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INFLUENCE OF TREATMENT ON THE BENDING BEHAVIOUR OF ANTISTATIC TEXTILES

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***Abstract**. Mechanical properties of knitted fabrics are very important when using them for different applications, such as clothing, technical textiles, composites, and e-textiles, etc. In this research, the bending behavior of 1x1 rib fabric and half-Milano knitted fabric developed using the eight cotton / antistatic polyester blend ratios such as 90 % cotton / 10 % antistatic polyester, 80 % cotton / 20 % antistatic polyester, 70 % cotton / 30 % antistatic polyester, and 65 % cotton / 35 % antistatic polyester was investigated. An M-100 (MATSUYA, Japan, 2016) 14E gauge automatic flat knitting machine was utilized with fixed machine settings for the development of investigated fabric samples. The effect of fabric dying, softening with AQUASOFT®SI hydrophilic softener, and Polygiene VO-600 antibacterial finish on the bending stiffness of the investigated knitted fabrics was evaluated along both courses and wales directions for both sides of the fabric (technical face side & technical back side). The method of free fold loop suggested by Raymond H Plaut was applied to test the bending stiffness of the developed antistatic knitted textile fabrics. The test results of the bending stiffness testing revealed that the bending stiffness increased after the dying, softening, and treatment with antibacterial finish compared to the untreated (raw) fabrics samples. The samples cut in the wale direction of the fabric were stiffer than the course direction samples. Stiffness for the fabric technical face side of the fabric & technical back side was found similar in the case of 1x1 rib knitted fabrics due to their well-balanced structure for both technical sides. However, small differences in terms of technical sides were determined for the investigated half-Milano rib fabrics.*

***Keywords:** bending stiffness; 1x1 rib; half-Milano rib; antistatic polyester; knitted fabric.*

1. Introduction

In contrast to other materials, weft-knitted constructions have an entirely elastic property, particularly in the transversal direction. Their elasticity, which is subjective by yarn twist, loop interlocking, and the desire to occupy a minimal energy position, influences their application potentials [1]. Knit fabrics could be developed using an extensive variety of textile fibers, yarns, and machine settings, picking a variety of knit stitch combinations for fabric patterns. As a result, they may show dissimilar qualities [2]. Physical comfort is a significant constraint intended for customers when buying a specific garment. Soft textile fabrics deliver a high drape and a soft touch that fascinates customers. The level of comfort of the fabric depends on the construction of the knitted fabric [3]. Fabric mechanical qualities such as shear, tensile strength, bending stiffness, etc., could be used to describe physical comfort.

Telli & N. Ozdil [4] showed that the bending stiffness of fabrics is affected by the percentage of natural and synthetic fibers present in the yarn mixture. Fabric bending stiffness reduces as the percentage of synthetic fibers increases, and vice versa. Chidambaram et al. [5], & Majumdar et al. [6] showed that the cross-sectional shape of the fibers also disturbs the bending rigidity of textile fabrics. The mass distribution around the neutral axis of the fiber significantly affects the bending rigidity. If the distributed mass is away from the axis, it will tend to increase the bending rigidity of the fiber [7]. M.E. Yüksekkaya et al. [8] showed in their study that thick or course yarns impart higher bending stiffness in the fabric than thin or fine yarns. Regardless of the yarn's linear density, several other manufacturing procedures impart different properties to the yarns. Manufacturing procedures also deliver erratic degrees of bending stiffness in the yarn that

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results in fabric bending stiffness. H. A. Kim & S. J. Kim [9] presented that the knitted fabric developed with air vortex yarn showed more bending stiffness than the compact and ring spun yarn. [10]. M.S Choi and S.P. Ashdown [11] showed that the fabric density and the higher tightness factor of the knitted fabric increased the bending stiffness. Loose fabric with slack fabrics construction and a long stitch length have lower bending stiffness. A combination of chosen knitting stitches for the development of knitted fabric also determines the stiffness of the fabric, and the least stiffness values are always seen in the cases of all knit materials. While the knit and the miss stitch and knit and tuck stitch combination delivered dissimilar fabric bending stiffness [3]. The mechanical performance of knit fabric is found to be anisotropic due to a significant change in yarn movement in the course and wale directions [12][13]. From the literature review it was evident that major work on bending stiffness was done in the domain of the effect of the structural parameters of the fiber, yarn and fabric, while the effect of treatments was not studied in detail. It was also noted that most of the researchers used KES-F and FAST methods for measuring the bending stiffness. This study aimed to investigate the effect of fabric dyeing and finishing treatment on the bending stiffness of the antistatic knitted fabrics developed by the free fold loop method proposed by Raymond H Plaut.

2. Materials and Methods

Haining TAIERXIN New Materials Co., LTD manufactured commercially available blended cotton/antistatic polyester yarns that incorporate carbon black for the manufacture of the antistatic knitted fabric. From the 3-ply or 4-ply yarns (Table 1) the raw samples of 1×1 rib knitted fabrics (MR) and half-Milano rib knitted fabrics (MM) knit patterns having the same thickness, wales and courses densities were knitted using an automatic flat knitting machine (model: M-100, 14E, MATSUYA, Japan).

Table 1

Characteristics of the investigated antistatic textiles

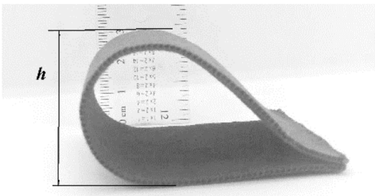
Sample code		Fiber composition (%)	Yarn linear density (tex)	Fabric density (cm^{-1}) wales	Fabric density (cm^{-1}) courses	Loops density (cm^{-2})	Fabric thickness (mm)	Fabric area density (g/m^2)
			1×1 rib knitted fabrics					
MR1	raw	90 % CO, 10 % PET	28.1×3	15.0±0.5	10.6±0.6	159.0	1.95±0.04	597.73±0.09
	S+P			16.0±0.0	12.0±0.0	192.0	1.80±0.02	603.60±0.05
MR2	raw	80 % CO, 20 % PET	28.1×3	15.0±0.5	11.0±0.0	165.0	1.95±0.05	577.60±0.10
	S+P			16.0±0.0	12.0±0.5	195.2	1.80±0.01	608.10±0.06
MR3	raw	70 % CO, 30 % PET	18.5×4	14.6±0.5	10.6±0.6	154.8	1.90±0.03	565.73±0.05
	S+P			16.0±0.0	12.0±0.0	192.0	1.87±0.02	616.40±0.09
MR4	raw	65 % CO, 35 % PET	14.8×3	15.8±0.5	11.6±0.6	183.3	1.89±0.02	511.07±0.12
	S+P			16.0±0.0	12.0±0.5	188.8	1.81±0.02	509.60±0.08
			Half-Milano rib knitted fabrics					
MM1	raw	90 % CO, 10 % PET	28.1×3	14.0±0.5	13.8±0.5	193.2	1.96±0.04	587.33±0.09
	S+P			16.0±0.0	18.0±0.0	288.0	1.83±0.01	641.20±0.05
MM2	raw	80 % CO, 20 % PET	28.1×3	14.2±0.5	13.8±0.5	196.0	1.95±0.05	588.40±0.09
	S+P			16.0±0.0	18.0±0.0	288.0	1.79±0.02	658.30±0.05
MM3	raw	70 % CO, 30 % PET	18.5×4	13.0±0.5	13.8±0.5	179.4	1.91±0.04	544.67±0.05
	S+P			16.0±0.0	18.0±0.0	288.0	1.94±0.02	667.60±0.06
MM4	raw	65 % CO, 35 % PET	14.8×3	14.0±0.5	12.2±0.5	170.8	1.91±0.03	498.13±0.07
	S+P			16.0±0.0	16.0±0.0	256.0	1.82±0.02	506.70±0.04

Note: CO – cotton; PET – antistatic polyester.

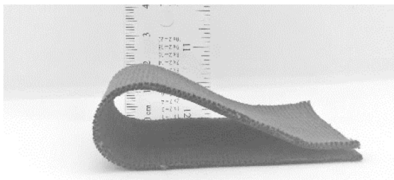
The raw knitted textiles samples developed were divided into two groups to evaluate the influence of treatment on the bending thickness of the investigated knitted fabrics. The first sample group was made up of unprocessed (raw) knitted materials. The second sample group was made up of dyed, treated with softener, and antibacterial finish samples (S+P). The developed knitted fabric was dyed with the THIES MINISOFT (Germany) dyeing machine. Softener and antibacterial finish was applied with the SANTEX CH9555 TOBEL machine (Switzerland). Hydrophilic softener (Aquasoft®SI) (20 g/l) was applied at 40-50°C temperature maintaining 5-6 pH for 15-30 min. Antibacterial finish Polygiene VO-600 (25 g/l) was applied by a normal padding process at 30-40°C temperature for 20-30 min.

The fabric thickness (in mm), the densities of the wales and courses (in cm^{-1}), and fabric area density (in g/m^2) of the studied samples was calculated according to the standards ISO 5084, ISO 3801, and EN 14971, respectively.

The free fold loop method established by R H Plaut was used to assess the bending stiffness of the tested materials [14]. The bending stiffness test principle of the free fold loop method (Figure 1) states that in the free fold loop method, one end of the fabric strip is placed on the other end freely on a horizontal plane surface. The fabric strip will form a loop and then the length of the loop (*h)* from the upper side to the bottom of the loop is measured with the help of a ruler. An average value of the loop height *(h)* is used to calculate the bending stiffness. The setup of the free fold loop method to measure the length of the loop *h* (mm) of the investigated fabric samples is shown in Figure 1. The height was measured for five samples cut along both the wales and the course direction in each sample group. The coefficient of variation did not exceed 5 %.



a



b

Figure 1 – Height measurement of free fold loop-shaped specimens: (a) – wale direction; (b) – course direction.

The bending stiffness *B* was calculated according to equation (1):

$$B = 1.32\ \frac{(wh^3)}{(b)} \quad (1)$$

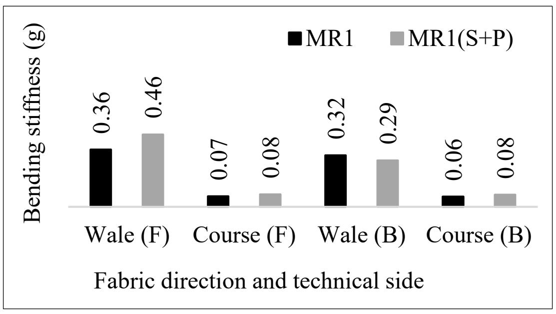
where: *B* is the free fold bending stiffness (g); *w* is the fabric weight in (g/mm^2); *h* is the loop height (mm), and *b* is the fabric specimen width (mm).

3. Results and Discussion

The results of the stiffness for the 1×1 rib knitted fabrics (MR) are presented in Figure 2, and for the half-Milano knitted fabrics (MM) in Figure 3.

Comparison of bending stiffness results with respect to fabric structure demonstrated that half-Milano rib fabrics (Figure 3) are stiffer than 1x1 rib fabrics (Figure 2) due to the difference in fabric structure influenced by different combinations of knit stitches, as mentioned by M.S Choi and S. P. Ashdown [11].

In Figure 2 it can be seen that the bending stiffness of 1x1 rib knitted fabrics was found almost the same for both wale (F) and wale (B) samples due to the well-balanced structure of 1x1 rib knitted fabrics on both the technical face side and the technical backside.



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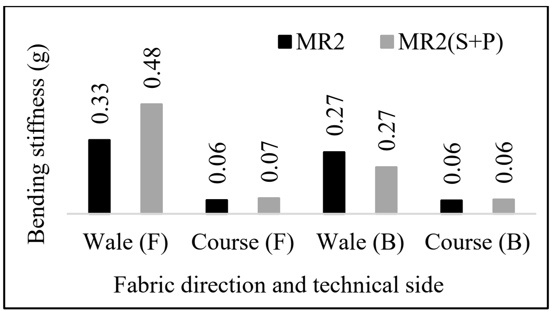

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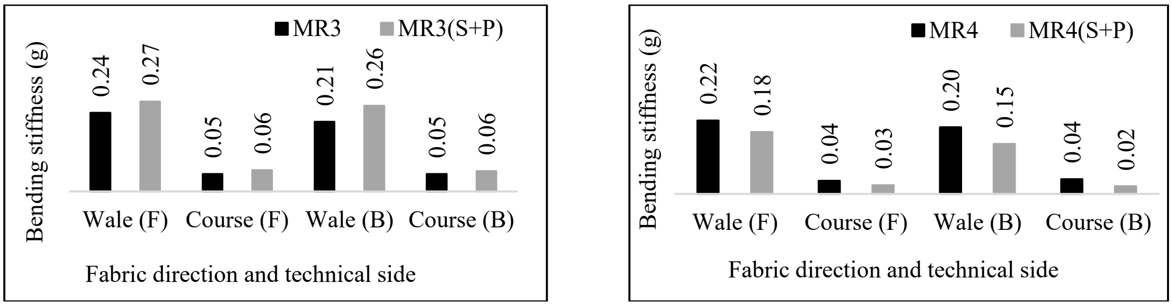
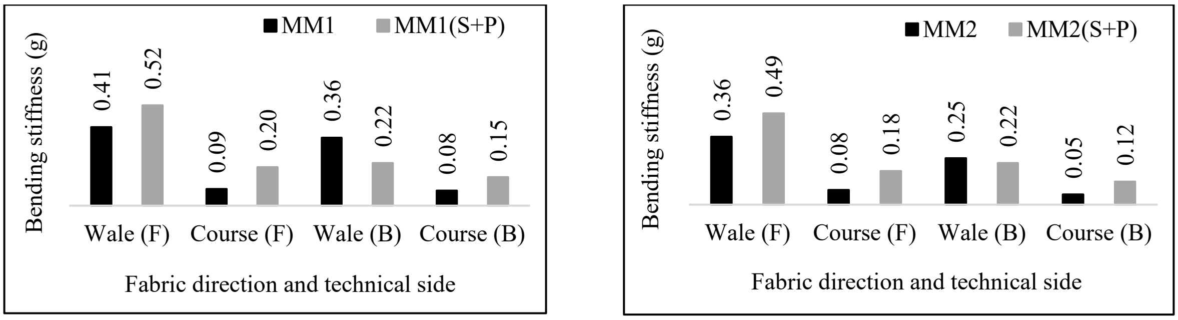


c d

Figure 2 – Bending stiffness of 1x1 rib knit fabrics (raw samples: MR1, MR2, MR3, MR4 and treated samples: MR1(S+P), MR2(S+P), MR3(S+P), MR4(S+P)); (B) - technical backside; (F) - technical face side of the fabric



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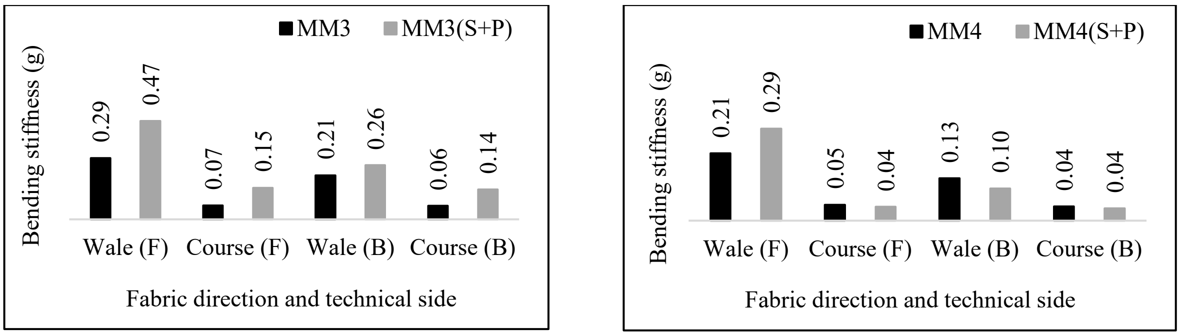

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Figure 3 – Bending stiffness of half-Milano rib knitted fabrics (raw samples: MM1, MM2, MM3, MM4; treated samples: MM1(S+P), MM2(S+P), MM3(S+P), MM4(S+P)); (B) - technical backside; (F) - technical side of the fabric.

An opposite situation was observed for the half-Milano knitted fabrics in Figure 3 showing small differences in the bending stiffness of the wale (F) and wale (B) specimens due to the unbalanced structure of the half-Milano knitted fabrics, as it was also found similar in the work of N. Emirhanova and Y. Kavusturan [15]. Lower bending stiffness was found in the course direction of knitted fabric samples than in the wale direction. This tendency could appear due to the absence of long straight vertical columns of loops (wales) in the fabric course direction, since the continuous presence of loops in wales reinforces each other to withstand external stress throughout the length of the fabric sample. Therefore, it results in high bending stiffness.

Evaluation of influence of the fabric dying, softening, and antibacterial finish treatment on bending stiffness of both investigated knitted fabric samples (1x1 rib & half-Milano knitted fabrics) exhibited an increase in bending stiffness due to treatment compared to raw knitted samples. Y. Wei et al. mentioned that it may be explained by the presence of a large amount of cotton fibers in the yarns that can swell [16]. Additionally, a higher absorption of moisture in the cotton fiber may occur due to the removal of natural waxes. Therefore, after treatment, cotton / antistatic polyester knitted fabrics swollen due to moisture absorption and later shrunk resulting in the higher bending stiffness of the treated samples compared with the raw samples.

4. Conclusion

The free fold loop method proved to be a highly practical way to assess the bending stiffness of cotton and antistatic polyester knitted fabrics before and after treatment, according to the findings.

The influence of fabric treatments on the bending stiffness of the developed antistatic knitted fabrics was significant. It was noticed that after dyeing, softening, and treatment with the antibacterial finish, knitted fabric samples became stiffer than the raw knitted fabrics due to the high content of cotton fibers in the yarn blends.

In addition, it was determined that the fabric structure affects the bending stiffness of 1x1 rib knit fabrics and half-Milano rib fabrics. While analyzing both raw and treated samples groups, it was found that half-Milano rib knit fabrics are stiffer than 1x1 rib knit fabrics. On the basis of fabric direction, it was shown that the wale direction of all specimens has the higher bending stiffness than the course direction. The bending stiffness of the technical face side (F) and technical back side (B) of the knitted fabrics was found to be different for half-Milano rib knitted fabrics but similar for 1x1 rib knitted fabrics.

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