Nilgün Özdil,
Esen Özdoğan,
Alparslan Demirel,
Tülin Öktem

Ege University
Department of Textile Engineering
Bornova, Izmir, Turkey
nozdil@textil.ege.edu.tr
esen@textil.ege.edu.tr
alpars@textil.ege.edu.tr
oktem@textil.ege.edu.tr

# A Comparative Study of the Characteristics of Compact Yarn-Based Knitted Fabrics

**Abstract**
*The compact spinning system was based on the conventional ring-spinning system. The vast majority of previous work deals with the properties of compact yarn in yarn form. In this study, we inspected fabric samples knitted from compact spun yarn in comparison with fabric samples knitted from classic ring-spun yarn. Knitted double jersey fabrics from 100% combed ring-spun and compact cotton yarns of the same raw material blend were used. The pilling properties, bursting strength and abrasion resistance of these fabrics at different process steps were tested. The effects of enzymatic treatment and washing & dyeing on these fabrics were also examined.*

**Key words:** *compact yarn, ring yarn, knitted fabric, pilling, fabric properties.*

## Introduction

Yarn production technique and the structure of the yarn are among the basic elements which influence the quality of the textile end product. Ring-spinning technology is the most widely accepted yarn production method; it is capable of spinning nearly all sorts of natural and synthetic fibre types within a very wide count range. The strength and elongation properties of ring-spun yarns are sufficient to meet the requirements of mill conditions. Despite the presence of new yarn production systems that have been introduced to the market with much higher production speeds, the ring-spinning system still dominates the market, and has also maintained its position as the 'reference' yarn.

The fashion industry is under a continuous and unplannable obligation to meet (or create) a diverse array of customer demands, a fact which inevitably finds its reflections in the yarn industry also. These reflections require the yarn industry to produce diverse, novel and creative yarns. Consequently, certain techniques have been introduced onto the spinning market which offer improved quality and/or reduced costs for yarn production by inducing some sort of modifications on ring-spinning technology [1]. The most accepted of them is the compact spinning system.

The compact spinning system is a modified ring-spinning process, developed initially for spinning cotton yarn, which belongs to the short staple fibre subgroup [2-5].

The spinning triangle that occurs while the yarn is formed is the reason why many fibres leave the drafting roving, or become partly spun into the yarn with one end only. This causes a greater waste of fibres, a lower exploitation of fibre tenacity in yarn, a poorer appearance and a greater hairiness of the spun yarn [6]. In the compact spinning system, in contrast to the classical ring-spinning system, the fibres are compacted aerodynamically just after the drafting. The fibres become more closely aligned and increasingly parallel within this compacting zone prior to yarn formation. This allows nearly all of the fibres to contribute to the yarn structure under relatively equal tension. As the twist is given at a location which is very near to the clamping line of the end rollers, short fibres also contribute to the yarn structure under controlled tension at this critical location. This enables yarn production with a reduced level of hairiness. Figure 1 demonstrates the comparison of ring-spun and compact spun yarns [7].

The compact spinning system enables nearly all of the fibres to be twisted. Thus, the enhanced incorporation of the fibre characteristics into the yarn structure would allow optimal exploitation of the raw material with increased yarn strength.

Since the compact spinning system has been introduced commercially onto the market, a large number of studies have been conducted related to the short-staple and long-staple compact spinning techniques, each of which claims to offer advantages, dramatically increased production speeds, enhanced quality and reduced costs. Hechtl (1996), Artzt et al. (1997), Topf (1998), Krifa, M., Hequet, E. & Ethridge, D. (2000), Babaarslan (2000), Oaud (2000), Kadoğlu (2001), Smekal (2001), Scheibe (2001), Çelik (2002), Gahlert & Hellwig (2003) have all conducted and issued several studies comparing the properties of compact spun yarns versus classic ring-spun yarns [8-12]. These studies revealed the consistent results of reduced yarn hairiness, the ability to produce yarns of enhanced strength and elongation properties even with a lesser amount of twist, which enables increased production speeds to be reached in favour of the compact spinning system.

The vast majority of the aforementioned studies deal with the properties of compact yarn as it is in yarn form. In this study, we inspected fabric samples knitted from compact spun yarn in comparison with fabric samples knitted from classic ring-spun yarn. The comparison tests dealt particularly with the pilling properties, strength properties, and abrasion properties of the fabric samples during different production processes, such

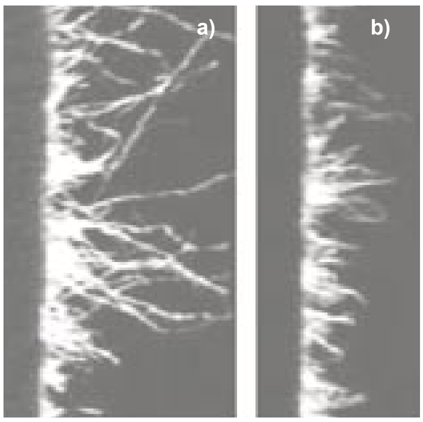


***Figure 1.** Hairiness of ring and compact yarns: a - ring yarn, b - compact yarn.*

***Table 1.*** *Characteristics of the sample yarns.*

| Parameter | Unit | Compact yarn | Ring yarn |
|---|---|---|---|
| Yarn count | Nec | 50 | 50 |
| Twist | T/m | 1069 | 1054 |
| Tenacity | cN/tex | 21.39 | 16.29 |
| Breaking elongation | % | 6.13 | 4.88 |
| Hairiness, Uster | H | 3.26 | 5.5 |
| Unevenness, Uster | %U | 10.06 | 10.31 |
| Hairiness, Zweigle | S3 | 954 | 3526 |
| Thin places | -50%/km | 4 | 4 |
| Thick places | +50%/km | 19 | 17 |
| Neps | +200%/km | 34 | 70 |

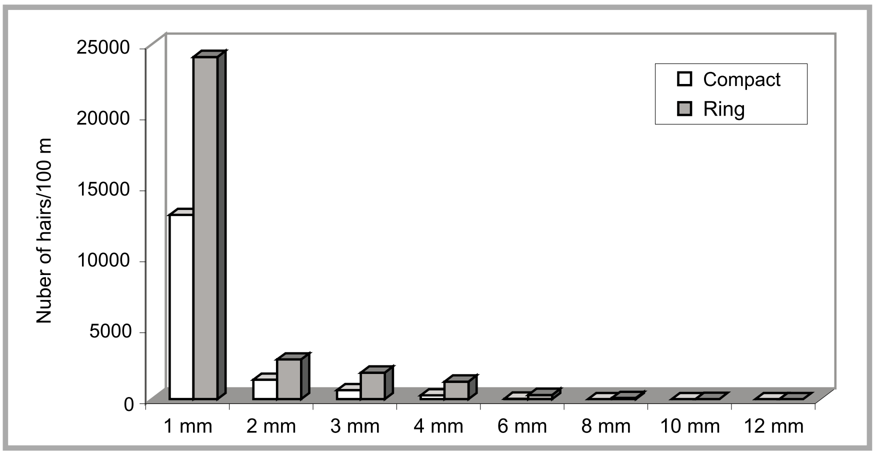


***Figure 2.*** *Zweigle instrument hairiness results of ring and compact yarns.*

as washing, enzymatic treatment and dying. This approach not only examines the behaviour of the compact yarn during further production processes, but associatively allows the manifestations of compact spun yarn on the end product to be observed.

## Material and Method

In this study, 50/1 $N_{ec}$ classic ring yarns and 50/1 $N_{ec}$ compact yarns were spun from the same cotton blend. The combed ring yarns were spun on a conventional system; the compact yarns were spun on a Rieter K 44 model machine. Interlock-type fabrics were knitted from these yarns as the subjects of further tests. Following the pre-treatment and dying processes, these fabric samples were subjected to pilling, bursting strength and abrasion resistance tests. Additionally, the K/S and Lab values of the samples were inspected in order to evaluate their dyeing characteristics.

### Characteristics of the sample yarns

The characteristics of the sample yarns are tabulated in Table 1. Yarn hairiness was evaluated by Uster Tester 3 and Zweigle hairiness testing instruments (Figure 2). The Uster tester results displayed that the compact yarns exhibited 40% less hairiness than the classic ring yarns. The Zweigle instrument tests showed that the S3 value (the number of encompassing protruding fibres which are 3 mm and longer) of compact yarns was 73% less in comparison to conventional ring yarns.

Unevenness was evaluated by the Uster Tester 3 instrument. The tests did not point out any significant difference in unevenness, but revealed that the compact yarns had a significantly lower amount of neps. The test results revealed that the strength and the elongation of the compact yarns were approximately 20% higher (Figure 3).

### Tests applied on fabric samples

The fabric samples were knitted on a 34”, 28-gauge Mayer OV.3.2 model interlock knitting machine from both the ring and compact yarns. These fabric samples were pre-treated and dyed under mill conditions.

A Martindale Pilling and Abrasion Tester was used to inspect the effects of yarn type on the pilling and abrasion properties of grey and treated fabrics. The Martindale tests were carried out at 500, 1000, 2000 and 5000 revolutions, in compliance with ISO Standard 12945-2. Test results were evaluated acocording to the 5-graded scale (1: severe pilling, 5: no pilling).

The strength values of the fabric samples were tested with a TruBurst instrument by using the bursting strength diaphragm method in compliance with ISO standard 13938-2. The dyestuff concentration of the dyed fabric samples were calculated by the formula

$$\frac{K}{S} = \frac{(1-R)^2}{2R}$$

according to the Kubelka-Munk theorem. In this nomenclature, K signifies the light absorbance and S signifies the light reflectance. The K/S values and light

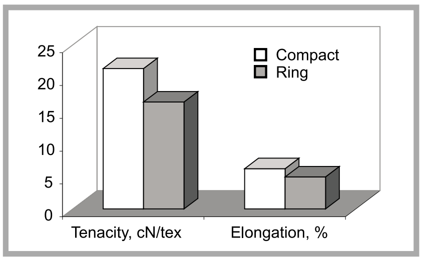


***Figure 3.*** *Strength and elongation values of compact and ring yarns.*

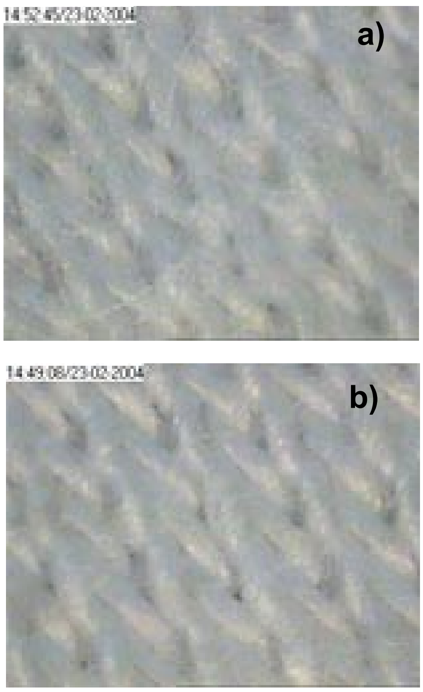


***Figure 4.*** *Projection microscopic views of interlock knitted fabrics from conventional ring yarns (a) and from compact yarns (b), both after pre-treatment.*

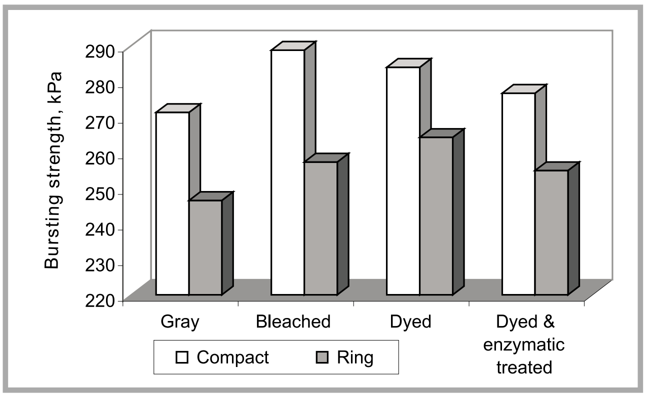


***Figure 5.*** *Histogram of bursting strength test results.*

differences were tested with a Hunterlab Proquest II instrument.

**Treatments on the fabric samples**

Following the pre-treatment, each group of the fabric samples was washed in a Wascator washing instrument 1, 5, 15 or 20 times separately, and was tested to evaluate their pilling properties in relation to washing frequency.

Enzymatic treatments for reducing fuzz are used widely in industrial applications. For this purpose, we treated each group of fabric samples with the Gempil 4L CONC cellulase enzyme. Each group of the fabric samples was treated with 1% cellulase enzyme for 15, 30, and 45 minutes separately in a Wascator instrument (pH 5, 55°C).

## Results

**Fabric properties**

Figure 4 shows the projection microscopic views of interlock knitted fabrics from compact and conventional ring yarns, both after pre-treatment. Inspections of projection microscopic views revealed that the fabric samples from compact yarns developed a more even surface appearance after pre-treatment.

**Bursting strength**

Each of the grey, pre-treated, dyed, and dyed & enzymatic treated fabric samples from ring and compact yarns were tested for bursting strength. Figure 5 shows the related test results. Test results showed that the fabric samples knitted from compact yarns exhibited better bursting strength values at every production stage (grey, pre-treated, dyed, and dyed & enzymatic treated) than the fabric samples knitted from ring yarns. The reader should nevertheless be cautioned that enzymatic treatments cause strength loss in yarns.

**Abrasion resistance**

Fabric samples from ring and compact yarns were tested for abrasion resistance under 9 kPa pressure on the Martindale instrument. The number of revolutions at which the first breakage occurred was registered for both types of samples. Table 2 shows the related test results. The abrasion resistance tests did not reveal any significant difference between the samples.

***Table 2.*** *Results of abrasion resistance test.*

| Production stage | Ring, rpm | Compact, rpm |
|---|---|---|
| Grey | 21500 | 21572 |
| Pre-treated | 40300 | 39000 |
| Dyed | 42000 | 41000 |

**Pilling**

Each of the grey, pre-treated and dyed (industrial scale) fabric sample groups were tested with a Martindale pilling and abrasion tester instrument at 500, 1000, 2000, and 5000 revolutions. Figure 6 shows the related results. The test results revealed that the knitted fabric samples from compact yarns demonstrated better pilling properties. However, the reader should be cautioned that, as the subsequent processes proceed (i.e. knitting, pre-treatment and finally dying), the difference in pilling behaviour between compact yarn and ring yarn-based fabric samples becomes less apparent.

**Inspection of the effects of washing process on pilling**

Knitted textile commodities, as items in daily use, are among the most frequently washed items. Frequent washing may eventually cause deformations in their structure. Therefore the effects of washing on pilling were inspected particularly closely in this category. For this purpose, pre-treated fabric samples were washed 5, 10, 15 and 20 times separately at 40°C. Thereafter, each group of washed fabric samples was tested for pilling at 500, 1000, 2000 and 5000 revolutions; Figure 7 shows the results.

After repetitive washing, the compact yarn-based fabric samples displayed better pilling properties. However, as the number of washing repetitions increased, both types of fabric samples displayed improved pilling behaviour. This suggests that the repetitive mechanical movements have the potential to sweep away the short fibres which are prone to cause pilling, and also any already formed pilling. Consequently, that leads to the following assumption; as the number of washings increases, so the amount of pilling formation decreases.

**Effects of enzymatic treatment on pilling behaviour**

Pre-treated fabric samples were treated with cellulase enzyme for 15, 30, 45 minutes separately. Thereafter, these samples were subjected to a pilling test. Table 3 show the achieved results (R denotes ring and C denotes compact). Table 3 shows that both sample types exhibited better pilling behaviours as the duration of enzymatic treatment increased.

The fabric samples from compact yarns displayed better pilling behaviours for all enzymatic treatment durations. Enzymatic treatment for 15 minutes did not produce any significant enhancement for either kind of samples. Enzymatic treatment for 30 minutes produced significant enhancements for the fabric samples from ring yarns, whereas the fabric samples from compact yarns required at least 45 minutes of enzymatic treatment for a significant enhancement. This suggests that,the hairier surface structure of ring yarns allow enzymatic treatment to achieve a quicker response than the less hairy surface structure of compact yarns.

**Effects on dyeing behaviour**

Table 4 shows the K/S and Lab values of the fabric samples knitted from ring and compact yarns, which were dyed under laboratory conditions with different direct dyestuffs. Table 4 reveals that there was no significant difference in the K/S and Lab values for any of the fabric samples.

## Conclusions

In this study we have compared the principal fabric properties of compact yarn-

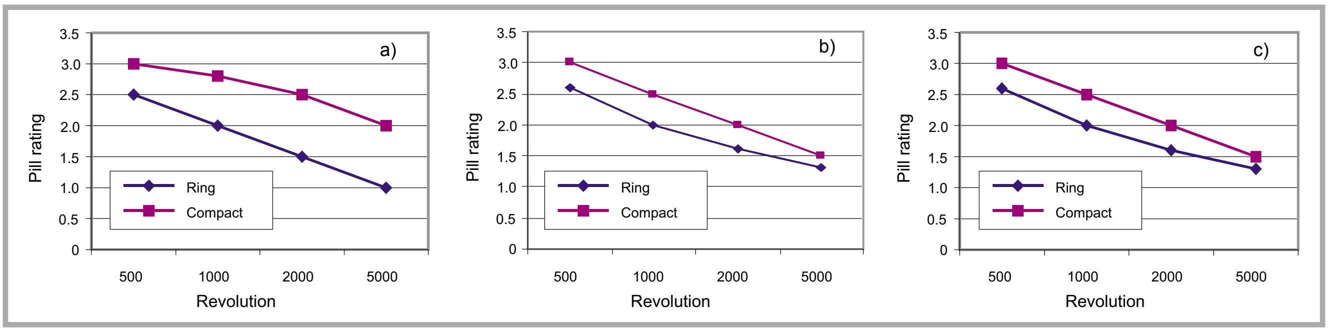


*Figure 6. Pilling evaluations of the fabric samples: a - grey, b - pre-treated, c - dyed.*

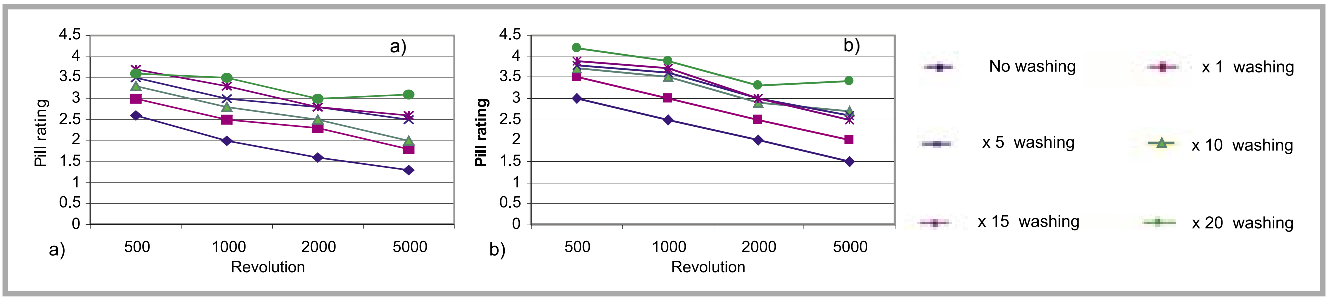


*Figure 7. The effects of washing process on pilling behaviours of knitted fabrics from: a - ring yarns, b - compact yarns.*

*Table 3. Pilling evaluation grades of fabric samples after enzymatic treatment.*

| Kind of yarn used for fabric and enzyme treatment period | Pilling evaluation grades after following revolutions applied, rpm | | | |
|---|---|---|---|---|
| | 500 | 1000 | 2000 | 5000 |
| R (without enzyme) | 2.6 | 2.0 | 1.5 | 1.0 |
| C (without enzyme) | 3.0 | 2.5 | 2.0 | 1.5 |
| R1 (15 minutes) | 2.5 | 2.0 | 1.7 | 1.0 |
| C1 (15 minutes) | 3.0 | 2.5 | 2.3 | 1.5 |
| R2 (30 minutes) | 3.5 | 3.0 | 2.5 | 1.5 |
| C2 (30 minutes) | 3.3 | 2.8 | 2.4 | 2.0 |
| R3 (45 minutes) | 3.5 | 3.3 | 2.7 | 2.0 |
| C3 (45 minutes) | 4.0 | 3.5 | 3.0 | 2.5 |

based knitted fabrics versus ring yarn-based knitted fabrics. The previous studies revealed the superiority of compact yarns in many aspects. This study aimed to inspect the reflections of the yarn enhancements on the fabric properties. This study was based on the following assumptions; as the end product's properties have the utmost importance from the customers' viewpoint, examining the properties of compact spun yarn-based fabrics would be more enlightening for comparative purposes.

This study led to the following conclusions:

- The fabric samples from compact yarns displayed tangible improvements.
- Fabrics knitted from compact yarns have divergent visual properties; namely, they are more brilliant and glossier.
- During the testing, we noticed that fabrics knitted from compact yarns had finer and smoother handling quality.
- The test results displayed that the fabric samples knitted out of compact yarns exhibited better bursting strength values at every production stage, but the abrasion resistance tests did not reveal any significant difference between the samples.
- Fabric samples out of compact yarns displayed better pilling behaviours at each production stage (i.e. grey, repetitive washed and enzymatic treated).
- Difference is an important notion in the fashion industry; this suggests that compact yarn-based fabrics have prospects for the design of novel textiles.

*Table 4. K/S and Lab values of samples dyed with direct dyestuffs under laboratory conditions.*

| Dyed fabric samples | Compact - yarn used | | | | Ring - yarn used | | | |
|---|---|---|---|---|---|---|---|---|
| | L | a | b | (K/S) | L | a | b | (K/S) |
| Sirius Direkt Gelb K-CF | 77.53 | 13.49 | 72.74 | 6.7012 | 78.35 | 14.04 | 72.95 | 6.2774 |
| C.I. Direct Red 212 | 38.71 | 49.13 | 9.29 | 14.1536 | 37.23 | 48.94 | 10.05 | 14.0679 |
| C.I. Direct Black 112 | 26.56 | -1.58 | -12.82 | 13.9848 | 26.86 | -1.46 | -13.01 | 13.9475 |
| C.I. Direct Blue 86 | 65.67 | -27.56 | -25.84 | 3.0042 | 67.17 | -26.95 | -24.89 | 2.7445 |
| C.I. Direct Blue 229 | 33.37 | -2.80 | -24.58 | 10.2814 | 33.46 | -2.76 | -24.68 | 10.1721 |
| Sirius Orange K-BE | 63.42 | 35.55 | 61.05 | 10.5169 | 63.56 | 35.15 | 61.72 | 9.4465 |
| Sirius Blau K-CFN | 25.68 | -0.70 | -21.02 | 17.9956 | 25.42 | -0.74 | -20.88 | 17.8466 |
| C.I. Direct Red 95 | 35.43 | 49.82 | 26.26 | 26.3046 | 35.82 | 50.02 | 26.41 | 24.6478 |

- Compact spun yarns are not merely a modification of conventional ring spun yarns. Compact spinning technology is something more than just marketing rhetoric. Actually, compact spun yarns should be considered as a new phenomenon, and they deserve to be classified under a subcategory of the ring-spining technology.
- Consequently, compact spinning technology is emerging as an evolutionary step in ring spinning technology which is certainly posing novel and probing questions for the extended possibilities within the range of ring spinning technology.

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