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Effects of Enzymatic Treatment on Various Spun Yarn Fabrics

Abstract
Pilling and fuzz, which were not a problem at all in previous years (especially for cotton fabrics), have become a major problem recently. Fibre type, the yarn spinning system, fabric type, and finishing process play an important role in the pilling properties of fabrics. In this study, single jersey fabrics knitted with 100% combed, carded and open-end cotton yarns were used. An enzymatic process for fuzz reduction was applied at different stages, and the effect of this on pilling, strength, weight loss and the colour differences of the fabric were tested. Previous studies on this subject were carried out with small-scale samples, and therefore do not reflect the facts exactly. For this reason, all the phases of this study were specifically carried out under common working conditions like those prevailing in industry.

Key words: *knitted fabrics, spinning systems, pilling, enzymes, bio-polishing.*

Introduction

The change, development and globalisation of the world have brought up new notions and developments in the textile sector, in accordance with all the other sectors. The number of features expected from textile products has increased due to changes in the buyers' expectations and their awareness of quality and environment. For example, pilling is one of the major undesirable and serious problems in apparel and textile products. It does not cause an unsightly appearance or bad handle properties, but it has an accelerating effect on the rate of fibre removal from the yarn structure, and hence materially reduces the service life [1].

Fabric pilling is a complex phenomenon comprised of different stages, and it is influenced by several factors. Fibre type and cross-sectional shape, yarn type and construction, fabric type & construction and fabric finishes play an important role in the pilling properties of fabrics [2].

Many researchers have reported that the spinning system affects the pilling resistance of fabrics. The yarns produced by different spinning systems have structural differences that are expected to impact upon pill resistance [3-5]. The essential steps of ring spinning are opening, cleaning, carding and drawing of the fibres and spinning them into yarn with twist. So, ring-spun yarn has real twist and good fibre orientation. But in an open-end spinning system, the fibres of a sliver are fed into the rotating rotor, and the twist is inserted as the yarn is removed from the rotor and formed into the yarn. Rotor spin yarn also has real twist but poor fibre orientation, with fibres wrapped around the yarn core.

As a consequence of the difference in the spinning methods, the yarn constructions are different. OE yarns have a twisted core and loosely wrapped sheath with trailing loops, while ring-spun yarns are well aligned along the axis (Figure1). Ring-spun yarns have good fibre orientation. As a result of this, the strength of ring-spun yarns is 15-20% greater than that of OE spun yarns. But OE yarns have lower strength and higher elasticity than the corresponding RS yarn. Due to the differences in spinning methods, RS yarns have approximately 20-40% higher hairiness than OE yarns [6,7].

Pilling is a very important problem, principally for knitted fabrics rather than woven fabrics. Although knitted fabrics have many advantages such as higher production rates along with lower production costs, comfortable and softer fabric structures, the pilling problem remains an important objection because of the slack fabric structure.

The problem associated with fuzz can also be eliminated in order to improve and maintain quality during the garment's

Figure 1. Photographs of ring and open-end yarns.

life by removing the fuzz, by using treatments such as singeing or by applying a surface active agent such as silicon softener to soften the surface of the fabric, or by enzymatic bio-polishing. As a general rule, woven fabrics are singed to remove protruding fibres and give the fabric a smooth handle and surface appearance. On the other hand, knitted fabrics are not normally singed or defuzzed. Singeing involves the risk of scorching the fabric, whereas the use of surface-active agents reduces the water absorbency of the fabric. They are also washed out from the fabric, which eventually makes them rough again. However, enzymatic removal of the fuzz is absolutely safe, efficient and permanent as it is carried out under mild chemical and physical conditions with accurate control [8,9].

The enzyme most widely used in finishing processes involving cellulosic fibre is cellulase. This enzyme is used extensively in the bio-polishing of cellulosic fabrics. Bio-polishing can be applied to the fabric to remove the pills and fuzz from fabric surface, to reduce the tendency of pilling, to improve the smoothness, drape, flexibility and lustre [10]. Bio-polishing consists of a cellulase enzyme treatment to give a partial hydrolysis of cotton; so the short fibre ends are hydrolysed, leaving the surface of the fibres free and providing a more even look [11,12]. But it should be considered that there is also a loss of strength related to the amount of weight reduction.

In this study, an enzymatic process for fuzz reduction was applied to the knitted fabrics made from different kinds of spun yarns at three different stages; the effect of these process on pilling, strength & weight loss and the colour differences of the fabric were tested.

Table 1. *Physical properties of yarns.*

Parameter	Unit	Combed	Carded	Open-end
Count CV	%	1.7	1.5	0.8
Twist	TPI	20.50	20.90	20.80
Tenacity	cN/tex	14.2	13.8	9.5
Breaking elongation	% E	5.6	5.6	4.4
Variation of strength	% CV	7.5	7.8	8.0
Unevenness	% U	10.2	12.1	12.8
Thin places (-50%)	-	2	17	88
Thick places (+50%)	-	19	175	142
Neps (+200%)	-	32	310	36
Hairiness	-	5.9	6.9	4.9

Experimental

Materials

100% open-end, carded and combed ring-spun 20 tex (Ne 30) cotton yarns, produced from the same blend, were used. The physical properties of the yarns are tabulated briefly in Table 1. In this research, single jersey fabrics knitted from the above-mentioned yarns were used.

Enzymatic processing

Bio-polishing process was applied to the samples along with different finishing steps:

- Enzymatic treatment after pre-treatment.
- Enzymatic treatment after dyeing.
- Enzymatic treatment after pre-treatment and also dyeing.

The cellulase enzyme Gempil 4L Connect from the Gemsan Chemical Company was employed. The fabric samples were dyed with Reactive Blue 19 dyestuff. All tests were carried out in mill conditions. Enzymatic treatments were carried out in an industrial jet dyeing machine at 50°C for 45 minutes in a dyebath containing 1% acidic cellulase [13].

Investigation methods

Weight loss

After the enzymatic treatments, the weight losses of the treated fabrics were inspected. The amount of weight losses were calculated according to the following formula:

$$\%W_L = (W_1 - W_2)/W_2$$

where:

W_1 - the weight of fabric before enzymatic treatment,

W_2 - the weight of fabric after enzymatic treatment.

Strength loss

Bursting strength tests were performed according to ISO 2960, appropriate to the diaphragm method. The bursting strength values in kPa (kG/cm^2 × 10^{-2}) and the bursting heights were measured.

ΔE value

The colour intensity values of the dyed fabrics were measured by using the HunterLab Colour Quest II instrument.

Pilling

The pilling resistance of the fabrics was determined using a Martindale pilling and abrasion tester, according to ISO 12945-2 [14]. We rated the samples for 500, 1000, 2000 and 5000 revolutions respectively for three couples of the test sample at each trial.

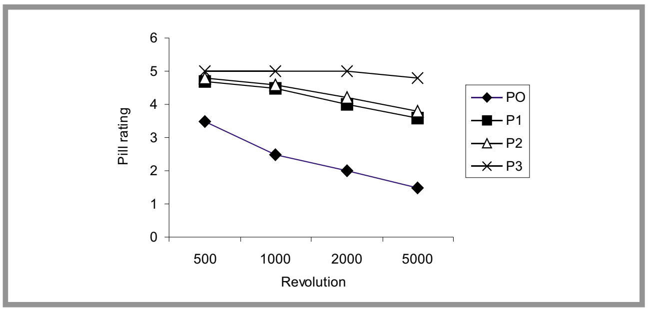

Figure 2. *Pilling rates of fabrics knitted from combed yarn; 0 - untreated fabric, 1 - enzymatic treatment after pre-treatment, 2 - enzymatic treatment after dyeing, 3 - enzymatic treatment after pre-treatment and also dyeing, P - combed, K - carded, OE - open-end.*

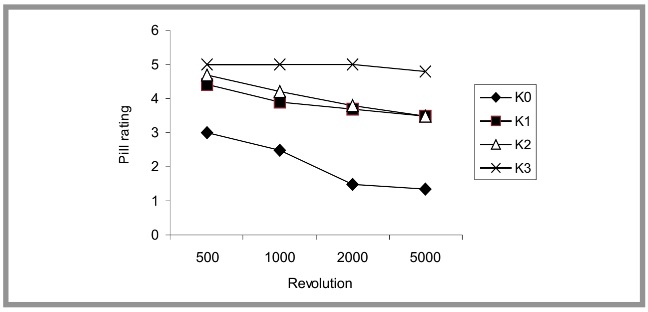

Figure 3. *Pilling rates of fabrics knitted from carded yarn; 0 - untreated fabric, 1 - enzymatic treatment after pre-treatment, 2 - enzymatic treatment after dyeing, 3 - enzymatic treatment after pre-treatment and also dyeing, P - combed, K - carded, OE - open-end.*

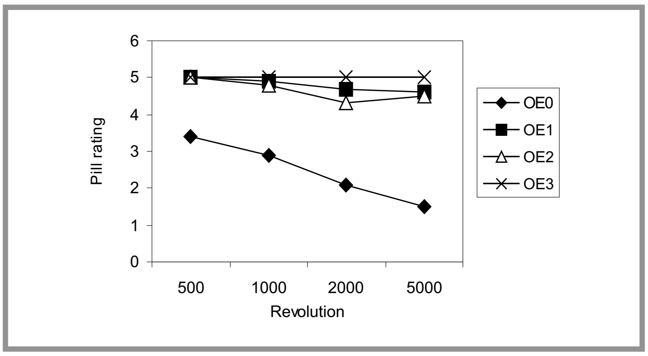

Figure 4. Pilling rates of fabrics knitted from open-end yarn; designations as in Figure 2.

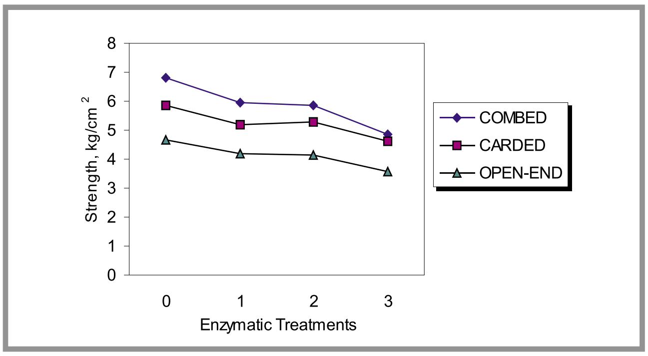

Figure 5. Bursting strength outcomes of fabric samples; designations as in Figure 2.

Results and Discussion

Pilling

First, untreated fabrics knitted from open-end, carded and combed yarns were tested for pilling. After the evaluation of these results, it was observed that the pilling resistance ratings of the fabric samples knitted from combed yarn and from open-end yarns were similar to each other, and there was no significant difference between them. The pilling resistance of open-end yarn-based knitted fabrics and combed ring-spun yarn-based knitted fabrics were better than the carded ring-spun yarn-based knitted fabrics. It was observed that, when the number of turns of the Martindale Instrument was increased up to 5000 t/m, both ring- and open-end yarns demonstrated higher pilling values.

When the fabric samples were tested after enzymatic treatment for pilling, it was established that the best pilling ratings came from the open-end yarn-based knitted fabric samples. It was observed that the knitted fabric samples from carded yarn had the worst pilling tendency, while the fabric samples from combed yarn were somewhere between. However, we found that if enzymatic treatment was applied two times, the pilling ratings for all the fabric samples were similar, approximately 5. But we should warn the reader of the inevitable consequences of applying the enzymatic treatment twice, namely loss of weight, strength and possible deviation in colour shade. Single jersey fabrics have been rated separately in order to observe the effects of yarn spinning systems on pilling properties.

Figures 2, 3 and 4 show that the enzymatic treatment after pre-treatment and dyeing affects the pilling tendency without causing any significant deviation. The graphics also show that the twice-performed enzymatic process gives the best pilling rating outcomes.

Effects of enzymatic processes on strength

The bio-polishing process partly hydrolyses the cotton, which has a negative effect on fabric strength level. Fabrics from combed yarns gave the best strength values for untreated and enzymatic treated in three different stages, rather than fabrics from carded and open-end yarns.

The fabric samples' strength loss caused by enzymatic treatment after pre-treatment or dyeing processes is nearly the same in all type of fabrics, approximately around 11%. In fabric samples enzyme-treated twice after pre-treatment together with the dyeing processes, loss in strength is about 25 % in average, and the fabric samples from combed yarn exhibit a noticeably higher loss of strength.

Effects of enzymatic processes on fabric weight

After the bio-polishing process, 1-5 % loss in fabric weight is an expected result. This amount shows the efficiency of the process. Weight loss of enzymatic-treated fabric samples after pre-treatment was slightly higher than for those which were enzymatic-treated after dyeing. The reason for this is the high number of process phases, the high amount of mechanical forces and the long process period, which cause the removal of the fuzzes from the yarn surface. When the weight loss is compared according to the yarn spinning system, the fabric from carded yarn had the highest value while the open-end yarn had the lowest. The amount of weight loss that occurs after the double enzymatic treatment was significantly higher.

Effects of enzymatic processes on colour change

The colour differences (ΔE) of fabrics after enzymatic processes at different steps and untreated fabrics were measured. As Figure 8 shows, the greatest colour difference values were observed in the fabric samples that had been enzyme-treated twice after pre-treatment together with dyeing processes.

Analyses of Results

In accordance with the results of this study, we can assert that bio-polishing enables the fuzz to be removed to a remarkable degree, substantially reducing the tendency to pilling. We observed that the worst pilling properties occurred on the carded yarn-based knitted cotton fabrics which had been treated with ordinary

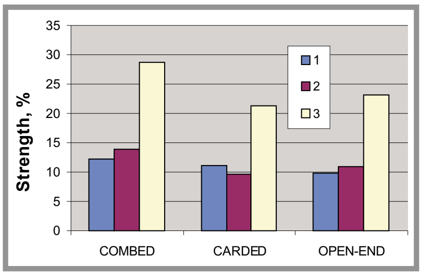

Figure 6. Bursting strength loss (%); designations as in Figure 2.

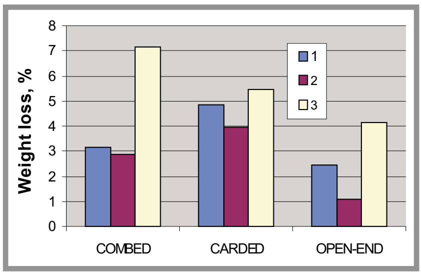

Figure 7. Weight loss (%); designations as in Figure 2.

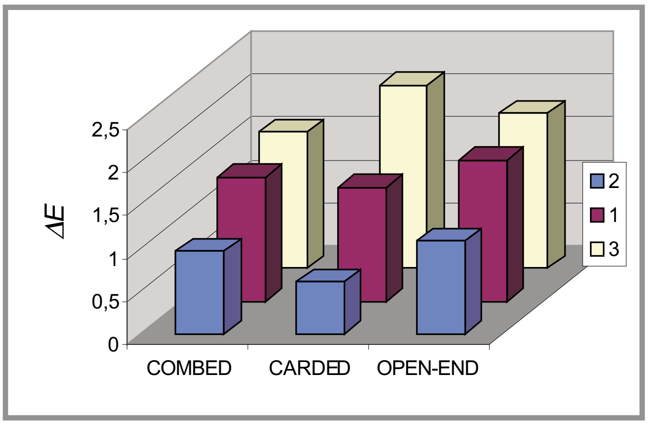

Figure 8. Colour differences (ΔE); designations as in Figure 2.

chemicals without enzymes. The lower pilling ratings of samples from carded yarn can be attributed to the hairier structure of the carded yarns with fibres that partly protrude from the yarn nucleus. This yarn structure causes fibre fuzz, as the protruding fibres accumulate the abrasion forces. On the contrary, open-end yarns display less hairiness, and combed yarns have a well-aligned long fibre structure. Consequently, the pilling tendency of the fabrics knitted from those yarn types is significantly lower.

Open-end yarn-based knitted fabrics exhibit excellent enhancement in pilling properties. But it should be noted that the open-end yarn characteristics cause coarser fabrics to be produced. This will interfere with the enhancement of the enzymatic process, as bio-polishing targets finer fabrics for fashionable apparels.

We have observed that there was no significant difference between the pilling behaviours of the fabric samples, irrespective of whether the fabric samples had been pre-treated or dyed before the enzymatic process.

Once applied, enzymatic treatment causes a strength loss which falls within acceptable limits. But readers should be cautioned that twice-applied enzymatic treatment causes severe strength loss beyond acceptable limits. This may be explained by the mechanism of bio-polishing. Enzymes are surface-active; during the first bio-polishing process, they will most probably act mainly on the protruding excessive fibrilious surfaces, and also on the outer surfaces of the yarn. If we employ a second bio-polishing process, enzymes will react on the increased surface area, and they will damage the yarn sufficiently to cause severe strength and weight loss. Although twice bio-polishing improves pilling properties, this will take place at the expense of basic fabric requirements such as strength and weight.

The reasons for the slightly higher weight loss of fabric samples enzymatically treated after pre-treatment than those after dyeing are the high number of process phases, the high amount of mechanical forces and the long process period, which cause the removal of the fuzzes from yarn surface. When the weight loss is compared according to the yarn spinning system, the fabric from carded yarn has the highest value while that from open-end yarn has the lowest. The amount of weight loss that occurs after the double enzymatic treatment is significantly higher. Because of the higher loss of weight, the double enzymatic treatment is not recommended for normal applications.

When the colour difference values of dyed fabrics are examined, one readily notices more severe deviations in colour shade on the twice enzymatically treated fabrics. This is most probably because of the difference in light reflection together with yarn surface modification. This is consistent with weight and strength loss in twice bio-polished fabrics. However, one should take into account the usage of various reactive dyestuff combinations for different colours in textile applications (which is particularly important for mixed colours such as khaki and grey). This may cause diverse results to be presented.

Conclusions

- When carded, combed and open-end yarns are considered, carded yarn-based knitted fabrics and those treated with ordinary chemicals without enzymes exhibited the worst pilling properties.
- The pilling behaviour of enzymatic treated fabric samples did not display any significant difference whether they were pre-treated or dyed.
- It is evident that single enzymatic treatment reduces pilling tendency, and double enzymatic treatment reduces it more. But the reader should be cautioned that double enzymatic treatment interfaces with the weight and the strength of fabrics severely, even beyond the acceptable limits.
- The results demonstrate that enzymatic treatment causes weight loss in carded yarns to the highest degree.
- Twice enzymatic-treated fabric samples display severe colour deviations. It should be considered that single enzymatic treatment might also yield colour deviations. This subject merits a detailed investigation.

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