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EVALUATION OF THE PERFORMANCE PROPERTIES OF FABRICS CONTAINING RECYCLED COTTON FIBRE

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Abstract: *Recycling and reusing of textile waste as a resource can be an important opportunity to reduce environmental pollution and make a great contribution to sustainable development of society. Recycling cotton waste makes it low-priced and high return value. This way it can be easily industrialized and commercialized to extend the life cycle of cellulose resources. The aim of this research was to investigate the performance properties of fabrics made from recycled cotton and virgin polyester blends. The fabrics were knitted using different knitting constructions while keeping the yarn count and fabric content constant. The study focused on evaluating the pilling and elasticity properties of the fabrics and the effect of knit structure on these properties. Especially pilling is one of the performance characteristics that fabric manufacturers receive feedback from their customers and as it is stated in the literature, it should be improved. The results showed that knitting type had a significant impact on pilling and elasticity values. It was observed that the napping process negatively affected the pilling property as it caused mechanical deformation in the fabric. The findings of this research can help manufacturers and designers to select the appropriate knitting construction to achieve the desired performance properties in fabrics made from recycled cotton and virgin polyester blends. This research contributes to the ongoing efforts to promote sustainable practices in the textile industry.*

Key words: *Recycled cotton, pilling, elasticity, recycling, sustainability.*

1. INTRODUCTION

Worldwide production of fibre closely reflecting the consumption of textile products has nearly doubled in the last 20 years. Increasing from 58 million tonnes in 2000 to 109 million tonnes in 2020, it is estimated to increase another 34% in the next 10 years [1,2]. Cotton was the second most-produced fibre with a 23% share in worldwide fibre production in 2019 [3]. Intensive pesticide, fertilizer and water use, social problems in cotton planting and harvesting have a significant share in textile-related environmental problems [4]. Therefore, recycling cotton waste at all phases from harvest to usage can significantly decrease the cotton environmental burden by eliminating agricultural effects [4]. In cotton-containing waste products, due to dyeing and blending, sorting and separation are difficult and therefore the quality of the recycled products is not stable. An effective way of recycling post-consumer waste cotton is needed to produce higher quality and higher value-added products, decrease waste cotton production, and eliminate the environmental impacts of landfilling and incineration. Moreover, recycled cotton has a high potential and it is also a sufficient starting material for the recycled cotton industry.

However, recycling cotton waste is often problematic because cotton textiles are mixed with other natural and chemical fibres and textile dyes. Furthermore, the cotton waste materials are not proper for garment manufacturing because of the lower quality of recycled fibres. Current recycling methods of cotton waste consist of mechanical, chemical and biological recycling. The mechanical recycling method includes short technological processes and is low-cost [5].

Textile products are generally produced as blends to increase performance, quality features, durability and hand value and to achieve cost savings. Polyester fibre provides better performance in combination with any type of yarn due to its higher strength, resiliency, resistance to most chemicals, quick-drying, wrinkle resistance and easy care properties [6]. Since recycled cotton fibres have a short structure, mixing these fibres with polyester fibres adds strength to the yarn and facilitates spinning. In addition, fibre flys during knitting or weaving can be reduced by blending recycled cotton fibres with polyester fibres [7]. The fabric structures in which recycled cotton and virgin pes are used together do not meet the quality expectations for products with higher added value. There are some problems regarding the elasticity properties and surface unevenness of the fabrics. The pilling problem observed in fabrics is one of them. The most important fabric feature affecting pilling properties is fabric structure (knitted or woven), fabric texture or weave type, fabric density and fabric weight.

In this research, recycled Cotton - virgin PES blended fabrics with different knit structures at the same yarn count were determined. Elasticity and pilling properties, which are expected to be developed in recycled fabrics, were taken into consideration and tests were carried out. This research contributes to the field, as these properties significantly affect the acceptability and long-term use of the fabric for clothing.

2. EXPERIMENTAL

2.1 Materials

In the scope of the research, the commonly used fabric weave types were chosen as main parameter and 5 fabric constructions were evaluated. As seen in Table 1, all fabrics were knitted using 20/1 Ne yarns containing 70% r-Co and 30% v-PES. Since the yarns get thicker with the increase in the recycled cotton content due to the shorter fibre length, 20/1 Ne yarn count was chosen in this study which also commonly preferred for sweatshirt production. The cotton fibre was recycled from fabric scraps which are pre-consumer wastes. In this type of recycling, the collected scraps are sorted out according to their colour as well as their colour tone. Afterwards, the cotton scraps are turned into fibre by a textile shredding machine (Figure 1). The cotton bales are blended with virgin polyester in the blow room to achieve the quality of the rotor spinning process due to the shorter fibre length of recycled cotton. For this research, the yarns were knitted in five different constructions as presented in Table 1 in the original colours of recycled cotton. After the knitting process, the fixation was performed on all fabrics by the stenter machine. No chemical treatment was performed from defibering to knitting making cotton recycling more sustainable.

Fig. 1: The textile shredding machine (left) and defibred cotton (right)

The fabric constructions were determined for sweatshirt production for the winter season considering the aim of the research.

Table 1: The fabric properties

Fabric Code	Yarn Count (Ne)	Fabric Composition	Fabric Construction	Post-treatment
F1	20/1	70% r-Co 30% v-PES	2x2 Rib	-
F2	20/1	70% r-Co 30% v-PES	Three-thread fleece	Napping
F3	20/1	70% r-Co 30% v-PES	Single jersey	-
F4	20/1	70% r-Co 30% v-PES	Two-thread fleece	-
F5	20/1	70% r-Co 30% v-PES	Pique	-

2.2 Methods

The performance properties of fabrics were evaluated regarding the use of a sweatshirt as a winter garment. Therefore, the related tests presented in Table 2 were performed.

Table 2: Fabric tests, testing instruments and used standards

Fabric Tests	Testing Instrument	Test Standard
Mass Per Unit Area	Sartorius Scales	EN 12127
Thickness	SDL Atlas	ISO 5084
Elasticity	Zwick Z010 (Roell)	ISO 20932-1
Pilling	Martindale Tester	ISO 12945-2

For good elasticity, the fabric tends to regain its original size and shape soon after the force causing the deformation is removed [9]. Therefore, recovery becomes possibly the most important factor for the performance characteristics of a sweatshirt as the elbow joint undergoes regular exposure to movement. During the elasticity tests, the distance between clamps was arranged to 100 mm and the applied force was set as 35 N. Five repetitions were generated in a row and the average value was taken as the elongation in per cent. All fabrics were tested both in length and width wises. The equation used for the elongation values is presented in Eq. 1 [9, 10]. To measure the unrecovered elongation values, the reference length was marked as 50 mm distance on the testing specimen before the elasticity test and 30 minutes after the test, the marked distance was re-measured. Eq. 2 was used for calculating the unrecovered elongation [10].

$$Elongation\ (\%) = S = \frac{E-L}{L}\ x\ 100 \qquad \textbf{(1)}$$

(S = Elongation in percentage; E = The extended length of the specimen, L = The initial length of the specimen)

$$Unrecovered\ Elongation\ (\%) = C = \frac{Q-P}{P}\ x\ 100 \qquad \textbf{(2)}$$

(C = Unrecovered elongation of the specimen; P = The initial distance marked on the specimen before the elasticity test)

For the statistical analyses, IBM SPSS 20 program was used in the study. Determination of the effects of abric type on the elongation parameters were tested using One-way ANOVA tests with the significance level of α=0.05.

3. RESULTS AND DISCUSSION

The mass per unit area, fabric thickness and pilling test results obtained are presented in Table 3. As expected, the 2x2 Rib (F1) and fleece fabrics (F2 and F4) had greater mass per unit area values due to the knit structure. Additionally, F2-coded fabric had the greatest fabric thickness as a result of the napping process.

Table 3: The results of mass per unit area, fabric thickness and pilling tests

Fabric Code	Mass per Unit Area (g/m2)	Fabric Thickness (mm)	Pilling Grade
F1	330.3	0.47	3
F2	325.2	0.58	2
F3	158.4	0.21	3
F4	266.7	0.39	3-4
F5	188.5	0.28	2-3

In this research, since the yarn count was kept constant, the effect of knitting structure on pilling was examined. F2-coded Three-thread Fleece fabric had the worst pilling grade (Figure 2). The one that gives the best pilling grade result is the F4-coded Two-thread Fleece fabric. These two fabric structures (F2 and F4) have similar front-face surfaces, but it is thought that the napping process applied to the F2 fabric on the back face has a negative effect on the pilling property of the front face of the fabric. As stated in the literature, knit construction has a significant effect on the pilling property. It was found that Rib and single jersey fabrics have similar pilling grades [11]. In support of this, 2x2 Rib and single jersey fabrics had the same pilling grade the pique fabric was found to have a similar pilling grade with these two fabrics. In the structure of the pique fabric, the tuck stitches towards the fabric surface generate the three dimensions causing pilling formation on the surface [12].

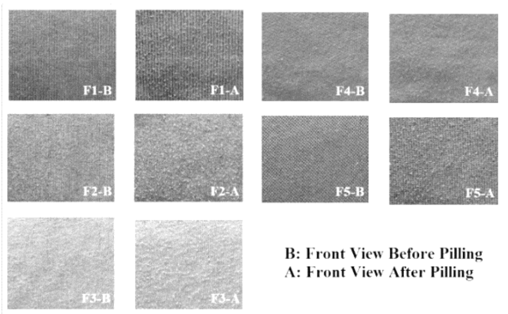

Fig. 2: Front view of fabrics before and after pilling tests

The elasticity values of fabrics were given in Table 4. Regarding data obtained, the fabric knit construction had a significant effect on the elasticity values of the fabrics both wale-wise (p= 0,00) and course-wise (p= 0,00). The elongation values wale-wise of 2x2 Rib fabric (F1) and single jersey fabric (F3) were found to be very close to each other as well as the highest values. These values support the statement that the longitudinal elongation of rib knits is limited and close to the longitudinal elongation of a single jersey [13]. As expected, 2x2 Rib fabric (F1) was found to have a very high elongation value course-wise compared to other fabrics due to the effect of knit structure. The elongation values of Two-thread fleece fabric (F4) were found to be the lowest, followed by Three-thread fleece fabric (F2). The fabric in the pique knit structure had a higher elongation value in the course direction.

When the unrecovered elongation values of these fabrics were examined, two-thread fleece fabric (F4), which had the lowest elongation value, had as well the lowest permanent elongation value as expected (Table 4).

Table 4: The fabric elongation and unrecovered elongation test results

Fabric Code	Elongation (%)		Unrecovered Elongation (%)	
	Wale-wise	Course-wise	Wale-wise	Course-wise
F1	43.94	309.59	9	41
F2	18.67	56.54	3	11
F3	43.92	69.23	9	13
F4	14.42	27.01	3	7
F5	32.32	98.29	5	31

Figure 3 gives unrecovered elongation values versus fabric thickness values for each fabric structure. As supporting the research conducted by Kawasaki and Ono (1968), the elasticity properties of knitted fabrics depend mostly upon the knit construction more than fabric mass per unit area and fabric thickness. This statement was supported in this research by performed statistical analyses; in which the statistically significant effect of fabric construction was found on fabric unrecovered elongation values fabrics in both wale-wise (p= 0,00) and course-wise (p= 0,00) [14].

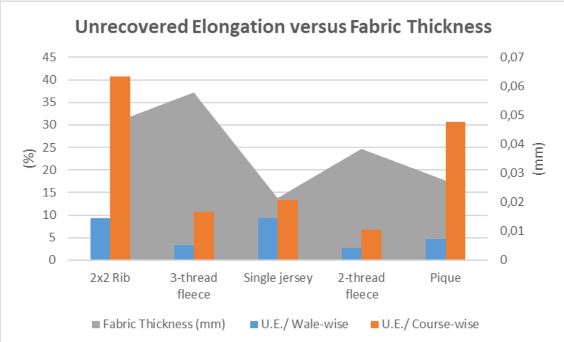

Fig. 3: Unrecovered elongation values versus fabric thickness values

4. CONCLUSIONS

In this research, performance properties of recycled cotton and virgin polyester blended fabrics were investigated. Fabrics were knitted in different knitting constructions by keeping the yarn count and the fabric content constant. The pilling and elasticity performances of these fabrics were evaluated and the effect of knit structure on these properties was investigated.

According to the results obtained, it was seen that knitting type had a significant effect on pilling and elasticity values. In addition, since the napping process causes mechanical deformation in the fabric, it was observed that it affects the pilling property negatively. Moreover, fabric elasticity is better to be judged by observing the knit construction other than the fabric thickness and mass per unit area values.

The study highlights the importance of expanding the use of recycled cotton in value-added products instead of conventional cotton. Additional research is needed to evaluate and develop fabric properties in order to achieve this goal.

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