TENSILE PROPERTIES OF KNITTED FABRICS FOR EMR SHIELDING

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Abstract: *This work deals with the tensile properties of knitted fabrics for electromagnetic (EMR) shielding. These properties are very important in determining the wearing behavior of textiles, especially knitted fabrics. The obtained results are discussed in relation to the effect of the presence of SS wire and its location in the knitted structure on the complex of tensile properties. In this study the knitting on 8 gauge flat-bed machine has been chosen as main technology. The metal wire (stainless steel 0.12 mm) is used separately or together with 30x2 tex cotton yarn. Two samples are produced which are differ by steel percentages and positioning in the structures.*

Keywords: *knitted fabric, half Milano rib, EMR, tensile properties, stainless steel, cotton*

1 INTRODUCTION

The development of new materials for EMR shielding and their shielding properties characterization are of great research interest [1], [2], [3]. These materials have good functional and thermo-physical properties. Investigation of the mechanical properties of shielding knitted fabrics is very important as well, for estimating the appearance of the product, the comfort of its operation, and the ability for dimensional stability and ease of processing.
The properties of clothing made from knitted fabrics, in contrast to products made from woven fabrics or other materials, are determined, first of all, by the structural features. At the same tine the main mechanical property of knitted fabric, which affects the design, manufacture and operation of the product, is tensile. The tensile is the ability of a knitted fabric to deform under the loads, and after their removal, partially or completely recover [4].

2 MATERIALS AND METHODS

2.1 Materials

For this study, the half Milano rib knitted structure was chosen as in the previous study it demonstrated the highest shielding efficiency [2] and good thermo-physical properties [3] due to the arrangement of the structural elements.
Samples were produced on 8 gauge flat knitting machines, using 0.12 mm diameter stainless steel (SS) wire and 30 x 2 tex cotton yarn. The reference sample (sample A) of half Milano rib is knitted from cotton yarn only. The two variants of on introduction of the stainless steel wire into the knitted structure were used. Firstly (sample B), SS wire and cotton yarn were fed separately and feeders were changed after every two courses. As a result, 2 courses of rib 1x1 are formed from cotton yarn and 2 from a SS wire according to the interlooping repeat (Fig. 1 a). Secondly (sample C), the SS wire was fed to the knitting area along with the cotton yarn. Therefore, all structure elements are formed from both cotton yarn and SS wire (Fig. 1 b). The structural characteristics of knitted fabrics are presented in Table 1.

a b

Figure 1 Photos of knitted fabrics: a – Sample B; b – Sample C

Table 1 Structural parameters of knitted fabrics

Properties		Sample *A*	Sample *B*	Sample *C*
SS wire content [%]		0	7	29
Weight per unit area [gram per sq. meter]		670±8	300±2	680±6
Thicknes [mm]		2.377	1.802	2.046
Loop length [mm]	SS wire	-	8.15±0.09	7.56±0.08
	Cotton	8.03±0.10	7.30±0.09	7.30±0.08
Stitch density per 10 mm	courses (Nc)	3,8±0.1	4.0±0.1	3.0±0.1
	wales (Nw)	4.5±0.1	4.0±0.1	3.0±0.1

2.2 Methods

The tensile properties of knitted fabrics were measured by KES-F (Kawabata Evaluation System), Tensile and Shear Tester (KES-F-1) [5] in the Technical University of Liberec. All measurements were made both in wale and in course directions on face side. Specimens of 20 cm × 20 cm were used. All the fabric samples were conditioned under the temperature of (20 ±2) °C and relative humidity of (65 ± 5) % for at least 24 hours before the experimental studies which were conducted in the same conditions. The mean value of four parallel measurement was used for analyses. The following properties were tested:

- Linearity of load-extension curve (LT) [-];
- Tensile energy per unit area (WT) [gf·cm/cm^2];
- Tensile resilience (RT) [%];
- Elongation at max. tensile force (EMT) [%].

3 RESULTS AND DISCUSSION

The parameters obtained for tensile hysteresis curves are defined in Table 2 and Fig. 2.

Table 2 Tensil properties of knitted fabrics

Sample	Direction	Parameters			
		LT *[-]*	*WT* *[gf.cm/cm²]*	*RT* *[%]*	*EMT* *[%]*
A	wale	0.940	1.505	37.93	13.578
	course	0.800	4.245	34.08	44.726
	average	0.870	2.875	36.00	29.151
B	wale	0.747	1.074	28.69	12.050
	course	1.002	0.903	65.54	7.726
	average	0.874	0.989	47.12	9.888
C	wale	1.838	0.107	60.00	0.491
	course	1.085	0.571	42.25	4.450
	average	1.461	0.339	51.12	2.470

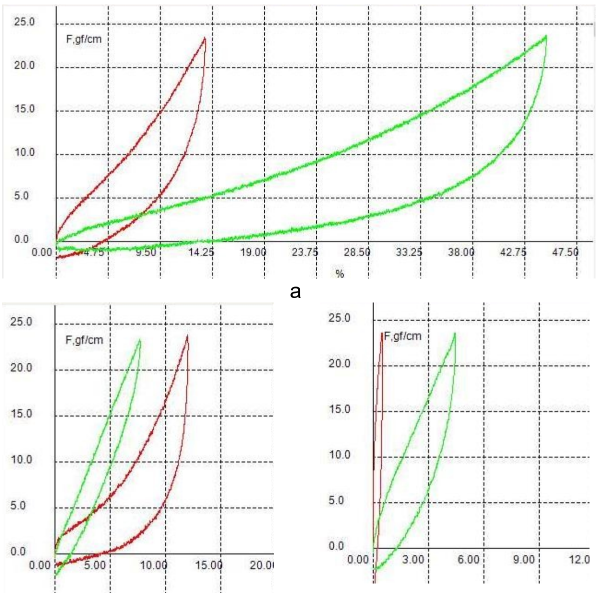

Figure 2 Tensile curves of knitted fabrics both in warp (red line) and weft (green line) directions: a - Sample A; b – Sample B; c – Sample C

As is known from previous studies [4], the LT parameter characterizes the linearity of the tensile curve and is an indicator of wearing comfort. As the value of LT increases, the extensibility of the knitted fabric decreases in the initial range of deformation, which indicates a more stable structure of the knitted fabric and the product from it. Of the three tested samples, Sample C has a more stable structure, in which the SS wire was fed to the knitting area along with the cotton yarn ($LT_{average}$ = 1.461). The structure of the fabric becomes more stable compared to cotton Sample A ($LT_{average}$ = 0.870).

The next indicator of the shape stability of the knitted fabric is its resilience. Resilience characterizes the stability of the knitted product throughout the entire period of its operation and evaluates the ability of the fabric to restore its original shape after removing the external load. RT is the parameter by which the fabric's ability to recover after tensile deformation is numerically evaluated. Sample A is characterized by the lowest RT value, which indicates the softness of the fabric ($RT_{average}$ = 36.00). With an increase in the amount of steel wire in the structure of the knitted fabric of Sample B (SS - 7%) and Sample C (SS - 29%), the tensile strength increases ($RT_{average}$ = 47.12) and ($RT_{average}$ = 51.12), respectively. Higher tensile resilience ensures greater stability of the dimensions of knitted fabrics after removal of deformation. As the tensile strain (EMT) increases, the elasticity of the fabrics decreases, that is, the shape stability and ability of the knitted fabrics to return to their original shape and size decreases. Of the investigated fabrics, Sample A has the highest tensile strain value ($EMT_{average}$ = 29.151). The knitted fabric with the highest content of steel wire Sample C (SS - 29%) has the lowest value of tensile strain ($EMT_{average}$ = 2.470). As the tensile strain (EMT) decreases, the tensile energy (WT) also decreases. Low extensibility of knitted fabrics corresponds to low tensile energy, while the tensile resilience increases. These regularities are observed for all tested samples of knitted fabrics.

4 CONCLUSION

In this study, the tensile properties of knitted fabrics, which have a steel wire in their structure and are intended for protection against electromagnetic radiation, were studied. Such knitted materials should ensure the stability of the shape and size of products made of them during the entire period of their operation, therefore, the study of the stretchability of these fabrics is an urgent task. It was found that the knitted fabric with a steel wire content of 29% and its simultaneous interweaving with cotton yarn has higher dimensional stability due to high tensile strength and low tensile deformation compared to sample A, which is softer and stretchier.

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