soft magnetic particles respectively the physical links occurring between particles and the suspension in the formulation that are different. The average yarns diameter measured increases directly proportional with the degree of charging both for hard magnetic CY (figure 5a) and for soft magnetic CY (figures 5b). It was measured the mass before and after each wash test. So, can be observed the destruction degree of yarn with magnetic cover layer of it. Thereby the wash test has a big influence for A1, A2, A5 and A8 yarns structure. The mass differences after 5 wash tests varies from a smaller value of 0,98 wt.% to 37,5 wt.% for all 8 yarns analyzed. For the yarn A1 was registered 8,2 wt. % from initial yarn mass, the yarn A2 had a the biggest destruction of the coated layer of 37,5 % from initial yarn mass This big destruction can be due to the big percent of PVA then A1. Almost the similar behaviors was registered by the yarn A5 with an amount of mass lost after 5 wash tests of 30,19% from initial yarn mass because of the too much percent of binder PVA. The yarn A8 has a smaller destruction then yarn A5 of 20, 58 wt. % from initial yarn mass having, also, a smaller percent of PVA then A5. In the case of A6 the amount of 10 wt. percentage of PU lead for improving the coating layer stability on yarn surface.

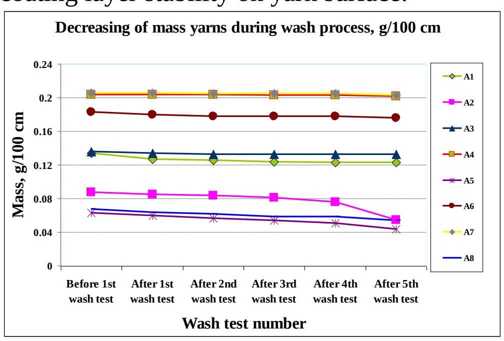


Figure 6: The weight lost after each wash tests

Therefore the degree of destruction of A6 is smaller than each one of the yarns without PU in mixing recipe with a 3,82 wt.% from initial yarn mass but is higher than yarns A3, A4, A7 because of the smaller adherence of the SS Yarn then cotton yarn. The stable behavior of the coated layers for A3, A4 and A7 is preserved; these tree yarns registered a very small destruction degree after 5 wash tests. A3 and A7 has the same 2,25 wt.% from initial yarn mass lost during wash tests and the great behavior after wash was registered by A4 with 0,98 wt.% from initial yarn mass. The cumulative graphic with all yarns mass is show below in the Figure 6.

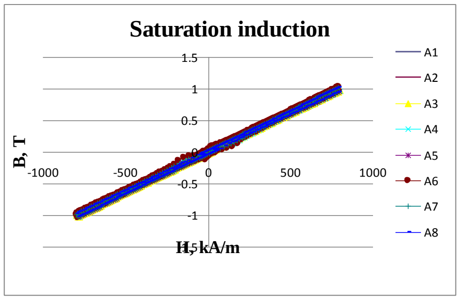
Because of the destruction degrees in different values for each yarn, it is necessary to improve the magnetic coatings layer for some yarns (A1, A2, A5, A6, and A8) but in the same time to keep constant the elasticity and softness of them and also magnetic response. In table 6 the value of the magnetic characteristics for all 8 samples are presented.

Table 6: Magnetic measurements of coated yarns

Sample no.	B_s [T]	B_r, jB_r [T]	H_c [kA/m]	jH_c [kA/m]	BH_{max} [kJ/m^3]	jBH_{max} [kJ/m^3]	μ_r
A1	1,028	0,026	-20,88	-792,64	0,11	28,42	1,05
A2	1,028	0,029	-22,77	-789,45	0,15	27,54	1,06
A3	1,027	0,028	-24,50	-795,45	0,15	29,65	1,05
A4	1,025	0,029	-22,30	-794,51	0,12	29,82	1,05
A5	1,029	0,029	-24,81	-792,50	0,17	27,96	1,06
A6	1,032	0,026	-20,82	-791,82	0,11	28,12	1,05
A7	1,028	0,038	-32,02	-790,17	12,03	12,07	1,07
A8	1,000	0,032	-26,61	-789,82	0,19	28,00	1,06

Where: Bs=saturation induction, Br=residual induction, jBr=residual magnetic polarization, Hc=coercive field, polarization coercive field, BHmax=induction maximum energy, jBHmax=polarization maximum energy, μr= sample permeability, T=Tesla, kA/m=kiloampers / meter;

The coated yarns present a magnetic response with remanence of the close values. The figure 7a present the saturation values and in the figure 7b presents the residual polarization/induction respectively coercive field values. The residual values are highlighted by zooming from saturation induction graph.



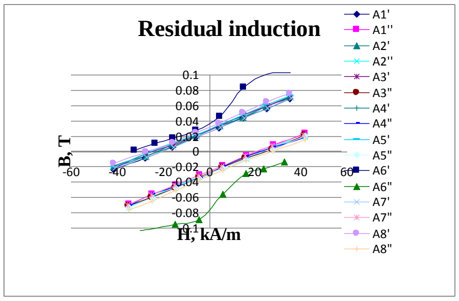


Figure 7: Coated yarns – magnetic behavior

a) Saturation induction *b) Residual induction*

The magnetic behavior is much closed for yarns cotton yarns coated with magnetic blends containing magnetic micro particles in the percent, which varies in the range 33 – 50 wt.%. In case of steel yarn it is easy to see the different shape of hysteresis with larger coercivity at charging and discharging into an external magnetic field due to its ferromagnetic structure.

4. CONCLUSIONS

- The yarns that reached a new kind of improvement by coating with magnetic blends as an alternative to use the magnetic micro powders inside of spinning polymer matrix represent new approach direction for realizing textile products with special applications such as antiradiant protection and the sensors due to the intrinsic electromagnetic waves absorption of the magnetic micro powders.
- Obtaining the composite yarns with magnetic properties can be realized using deposit around the yarn of one layer (sheath) made by fero and ferrimagnetic products, binders and plasticizers which the percent of magnetic substances doesn't overcome 50% mass proportion in the recipe. For coating was used a laboratory device that permit the deposit, calibration and thermo fixing of the layer into an electromagnetic field that orient along the yarn the magnetic dipoles and magnetizing in stripes till saturation the deposited layer.
- The utility of ferro and ferrimagnetic micro powders mix with specific binders of cotton and stainless steel has as result fixation of those on the yarn surface. Magnetic mixture realized represents a viable solution to create the composite yarns.
- The eight types of composite yarn obtained can give a conclusion regarding the charging degree of the yarn varies depending by the type of magnetic micro powder (hard and soft) and grain size by the type of yarn matrix and by the type of adhesive used.
- For the state when the magnetic powder is FBI, using PVA as adhesive material, the charging degree is bigger than situation when is used PU, and when is used CMP the charging degree is lower using PVA then PU. Depending on the charging degree, the diameter varies direct proportional.
- After the manual washing test has been observed the degree of stability higher at the composite with content of PU against to the situation of using only PVA;
- From the magnetic point of view all cotton coated yarns has similar magnetic behaviour. The coated stainless steel yarn behavior is quite different due to the ferromagnetic response at an external magnetic field.
- The future research directions include highlighting of multipolar magnetization of the composite yarns in the process of achieving in order to use them as weft yarns in weaving production.
- It aims to use other ferrimagnetics materials with higher contact capacity and use of synthetic filaments yarns with flat surfaces, to obtain a higher magnetization surfaces.

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