Evaluation of the impact of cotton sheath linear density of core spun yarn on the performance of denim fabrics

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ABSTRACT

In the textile sector, denim is one of the most iconic woven fabrics. The quality of denim fabric is influenced by several factors. For example, changes in the linear density of yarn might alter the projected fabric qualities, allowing it to fit current fashion market demands, which is the ultimate target of a textile product. The present investigation was designed to evaluate the impact of cotton sheath linear densities of core spun yarn (cotton/spandex) on performance properties like stretchability, tensile and tearing strength, weight, dimensional stability, pilling, and abrasion resistance of denim fabrics. Acquired results revealed that with the upsurge in the linear density of cotton sheath, several properties of the fabric, such as elongation and recovery percentage, tensile and tearing strength in the weft direction were improved because of the utilization of the variable linear density of sheath yarn in the same direction. Width-wise shrinkage and fabric weight were also decreased substantially. It was also found that increasing the sheath count enhances the denim fabric’s overall resistance to pilling.

1. Introduction

The colored warp and grey weft of denim fabric set it apart from other woven materials. The 2/1 Z, 3/1 Z, 2/1 S, 3/1 S twill, and 1/1 plain are the most common weave configurations for denim fabrics. Men’s and women’s clothing are the two main areas in which denim materials are used. The use of satin weave in women’s and children’s clothes has increased in recent years. Simultaneously, dobbi structured denim and knit denim are also gaining popularity because of their versatile design potential and availability in a range of fabric weights from 4–16 oz/yd². As warp cotton is the most frequently used cellulosic yarn because of its convenience and ease of dyeing. Weft yarn on the other hand, can be made from cotton, viscose, polyester, spandex, or any other combination of these fibers.

Stretch fabrics with exceptionally high elastic properties derive from the careful selection of the weft yarn. In most cases, core spun yarn promotes stretchability [1]. Elastane denim has witnessed a significant increase in demand over the past ten years due to its capacity to stretch and recover, as well as its wearability and superior fitness to other commodity textile products [2]. Elastic filaments like Lycra, Polybutylene terephthalate (PBT), Polyethylene terephthalate (PET), Polytrimethylene terephthalate (PTT), etc. are commonly used in casual clothes, denim, sporting, and medical textiles. Core-spun yarn spinning process is the most prevalent way of producing stretchy denim fabric. Core spun yarns are manufactured by placing spandex yarn in the center as a core and cotton yarn as a sheath to increase the elastic qualities of the fabric [3]. Figure 1 depicts the cross-sectional view of core spun yarn. As presented in Figure 2, core spun yarn is usually produced in the ring spinning process. Several studies have shown that core spun yarn significantly impacts the performance of denim fabrics. A. Cataloglu et al. found that as weft yarn content increased the fabric’s ability to stretch and expand decreased [4]. According to Babaarslan et al., using core spun (cotton/spandex) yarns with spandex may improve the woven fabric’s strength and elongation [5]. Additionally, they found that increasing the quantity of spandex in core spun yarn can increase the fabric’s performance attributes and comfort characteristics.

The dynamic and static ripping strength of denim is strongly influenced by the fineness of the yarn used in the fabric. Lower sheath linear density
density had little effect on static tearing strength, but a higher sheath count significantly increased the strength [6, 7]. For denim materials, Bansal et al. discovered that elastic performance rises when linear density is decreased [8]. The performance study of stretch denim after laundering was carried out by C. Kan et al., and it was determined that the laundering technique significantly impacts every aspect of the denim fabric’s properties [9]. Spandex draw ratio and stress have a substantial impact on elastic recovery, which can be optimized by varying the yarn’s linear density [10, 11].

The strength of denim fabric is influenced by the weft yarn count, weave pattern, and linear density [6]. The fabric strength varies substantially with the weft yarn variation, and it increases along with the picks per inch (PPI). Shrinkage is one of the essential qualities that assures the materials’ dimensional stability. The temperature of the heat setting, which typically ranges from 170–200 °C, determines the amount of denim shrinkage [12]. In the heat-setting process, lower shrinkage is caused by higher temperatures and vice versa. S. Pannu et al. found that as the linear density of spandex in a core-spun weft yarn increases, weft shrinkage decreases with time. They also established that the shrinking of denim fabric increases with the increase in cloth weight [13].

Denim is mostly associated with right and left hand twill. However, a common problem with right and left hand twill was and still is the twisted leg. The twisted leg is more common with non-sanforized denim after it has been worn and washed. The fabric shrinks and turns in the direction of the weave leaving the side seams in the middle of the leg. Twill lines are intentionally reversed at every two warp ends to create random patterns when using broken twill. The leg twist effect is eliminated as a result of this reduction in the natural torque characteristic of regular twill weaves. Since denim goods are updated according to fashion and customers’ requirements, the popularity of broken twill denim is also growing because of its comforts. The 2/2 broken twill possesses the highest porosity compared with 2/1 and 3/1 regular twill, which facilitate higher air permeability, and consequently increase comfortability [14]. In addition, systematic studies have been conducted on the properties of regular twill denim. In contrast, a few studies can be found on broken twill in terms of fabric properties. Considering all these issues, 2/2 broken twill was chosen for this study. Figure 3 illustrates the weave diagram of 2/2 broken twill fabric.

Numerous researches were conducted on the influence of yarn count and core spun yarn on the attributes of denim fabrics. Nevertheless, while searching on Scopus and Web of Science journals, it is identified that impact of sheath cotton count of core spun yarn has been overlooked in the previous investigations. Therefore, to minimize this research gap, this study is framed to measure the effect of change in sheath cotton count on the performance of denim fabric.

2. Materials and method

2.1. Materials

Core spun yarns are usually made with a two-element structure designating as core and sheath. Typically, filament yarn is used as the core and staple fibers are used as the sheath. Table 1 shows the properties of the cotton and spandex fibers used in core spun yarn. In order to produce the core-spun yarn, the ring frame (Zinser 315) was equipped with a special attachment (Pinter). Figure 4 represents how spandex filament was fed into the spinning system via a V-groove guide roller at the nip point of the delivery roller. In this study, denim fabric samples were manufactured cautiously by using core spun yarn of varying sheath linear density in the weft direction. The 40 Denier (D) (4.44 Tex) elastomeric yarns were used as core yarn with 16.52 Ne (35.74 Tex), 18.66 Ne (31.64 Tex), 20.82 Ne (28.36 Tex), 25.20 Ne (23.43 Tex), and 38.76 Ne (20.82 Tex)
Ne (15.23 Tex) sheath cotton yarn to produce the resultant count of 16 Ne (36.90 Tex), 18 Ne (32.80 Tex), 20 Ne (29.52 Tex), 24 Ne (24.60 Tex), and 36 Ne (16.40 Tex) core spun yarn. The actual yarn count of core spun yarn was 15.95 Ne (37.02 Tex), 17.98 Ne (32.84 Tex), 19.90 Ne (29.67 Tex), 23.89 Ne (24.71 Tex), and 35.82 Ne (16.48 Tex) respectively.

Figure 5(a, b) depicts the 16L40D core spun yarn.

| Properties  | Results                        |
|-------------|-------------------------------|
| Fiber type: Cotton |                          |
| Fineness (MIC)             | 4.10                         |
| Strength (g/tex)            | 31.32                        |
| Maturity                  | 0.82                         |
| Length (mm)                | 30.25                        |
| Uniformity Index (UI)      | 83.5                         |
| SCI                      | 140                          |
| SPI                     | 8.2                          |
| Elongation (%)             | 7.5                          |
| MR (%)                    | 7.8                          |
| Rd                      | 78                           |
| +b                    | 7.9                          |
| Fiber type: Spandex        |                             |
| Count (Denier)             | 40                           |
| Tenacity (g/denier)        | 1.24                         |
| Elongation (%)             | 530 ± 25                     |

Table 1. Fiber properties used in this study.

Figure 5. (a) Original view of the used core spun yarn; (b) Sections of the used core spun yarn.

3. Methods

3.1. Determination of fiber ratio in core-spun yarn

The calculation of fiber ratios such as cotton and spandex percentage in the core spun yarn, spandex draft ratio, sheath count, and resultant count of core spun yarn are demonstrated in Table 3. In accordance with TS 244 EN ISO 2060, the yarn count was tested. There were a total of ten tests conducted on each type of yarn.

3.2. Fabric production

In this experiment, the warp was made of cotton and was spun using the conventional ring-spinning technique. Indigo-dyed warp yarns were slasher-dyed and placed into the weaver’s beam before weaving. On the other hand, two types of yarns were used as wefts, such as core spun and ring yarn which remained undyed. A total of five broken twill structures were prepared using an air-jet weaving machine named Picanol Optimax-I (Origin: Belgium) with 12 heald frame design capacity. The loom parameters, including shedding, picking, beating-up, take-up, and let-off mechanisms, were pre-set for each sample. Reed count (50”) and denting plan (4 ends/dent) were also constant for all the samples which ensured the same ends per inch (EPI). Because of unchanged parameters
of pick density (take-up and let-off motion, input of picks/unit value in software), a uniform PPI was maintained for all structures. All the fabric samples were produced with identical weaving conditions in the same loom. Broken twill was designed by breaking the twill line of basic twill, and the straight draft was used to produce the weave. The details of the production parameters and the produced samples are presented below in Tables 4 and 5, respectively.

The manufactured fabrics were passed through the singeing process which was performed in a Cibitex machine at 12 m/min machine speed and 13 mbar flame intensity. Subsequently, de-sizing was carried out with hot water at 18 m/min speed followed by softening with 8 g/l Asuchem softener at 20 m/min. Finally, finishing was conducted using a stentering machine at 170 °C maintaining 33 m/min speed and 65-inch width setting.

3.3. Fabric testing

Before testing, all the samples were conditioned in the laboratory for a minimum of 24 h at (21 ± 2) °C and (65 ± 2)% RH.

3.4. Tensile and tearing strength

For tensile testing, the ASTM D5034 method was followed and the Elmendorf testing machine was utilized. The ASTM D412 standard was followed for performing the tearing test. In addition (100 × 75) mm template was utilized to cut the samples. A slit was created at the middle point of the specimen within the range of 20 mm to form a continuous tear from the opposite side within the distance of 43 mm.

3.5. Stretchability test

Before conducting the stretchability test, the samples were held in a tension-free state for 20 h. After preparing the test specimens, they were held in a tension-free state for another 4 h for conditioning. According to standard EN 14704-1-2005-A, five samples were taken from each group and it was ensured that no test samples were cut from within 150 mm of both edges of the samples. Each specimen was cut parallel to its warp and weft direction between 250 mm and 300 mm.

3.6. Dimensional stability test

In the case of dimensional stability testing, the AATCC-135 method was used. To determine shrinkage (%), all the samples were washed three times. To begin, samples were treated with the same heat setting temperature and machine settings. They were cut into (20 × 20) inch² sizes and marked with a permanent marker around (18 × 18) inch². After that, the entire sample was washed in detergent for 90 min at 60 °C. The second and third rinse processes took 45 and 15 min respectively. All the samples were dried in less than 5 min, and shrinkage was calculated.

3.7. Fabric weight

Fabric weight was measured following the ASTM D3776 method and expressed as gram/square meter (GSM).
Figure 7. Tear strength of samples.
shrinkage properties of denim fabrics. With the growth of sheath linear density, shrinkage (%) decreases in the weft direction as shown in the figure. Shrinkage properties of the core spun yarn (cotton/spandex) mainly vary with the amount of cotton in composition and heat setting temperature [17]. In this study, all the samples have gone through the same heat setting temperature (170°C), this issue can be disregarded in this instance [12], however the cotton percentage changes as the sheath count changes, which mostly affects the shrinking property. With the increase of sheath count, elastane percentage increased and cotton percentage is decreased in the core-spun yarn as well as in the fabric and consequently reduced shrinkage was obtained. Moreover, cotton fabrics with spandex tend to shrink when exposed to water. Larger-diameter yarns produced by swollen fibers must follow a longer warp thread path around the swollen weft threads. The cross-section of the yarn decreases as the yarn count rises and becomes finer. The finer yarn has lower fiber content in the unit area and lateral swelling is less when in contact with water [18]. That is why samples with a higher value of sheath count result in a lower shrinkage phenomenon. Since all the samples passed through the same dry and wet tensions, the result was interpreted in terms of fiber swelling and cotton percentage in the fabric. Since the cotton warp yarn used for each sample was the same, there was no discernible difference in the quantity of shrinkage along the warp direction.

4.5. Pilling and abrasion resistance

Table 6 represents the pilling and abrasion resistance properties of samples. Upgraded pilling resistance was achieved because of the improved yarn quality with the increment of sheath count. After 10,000 cycles, the samples’ abrasion resistance was evaluated. Abrasion refers to the removal of cloth elements by rubbing. A fabric’s abrasion resistance is mostly determined by its weave and yarn properties [19]. Float length is important, as is the number of interlacements in the structure because these factors contribute to yarn breaking and mass loss. Except for the yarn count, other parameters were kept the same, and the twill weave, which appears to have a smaller float with a higher number of interlacements, was used in this study. Because of this, all the samples had excellent abrasion resistance.

5. Conclusion

Investigation of the physical qualities of denim fabric revealed that sheath cotton’s linear density has a substantial impact on performance properties, which are vital for preferred end-uses. With the upsurge of the sheath cotton count from 16.52–38.76 Ne in core spun yarn, the yarn becomes finer with the reduced amount of cotton and increased amount of elastane percentage, which are mainly responsible for changing the ultimate properties of denim fabrics. However, the improvement of the fabric properties occurred in the weft direction only because of using variable sheath count in core spun yarn in that direction. With the
increment of sheath count, the tensile and tear strength, elongation, and recovery of samples increased in the weft direction, ranging from 4.5–24.1, 6.2–27, 7.7–29.5 and 1.6–11.8%, respectively, compared to the value of the 16.52 Ne sheath count. In the case of shrinkage and fabric weight, those values for similar samples are reduced with the increase of sheath linear density, ranging from 15.21–8.82 and 1.5–19.1%, respectively. Pilling resistance property also improved with the growth of sheath count in core spun yarn due to improved yarn quality. In addition, improvement of denim fabrics by changing the sheath count of core spun yarn to satisfy consumer demand.

Declarations

**Author contribution statement**

Md. Faisal Mahmud: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

A. N. M. Masudur Rahman: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Aswad Al Haque Sarker, Shilpi Akter: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Md Reajul Islam: Analyzed and interpreted the data.

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**Data availability statement**

Data included in article-supplementary material/referenced in article.

**Declaration of interests statement**

The authors declare no conflict of interest.

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**Additional information**

No additional information is available for this paper.

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