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VISCOSE BASED MAGNETIC YARNS – PHYSICAL AND MECHANICAL CHARACTERIZATION

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Abstract: *In the context of the rapid growth in the number of electrical and electronic devices and accessories that emit electromagnetic energy in different frequency bands we present and characterize here several magnetic functionalized viscose twisted yarns. A 100% viscose twisted staple yarn was covered through an in-house developed process with a polymeric solution containing micrometric sized barium hexaferrite magnetic powder. The in-house developed process allows deposition of micrometric thickness polymeric paste layer on the yarn surface. Barium hexaferrite is a hard magnetic material exhibiting high chemical stability and corrosion resistivity, relatively large saturation and residual magnetization and microwave absorbing properties. Five different percentages of the magnetic powder in the polymer solution were used, i.e. ranging from 15 wt% to 45 wt%. Physical characterization shows a very good adherence between the highly hygroscopic viscose staple fibers and the polymeric solution that contains polyvinyl acetate and polyurethane as binders. SEM images evidenced the fact that the polymeric solution penetrated more than 1/3 of the yarn diameter. The concentration of magnetic powder in the polymeric solution has a direct influence on the coating amount, diameter and density. The mechanical characterization of the coated yarns revealed that the breaking force is increasing with increasing magnetic powder content up to o certain value and then decreased because the magnetic layer became stiffer. At the same time, the elongation at brake is decreasing.*

Key words: *viscose coated yarn, magnetic particles, polymeric coating solutions, adherence, mechanical properties*

1. INTRODUCTION

Nowadays textiles find a myriad of applications in almost all fields. Textiles are everywhere around us, influencing our mood, protecting us, helping us to increase our performance, etc. Ensuring functional performance correlated with comfort characteristics, sustainability and environment protection is a priority in our current society [1], [2]. Increasing textile value through the integration of multifunctional elements in domestic textiles is a familiar trend line today. Development of textile elements, obtained by functionalization offers a wide range of applications [3]. Special emphasis is placed nowadays on developing eco and human friendly products which lead to reduced harmful materials consumption from non-renewable resources and minimize the need for landfills.

There is a growing interest in the field of intelligent textiles, which are sensitive to changes in the environment, through a series of features such as: electrical conductivity, photo-luminescence, UV protection, catalytic and antistatic characteristics, antimicrobial and self-cleaning characteristics, that prevent or limit the spread of fire, magnetic characteristics and electromagnetic protection [4], [5]. The growth and advancement of the electronics industry or the widespread use of various electronic and communications equipment, information technology and automation, aerospace and medicine, etc. are leading to many problems of electromagnetic interference (EMI). With the rapid growth in the number of electrical and electronic devices and accessories that emit electromagnetic energy in different frequency bands, it becomes essential to limit and protect electronic equipment against all these sources of electromagnetic interference [6]. Textiles are dielectric materials which can acquire magnetic properties thanks to magnetic functionalizing particles attached to them [7]. Magnetic textile yarns are composite yarns exhibiting properties which are specific to magnetic materials (anisotropy, attraction / rejection, magnetic flux, electromagnetic shielding properties at very high frequencies (microwave)). There are various ways to obtain magnetic textile, as outlined in references [8] and [9]. One of these ways is through coating with a polymer solution containing magnetic inclusions. This article is presenting our studies on the effect of optimizing the polymeric coating solution (paste type) with different percentage of functionalizing magnetic powder on an artificial twisted staple yarn support [10], [11].

2. MATERIALS AND METHOD

2.1. Materials used

A 100% viscose twisted staple yarn with fineness 70/2 (metric count) has been selected for this study which was performed in a similar manner to the one in reference [10] involving cotton yarns. Viscose was chose for its hygroscopicity and a high degree of retention of aqueous solutions. The main physical characteristics detailed in Table 1 were determined according to the SR 13231-95 and SR ISO 1833-95 standards.

***Table 1:** Physical characteristics of viscose yarn support*

Characteristic	Uncoated yarn - (A) - 100% viscose	
	Single yarn	**Twist yarn**
Measured diameter (μm)	-	200.8
CV of diameter (%)	-	6.69
Fineness Nm (m/g)	-	70/2
CV (%)	-	1.45
Twist/meter	846.0	483.0
CV (%)	3.68	5.45
Twist direction	Z	S
Hairiness/10 cm	-	187

The selected support yarn was analyzed from structural point of view (scanning electron microscopy) with a FEI Quanta 200 equipment with a GSED detector. The analysis was performed both along the longitudinal direction (Figure 1a) as well as in the cross section (Figure 1b).

For the functionalization, we prepared five polymeric solutions (paste type) containing different percentages of magnetic powder as described in [12]. These exhibited different densities. The densities of polymeric solutions increased from 1.26 g/cm^3 for a content of 15 wt% magnetic powder up to 1.69 g/cm^3 for a content of 45 wt%. We used polyvinyl acetate (PVA) and polyurethane (PUR) as binding polymers, micrometric sized barium ferrite powder ($BaFe_{12}O_{19}$) - BF as functionalizing hard magnetic material and glycerine (G) as recipe plasticizer. BF has magnetic residual in the absence of an applied magnetic field in addition to excellent chemical stability and corrosion resistance [13], [14], [15], [16]. The mixtures were used for coating of viscose support yarn. In accordance with experimental optimization plan described in [10] and followed in the preparation of the coating solutions, coating of the viscose support yarn A lead to the following magnetic inclusions: A1-15 wt%; A2-20 wt%; A3-30 wt%; A4-40 wt%; A5-45 wt%.

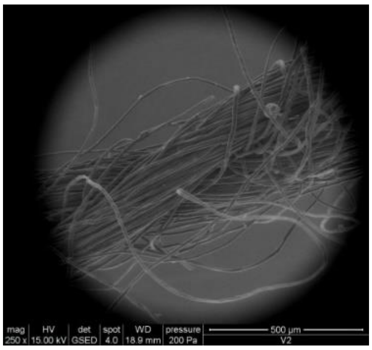

Fig. 1a: *Support yarn - SEM longitudinal position*

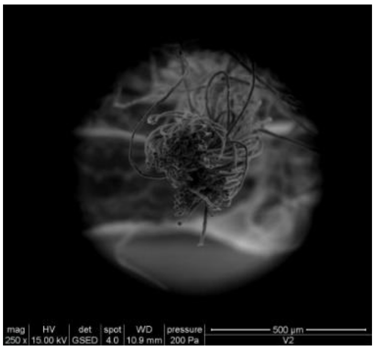

Fig. 1b: *Support yarn - SEM cross section*

2.2. Methodology

The viscose yarn was coated using an in-house setup which allows deposition of micrometric thickness polymeric paste layer on the yarn surface. An applied magnetic field is inducing orientation of the magnetic particles included in the paste. The constant magnetic field is generated by a DC electromagnetic induction bobbin with air gap [11]. The coating process was performed at ambient temperature. After coating, the yarn leaves the deposition room through a calibration system of spinneret type and arrives at the hot air dryer and fixing system.

3.RESULTS AND DISCUSSION

3.1. The adhesion mechanism

The physical characterization using SEM showed a strong adherence between the polymeric solution and the viscose support yarn. Compared to our previous research, where we used cotton as support yarn, the use of viscose allows a deeper penetration of the polymeric solution in the yarn fibers [10]. This is due to higher hygroscopicity and hairiness of the yarn. SEM images evidenced the fact that the polymeric solution penetrated more than 1/3 of the yarn diameter. The air gaps between fibers that were not bonded by coating solution were present only in the center of the yarn. The coating layer was eccentric to the yarn axis. Figures 2 a-e show SEM images of the cross sections of the coated yarns: A1 (Figure 2a), A2 (Figure 2b), A3 (Figure 2c), A4 (Figure 2d), A5 (Figure 2e).

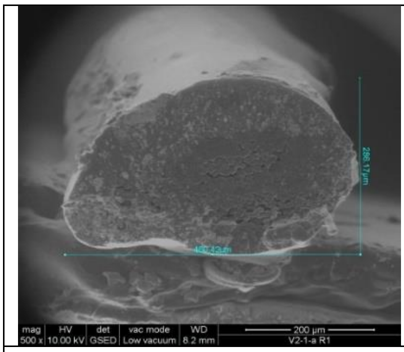

Fig. 2.a: *A1 coated yarn*

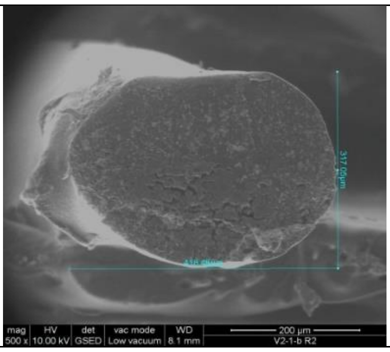

Fig. 2.b: *A2 coated yarn*

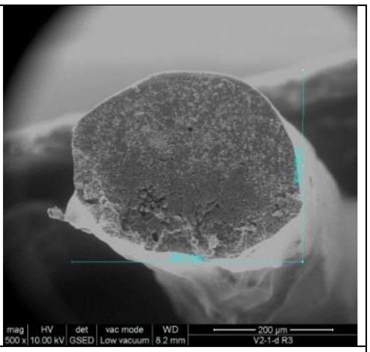

Fig. 2.c: *A3 coated yarn*

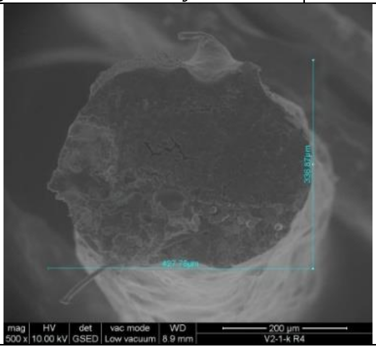

Fig. 2.d: A4 coated yarn

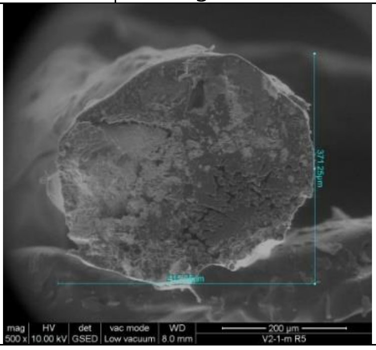

Fig. 2.e: *A5 coated yarn*

The size of barium ferrite magnetic inclusions was in the range 300 nm - 1.3 µm. From the SEM structural characterization we concluded that coating solutions with smaller amounts of magnetic powder penetrated more into the structure of the yarn, leading to a thinner layer, than solutions containing a higher percentage of the magnetic inclusions. In the latter case, the polymeric solutions become more viscous and thus penetration into the yarn structure is smaller which means a thicker layer at the surface of the yarns.

Table 2 shows that the apparent measured diameter of the coated yarns increases from 289,6 µm in A1 to 354,4 µm in A5. The increase is linear and directly proportional with the amount of magnetic inclusions in the coating solutions.

The degree of charging of these 5 coated yarns was also increasing by ~81% in the case of A1 and by more than 83,7 % in case of A5 which has a higher content of magnetic inclusions. The degree of charging was calculated using equation 1.

$$\mathrm{D_c} = \frac{\mathrm{m_{Ai}} - \mathrm{m_A}}{\mathrm{m_A}} \cdot 100(\%) \qquad \textbf{(1)}$$

where:

- D_c degree of charging;
- m_{Ai} – coated yarn mass (i=1÷5), g/m;
- m_A – uncoated yarn mass, g/m.

The mechanical characteristics of both uncoated and coated support yarns were obtained with a Tinius Olsen H5KT tensile testing machine. The average values of the breaking strength and elongation at break, shown in Table 2, have been performed according to EN ISO 2062/2010.

Table 2: *Physical characteristics of uncoated support yarns and coated yarns*

Characteristics	**Uncoated Yarn**	**Coated Yarn**				
	A0	**A1**	**A2**	**A3**	**A4**	**A5**
Measured diameter (µm)	200.8	289.6	302.0	324.8	348.0	354.4
CV (%)	6.69	7.7	7.99	11.0	11.69	12.49
Degree of charging (%)	-	81.09	81.26	81.38	83.35	83.72
Breaking strength (N)	6.75	7.58	7.25	7.18	6.75	6.58
Elongation at break (%)	11.44	13.73	13.07	12.38	11.09	11.48

The breaking strength was higher for A1, A2 and A3 coated yarns than for the support yarn and increased slightly with the magnetic inclusion content (15wt%÷30wt% magnetic content). This is due to the fact that the thicker coating layer bonds stronger to the fiber components than the thinner one. For a higher magnetic inclusion content (>30 wt%), the strength decreased because the magnetic layer became stiffer. On the other hand, an increased coating layer thickness leads to a decreased elongation to brake of the yarns.

4.CONCLUSIONS

The design and development of the coated yarns with hard ferrimagnetic inclusions in polymeric matrix represents a new approach of functionalized textiles with potential applications in EMI shielding of electronic devices. In this research the support yarn was an artificial 100% viscose staple yarn with metric count 70/2 designed for woven fabrics.

Five coating solutions with various mass percentages of magnetic powder, varying in range from 15% to 45% wt, two polymers in liquid state and glycerine have been used to optimize the coating solutions. The binding polymers in the coating solutions showed a very good adherence to the viscose yarns due to high hygroscopicity and hairiness of the yarns. The solutions penetrated deep in the yarn structure without air gaps between fibers in coated layer.

From the physical characterization of the coated yarns we concluded that both the diameter and the degree of charging depend on the percentage of the magnetic inclusions in the coating solutions. Both properties exhibit a linear variation with the magnetic content.

The breaking strength of the coated yarns was higher up to a certain degree of charging value (< 82%) than the breaking strength of the support yarn and then decreased directly proportional with the increasing of magnetic content.

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