BEHAVIOUR OF COATED MAGNETIC WOVEN TEXTILES SUBJECTED TO HAND-WASHING

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REZUMAT. Lucrarea prezintă rezultatele comparative privind comportarea la spălare manuală a 3 mostre de ţesături magnetice. Pentru experimentări au fost utilizare 3 suporturi textile ţesute din bumbac cu fineţe diferită. Ţesăturile suport au fost acoperite cu un amestec polimeric cu conţinut de microparticule magnetice dure (hexaferită de bariu – 35%), polimer care asigură dispersia microparticulelor magnetice (acetat de polivinil – 60%) şi plastifiant cu efect emolient (glicerină – 5%). Acoperirea s-a realizat cu ajutorul unui cuţit tip raclu, urmat de un sistem de calibrare a grosimii stratului depus cu role de presare. Testul de spălare manuală a fost realizat într-o baie termostatată SRM Tarnow UTU-4, în condiţii standard. In urma ciclilor de spălare au fost măsurate masa şi grosimea, respectiv evaluată starea de suprafaţă probelor, prin analiză microscopică.

Cuvinte cheie: microparticule magnetice dure, țesături din bumbac, spălare manuală

ABSTRACT. The paper presents the comparison between the results obtained on the hand-washing behavior of 3 samples of magnetic fabrics. For the experiments, three cotton woven textile supports with different fineness were uses. The support fabrics were coated with a polymeric mixture containing hard magnetic microparticles (35 wt.% barium hexaferrite), a polymer that provides dispersion of magnetic microparticles (polyvinyl acetate- 60 wt.%) and emollient plasticizer (glycerin – 5 wt.%). The coating was made by means of a scraper, followed by a thickness-calibrating system with pressing rollers. The manual hand washing test was performed in a SRM Tarnow UTU-4 thermostatic bath under standard conditions. After the washing cycles, the mass, thickness were measured and based on microscopic analysis the samples surface area was evaluated regarding the behavior to hand washing.

Keywords: hard magnetic microparticles, cotton wovens, hand-washing

1. INTRODUCTION

The development of industrial technologies, thanks to scientific research, directly or indirectly reflects the influence on the economic and social aspects of life. These socio-economic areas are constantly looking for a harmonious development from a constructive point of view and economic efficiency. [1]

From a socio-economic point of view, the textile industry is a major user of most modern technologies and therefore, it is responding positively to a larger number of market challenges. Increasing value by integrating multifunctional elements into common textiles is a familiar line of development today. [2]

In the above context, textiles with magnetic properties (nano-micro-meso-macro fibers, yarns, textile surfaces) are actively researched during the last years thanks to their large number of possible applications: medical (monitoring of physiological functions), biomedical (MEMS, BioMEMS) [3, 4], military (protective textile clothing and non- clothing), protection against sources of electromagnetic interference [5], data security, electronic (electronic / sensors, actuators), sport and leisure, industrial niche applications [6], etc. The magnetic nature can be conferred to:

- fibers (e.g. magnetic nanofibers electrospinning, [7] magnetic microfiber extrusion [8];
- yarns (the incorporation of magnetic particles into their structure) [9], coating of spun yarns with magnetic blends [10, 11];

by:

- weaving, knitting, embroidering, or unconventional technologies using wires and magnetic fibers [12, 13];
- by polymeric coating with magnetic inclusions [14, 15, 16]

Polymeric coating of textiles is the application of a polymeric layer on a textile product in order to improve its multifunctional properties. By coating, it is possible to completely change the surface condition of the substrate, the feel and the technical performance. [17]

Making polymer blends with magnetic inclusions (particles) to cover textile surfaces in order to achieve multifunctionality is an area of interest for researchers.

Campos *et al.* provide an example of producing a magnetic textile surface through coating with polymeric solutions (polyester-polyurethane aqueous dispersion) containing composite magnetic particles marketed under the name MPQ-S11-9®. Through multipolar magnetization, the magnetic nature of the textile surface remains present even after several months.[14]

In their book, Blachowicz and Ehrmann have presented possibilities of making magnetic polyester fabrics by coating with polymer blends containing core powders with Ferricon®. Another work describes a method of coating fabrics by mono or multilayer 3D magnetic printing. The printing solution, known under the trade name of Proto-paste®, contains iron magnetic powders. [18] Onar *et al.* is presenting the possibility of obtaining textile surfaces with both magnetic and electrically conductive properties by coating a cotton fabric with an electroconductive polyaniline solution containing barium ferrite particles ($BaFe_{12}O_{19}$). [16]

This paper presents experimental research on textile surfaces coated with barium ferrite particles using polymer binders and additive companion substances.

2. MATERIALS AND METHOD

Three cotton woven fabrics, identified by A, B and C, listed in Table 1, were selected for the experiments.

Table 1. **Textile supports used for coating**

Suport	A	B	C
Fabric picture			
Yarn type	100% cotton fibers, carded, conventionally spun on ring spinning machines	100% cotton fibers, combed conventionally spun on ring spinning machines	100% cotton fibers, carded, conventionally spun on open end spinning machines
Mass per unit area, g/m^2	100	210	290
Thickness (mm)	0.6	0.78	1.01

Coating of the fabric samples was done with a viscous polymer mixture containing barium hexa-ferrite isotropic (BaFe) magnetic particles. For the calculation of volume concentration, the mass percentages of the components and their densities were used using the relation:

$$\beta_i = \frac{\frac{\alpha_i}{\rho_i}}{\sum_{i=1}^{n}\left(\frac{\alpha_i}{\rho_i}\right)} \quad (1)$$

Knowing both the percentages of mass and the percentages by volume, we have calculated the density of the mixture with following relation:

$$\rho_m = \frac{\sum_{i=1}^{n}\beta_i \cdot \rho_i}{100} \quad (2)$$

The characteristics of the mixture used and its components are shown in Table 2.

The components were mixed with a mechanical stirrer. The resulting solution was spread on the fabric samples by means of a scraper blade. The deposition of the polymeric mixture on the textile support was carried out by placing this support on a NdFeB plane magnetic plate with the magnetic induction of 0.7 T in order to orient the magnetic particles of the mixture component in the direction of the field lines.

The uniform deposition of the magnetic layer was possible by using a pressing cylinders device, of which pressure can be adjusted. With this device (Fig. 1), the thickness of the mixture deposited by the textile support was calibrated.

After drying and fixing the deposited polymer mixture, the coated fabric will preserve the orientation of the magnetic particles, this multipolar orientation being evident with the same magnetic plate on which the deposition is made (Fig. 2).

Table 2. **Characteristics of the polymer mixture**

Polymeric mixture, (α), (β)	**BaFe**	**PVAc**	**G**
BaFe (α=35%), (β=12,63); PVAc (α=60%), (β=80,99); G (α=5%), (β=1,71)	Barium hexaferite is a magnetic ferrite with the magnetoplumbite structure, which has permanent magnetic properties. BaFe was purchased from Rofep Urziceni, Romania	Polyvinyl acetate is a thermoplastic adhesive of hardness class 3, with an irreversible phase, with superior adhesive properties on cellulosic materials. PVAc was purchased from Hankel Company	Glycerin is a wetting, thickening and plasticizing agent. It was purchased from Humco
ρ_m: 1600 kg/m^3	ρ_{BaFe}: 4458 kg/m^3	ρ_{PVAc}: 1190 kg/m^3	ρ_G: 1260 kg/m^3

α – mass percentage, β – volume pergentage, ρ – density;

Fig. 1. Device for calibrating the thickness of the magnetic layer on textile fabrics

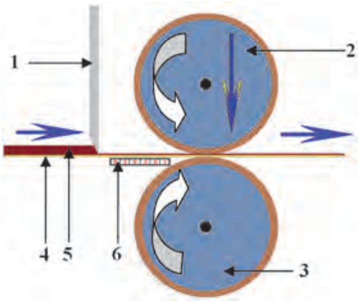


Fig. 2. Device for calibrating the thickness of the magnetic layer on textile fabrics: 1) scraper knife; 2) upper cylinder with rubber sleeve; 3) lower cylinder; 4) textile support; 5) polymeric mixture; 6) multipolar magnetic plate

The hand-washing test as a validation of the stability over time of the magnetic coating layer (with magnetic component) was performed according to ISO-6330-2000.

The microscopic images of textile supports and coated samples were done using an Olympus SZX 10 microscope equipped with an Olympus DP 72 video camera at a zoom ratio of 6.3X. For the microscopic analysis was used the Olympus Motion Solutions software 1.5.1.

The values of thickness and mass / surface area, before, after coating and after each of the 10 hand-washing tests, of the analyzed samples were obtained using a Tilmet 73-Grubosciomierz device (according to PN-EN 29073-2: 1994) and a Radwag Radon RS digital balance 232C (in accordance with SR 6142: 2007).

3. EXPERIMENTAL

For the hand-wash test of the coated textile samples has been used a glass bowl containing 500 mL of water and 5 g of granular soap. The solution was heated to 40^{0}C in a SRM Tarnow UTU-4 thermostated bath (Fig. 3).

Fig. 3. Thermostated bath SRM Tarnow UTU-4

When the desired temperature was reached and stabilized, the samples were placed in the bath where they were mixed using a glass rod for 30 minutes. After washing, the samples were rinsed with cold and clean water to remove the soap traces. After rinsing, the samples were dried in an oven at 50^{0}C for about 25-30 min. For drying, a Mera Lumer SHU-01 oven was used. Then the samples were ironed.

4. RESULTS AND DISCUSSIONS

In accordance with previous research, the mass and thickness of the coated samples increased with the increasing of the magnetic powder percentage from polymeric mixture. In this study we selected polymeric solutions containing 35% magnetic powder. Previous experience showed that the deposition on textile surfaces could be increased up to 45% magnetic powder content [10]. The percentage of 35% powder was found to be appropriate in terms of the deposition capacity. Table 3 shows images of the samples coated with the polymeric solution, the mass and thickness average values.

A 0.03 g polymeric mixture was used to uniformly coated a 1 cm^2 fabric surface. For the hand washing tests, rectangular samples with a surface area of 50 cm^2 were used.

The degree of loading (D_l) with polymeric magnetic mixture on the textile support was calculated using the following relationship:

$$D_l = \frac{m_{cs} - m_{us}}{m_{ss}} \cdot 100(\%) \qquad (3)$$

where: m_{cs} – mass of coated sample, g/m^2; m_{ss} – mass of support sample, g/m^2

A number of 10 hand-washing tests were performed on the coated variants, noted as Ac (by covering fabric A) Bc (by covering fabric B) and Cc (by coating the fabric C).

For each coated fabrics sample, 10 mass and thickness measurements were done before and after each washing test. The data has been centralized to see the differences that occur. For all numeric data obtained, the average value has been calculated.

We notice that the support A allowed a loading degree with a magnetic mixture of 154.3%, the support B allowed a loading degree of 117.05% while the support C of only 101%. Table 4 shows microscopic images of coated wovens after the last washing test (noted as Ac10, Bc10 and Cc10, respectively). These images highlight the destruction degree of coated magnetic layer. Also, Table 4 shows the mass, loss mass, thickness and thickness loss average values of washed coated wovens after the last washing cycle.

Table 3. **Characteristics of coated variants before the first washing test**

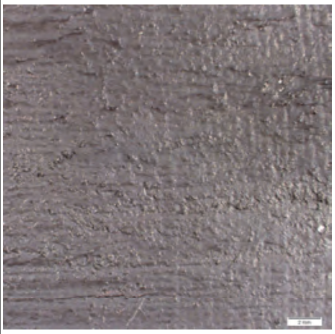
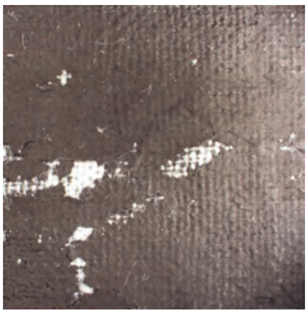
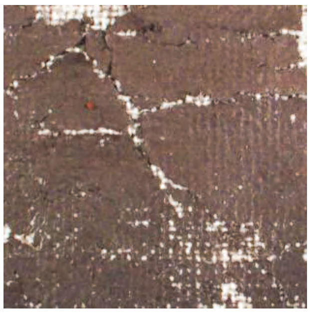
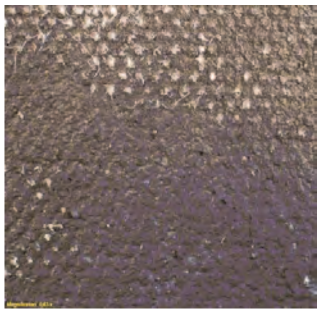
	Ac	**Bc**	**Cc**
Coated fabric image before washing test			
Mass per unit area (g/m^2)	447,5	557.5	637.5
Thickness, mm	1.03	1.42	1.37
Thickness of magnetic layer, mm	0.43	0.64	0.36

Table 4. **Characteristics of the coated samples after the last washing test**

	Ac10	**Bc10**	**Cc10**
Image of coated fabric after the 10th washing test			
Mass per unit area, g/m^2	203.6	306.6	443.8
Mass loss, %	54.5	45	30.4
Thickness, mm	0.74	1.18	1.23
Thickness loss, %	28.15	16.9	10.22

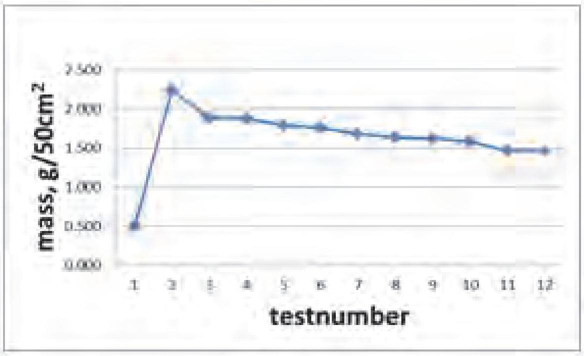


Fig.4.a. Mass variation of the Ac coated woven

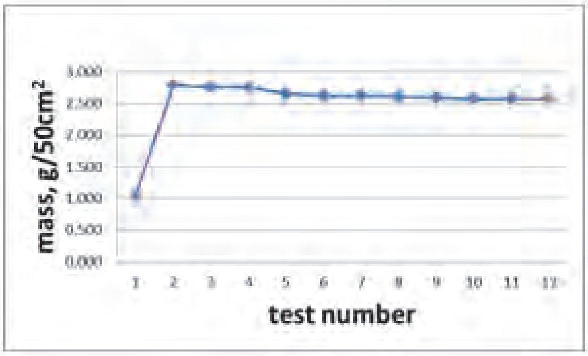


Fig. 4.b. Mass variation of the Bc coated woven

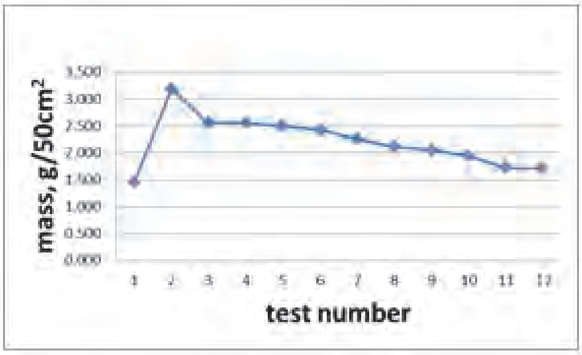


Fig. 4.c. Mass variation of the Cc coated woven
1 – mass before coating; 2 – mass after coating (before first hand wash test); 3-12 – mass after each of the 10th hand-washing tests

The data has been centralized to see the differences that occur. The diagrams shown in Figures 4a to 4c show the mass of each sample before the first washing test and after each washing test.

After the first washing test, instability of magnetic layer has been observed in special for Ac and Bc samples. These wovens suffered visible destruction of magnetic layer even after first test.

However, after the last hand washing test, the highest mass loss was registered at Ac coated sample.

The Cc coated sample had the lowest mass loss, due to type of yarns used to obtain the woven support. The magnetic layer was fixed better on the yarn surface having more fiber ends standing out of surface.

It is noted that mass losses are directly proportional to the loading degrees.

After washing, an increase in bending stiffness of Ac and Bc samples is observed as a consequence of depositing the magnetic layer on them, which is more pronounced than the Cc sample. This different bending stiffness may be due to the higher fineness of the two textile supports A and B, respectively the smaller thickness. The diagrams of Figures 5a to 5c show the thickness of each sample before the first washing test and after each test.

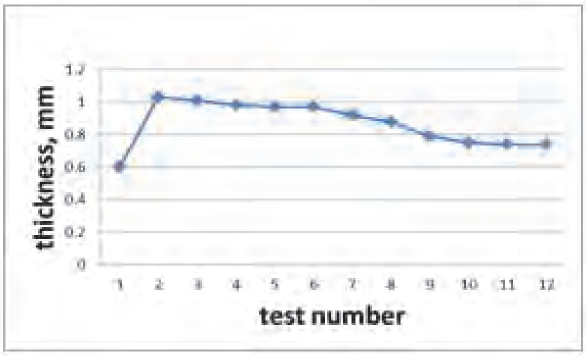


Fig. 5.a. Thickness variation of the Ac sample

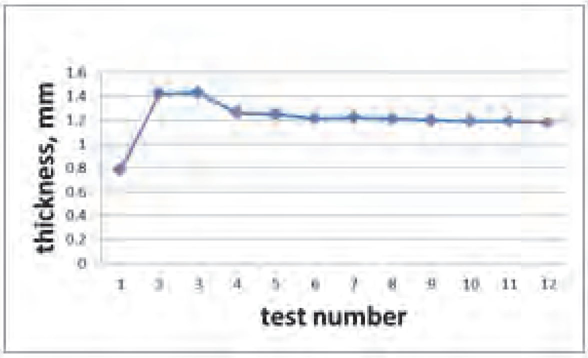


Fig. 5.b. Thickness variation of the Bc sample

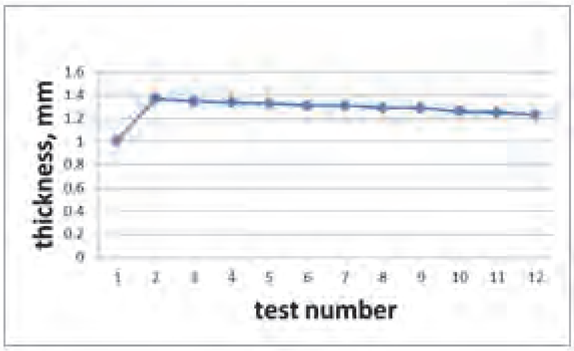


Fig. 5.c. Thickness variation of the Cc sample
1 – thickness before coating; 2 – thickness after coating (before first hand wash test); 3-12 – thickness after each of the 10th hand washing tests

Thickness losses after the 10 wash cycles are 28.15% for sample Ac, 16.9%, Bc sample and 10.22% for sample Cc. It can be noticed that the lowest thickness loss was registered at Cc sample because the magnetic solution penetrated the pores between warp and weft open end yarns more deep than in case of Ac and Bc samples.

5. CONCUSIONS

The washing behavior of samples in this study is very different. For samples Ac and Bc it can be appreciated that the coating does not meet the expectations for washing resistance. For the sample Cc, the washing tests determine the lowest losses of mass and thickness but these lose is uniformly distributed over the entire surface of the sample.

For the samples Ac and Bc there is a destruction of the magnetic layer over portions that exceed 10% of the coated surface even after the first wash.

After washing, the rate of destruction of the layer becomes very slow. The result of washing for the 3 samples considered in this study leads to the conclusion that the adhesive used in polymeric mixture must be added with substances that show better water resistance.

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