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Cotton-Nylon Hybrid Ring Spun Yarn for Stylish Fabric

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ABSTRACT

The demand for stylish fabrics has grown in recent years as consumers seek both visual appeal and functional performance. Yarn variety and quality are very important for the requirement of stylish fabric. The development of hybrid yarns has long been a focus of textile research, as combining different fibers can enhance fabric performance and create innovative stylish cloths with expanding existing product lines. In this work, cotton-nylon hybrid yarn (CNHY) was produced using short staple spinning process with cotton-nylon mixing ratio of 80:20 and 90:10. Yarn counts of 16^S, 20^S, 30^S, and 40^S have been developed following the optimum parameters of preparatory and ring spinning process. Moreover, yarn appearance, evenness and mechanical properties have been characterized by black board, evenness tester and universal strength tester respectively. Yarn surface and integrity properties like black board images, unevenness (U%), co-efficient of mass variation (CVm%), thick, thin, neps, and hairiness of produced yarns were also examined. Mechanical properties like count strength product (CSP), Reisskilometer (RKM), force maximum (F.Max), elongation (%) of the developed samples were evaluated. The yarn appearances of CNHY show more uniform. Higher E@MF (%) has been achieved due to incorporating the nylon short staple fibers in CNHY. These CNHY will be able to grow its present yarn product lines and appeal for application in fashionable fabric.

Keywords: Cotton; Nylon staple fibers; Ring spinning; Stylish fabric

1. Introduction

The textile business is always looking to create new fabrics that are stylish, comfortable, and functional. Textile research has long focused on the creation of blended yarns since mixing various fibers can improve fabric performance and lead to creative textile solutions. As a natural fiber, cotton is valued for its softness, breathability, and comfort, which makes it a perfect choice for a variety of garments. However, its limitations, such as low tensile strength and reduced durability when subjected to friction or wear, have driven researchers to explore fiber blending to overcome these challenges. Synthetic polymer nylon has shown great promise as a complementary fiber because of its strong tensile strength, flexibility, and resistance to abrasion. Furthermore, cotton mixes with synthetic materials enhance the mechanical and comfort qualities of textiles, especially when creating useful and long-lasting textiles. In particular, nylon has several advantages over cotton-based textiles, such as increased tensile strength and resistance to deformation [1–3].

Numerous studies have explored the blending of cotton with synthetic fibers such as polyester, viscose, and nylon. For instance, Babaarslan O et al. investigated that the performance of cotton/polyester blends in various yarn structures is significantly influenced by the blend ratio, yarn type, and processing methods. This research indicates that increasing the polyester content enhances yarn strength and elongation while reducing unevenness and imperfections [4]. Wei et al. introduced a novel ring spinning approach to create polyester/cotton composite yarns with alternating segmented structures, enhancing mechanical properties and visual effects [5]. Furthermore, some study investigated the blending cotton with nylon like Zhezhova et al. explored that blending cotton with nylon results in fabrics that maintain softness while significantly improving durability, essential for high-performance sportswear [6]. Kakvav et al. investigated the thermal comfort properties of different cotton/nylon/Kermel fiber blend ratios. Their findings showed that increasing the Kermel content enhanced porosity, air permeability, and thermal resistance, while affecting water vapor resistance [7]. Adamu et al. found that woven fabrics made from cotton and nylon exhibited improved wicking properties with coarser yarn counts, though they experienced reduced air permeability. Nylon contributed to better wicking performance but hindered air permeability and moisture transfer also this studies found that cotton-nylon blends tend to perform better in terms of moisture management and comfort compared to cotton-polyester blends, which are more common [8].

Due to processing issues, cotton-nylon blended yarn has not yet become widely used in industry, while nylon filaments are readily available to make cloth [9]. In order to obtain consistent quality and performance during the spinning process, blending cotton with nylon involves a number of challenges. The purpose of this work is to produce and assess cotton-nylon hybrid yarn (CNHY) utilizing the short staple spinning process for use in fashion apparel. Additionally, it explores the yarn's strength, elongation, and look, developing textile materials for use in modern fashion.

2. Materials and Methods

2.1 Materials

Two types of cotton fibers Burkina Faso and Cameroon were used where 40% were Burkina Faso and 60% were Cameroon. Cotton fibers were processed from blow room to combing to produce the clean combed cotton fibers. Staple nylon fibers were sourced from China and supplied by Ningbo Lucky Import & Export Ltd. Clean-combed cotton and nylon fibers were mixed in ratios of 80:20 and 90:10 by hand.

Physical properties of cotton and nylon fibers are provided in Table 1.

Table 1: Properties of cotton and nylon fibers

Properties	Burkina Faso	Cameroon	Nylon
Fineness (mic)	4.2	4.4	3.95 (1.4 D)
Length (mm)	30.36	29.35	38
Tenacity (gm/tex)	31.3	29.4	58.5

2.2 Manufacturing process

At first 80% of clean-combed cotton fibers and 20% staple nylon fibers by weight was manually mixed and fed into a Unimix machine (Rieter, model B34), which was integrated with a carding machine (Rieter, model C70) which delivered card sliver and that's 6-yard carded sliver's weight was 480 grains. Then, six carded slivers were fed into the breaker draw frame (Toyota, model DX7A), producing 6-yards sliver weighing 385 grains. Subsequently, eight breaker-drawn slivers were processed through the finisher draw frame (Toyota, model DX7A-LT), and the 6-yard finisher sliver weight was 380 grains. A roving of 1.05 Ne with a twist per inch (TPI) of 1.15 was prepared using a roving frame (Toyota, model FL 200). After that, the roving was passed through a ring spinning machine (Jingwei, model F1508) to produce the CNHY. Finally, a winding machine (Muratec, model 21C) was used to wind the yarn onto cones from the ring cops. A schematic diagram of the CNHY manufacturing process is presented in Fig. 1.

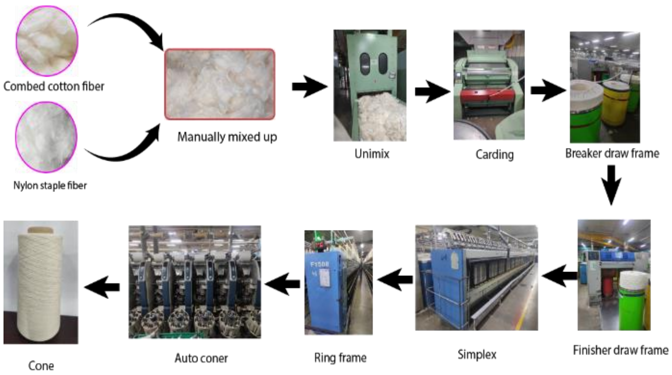

Fig.1: Manufacturing process of CNHY

2.3 Characterization

The cotton fiber properties were evaluated using a High-Volume Instrument (HVI), while the quality of the sliver, roving, and yarn was assessed with an Uster® Tester 5. Parameters such as unevenness (U%), coefficient of mass variation (CVm%), thin places (-50%) per km, thick places (+50%) per km, neps (+200%) per km, and hairiness were analyzed in the developed samples. The mechanical properties were tested using a MesdanLab strength tester (Tenso-Lab4, model 2512E), following the Test GenericYarnTraction protocol dated 2024-09-08T16:41, adhering to the standard yarn traction parameters. The test conditions included a sample length of 500 mm, a traverse speed of 500 mm/min, a pretension of 0 cN/tex, and a recording rate of 0 mm. The traction properties measured included the tenacity (RKM), maximum force, and elongation at maximum force. The electronic wrap reel (Mesdan, model 161W) and wrap drum (Mesdan, model 254B) were employed to measure the yarn and sliver/roving length, respectively. The yarn's count strength product (CSP) was determined using a Lea strength tester (model MAG-Y0501, India). Uster® Tensojet 4 (Switzerland) was used to examine the breaking-force (B-Force), breaking-work (B-Work), tenacity, scatter diagram. Electronic wrap reel (Mesdan, model: 161W) and wrap drum (Mesdan, model: 254B) were used to measure the length of yarn, sliver/roving respectively. Lea strength tester (model: MAG-Y0501, India) was used to measure the count strength product (CSP) of the yarn. To determine the mean for each sample, the average of ten tests was taken into account. Every test was conducted at 20 ± 2°C with a relative humidity of 65 ± 2%.

3. Result and Discussion

3.1 Results of the preparatory process

Carding is the challenging process for fiber blending. Process parameters of carding were adjusted by trial and error method. Numbers of working flats were 35 among total revolving flats 99. Taker-in, cylinder, flat, feeding and delivery speed were 1206 rpm, 653 rpm, 0.3 m/min, 660 g/min, and 30 kg/hr. respectively. Two drawing passages were used to straight, parallel and uniform the fibers by drafting and doubling. Break draft 1.15, total draft 6.54 and doubling 6 were applied in breaker drawing (B/D). Break draft 1.12, total draft 7.30 and doubling 8 were applied in finisher drawing (B/D). Delivery speed of both drawing frame was 400 m/min. Flyer speed of the roving frame was 900 rpm and beige color spacer was used. Sliver and roving quality values for two types of cotton-nylon mixing ration are given in Table 1. When the two mixing ratios were compared, the cotton-nylon 90:10 mixing ratio demonstrated superior quality in terms of U% and CV%.

Table 1: Sliver and roving quality for CNHY

Process	For cotton-nylon 80:20 ratio			For cotton-nylon 90:10 ratio		
	Linear density (ktex)	U (%)	CVm (%)	Linear density (ktex)	U (%)	CVm (%)
Card sliver	5.668	3.65	4.43	5.668	3.53	4.39
B/D sliver	4.546	2.92	3.67	4.546	2.78	3.45
F/D sliver	4.487	2.05	2.58	4.487	1.91	2.46
Roving	0.566	3.22	4.04	0.566	2.97	3.66

This indicates that the higher cotton content consistently reduced U% and the CVm% across all stages, from card sliver to roving. The lower U% and CVm% in the 90:10 ratio can be attributed to the superior cohesion and alignment properties of cotton fibers, which enhance consistency during drafting leading to more consistent and uniform sliver and roving.

3.2 Black board images

Fig. 2 shows the actual images of 16^S, 20^S, 30^S and 40^S CNHY at cotton-nylon 80:20 and 90:10 mixing ratios. Each yarn appears uniform when viewed in visual form. Moreover, Fig. 2(a, b, e, f) show better uniform yarn appearance compared to its other images (Fig 2 (c, d, g, h)).

Table 2: U%, CVm%, thin, thick, neps, and hairiness values of CNHY at different mixing ratio

Cotton-nylon ratio	Count (Ne)	U (%)	CVm (%)	Thin/km (-50%)	Thick/km (+50%)	Neps/km (+200%)	Hairiness (-)	Sh (-)
80:20	16^S	8.40±0.15	10.58±0.2	0.0±0.0	3.00±2.74	0.50±1.12	6.45±0.3	1.18±5.19
	20^S	9.05±0.14	11.38±0.15	0.0±0.0	8.5±5.18	6.0±4.18	5.31±0.2	1.16± 0.07
	30^S	10.81±0.11	13.64±0.18	5.5±2.09	46.5±20.41	34±12.82	5.14±0.06	1.14±0.015
	40^S	11.75±0.14	14.91±0.19	15±5.0	127.5±5.35	65±6.83	4.81±0.13	1.15±0.06
90:10	16^S	8.12±0.15	10.25±0.22	0.0±0.0	9.5±10.8	10±11.59	6.03±0.2	1.17±0.022
	20^S	8.84±0.2	11.14±0.26	0.0±0.0	11±5.48	9.5±4.10	6.07±0.3	1.18±0.08
	30^S	10.76±0.18	13.55±0.22	5.0±5.0	43±10.36	57.5±17.60	5.15±0.1	1.16±0.04
	40^S	10.60±0.21	13.43±0.21	3.5±4.18	54.5±15.26	41.0±8.94	4.92±0.38	1.05±0.05

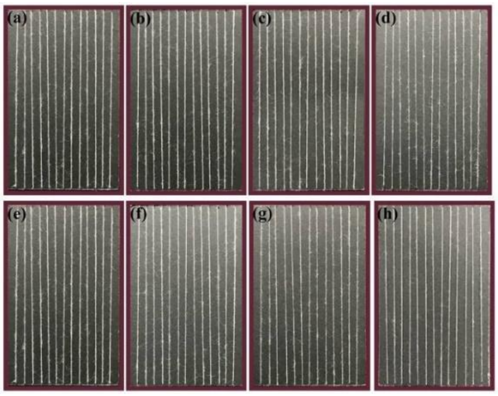

Fig.2: Black board images of (a) 16^S, (b) 20^S, (c) 30S and (d) 40^S CNHY at cotton-nylon 80:20 mixing ratio and (e) 16^S, (f) 20^S, (g) 30S and (h) 40^S CNHY at cotton-nylon 90:10 mixing ratio

3.3 Appearance and surface integrity property

Appearance integrity (U%, coefficient of mass variation (CVm%), thick places, thin places, neps) and surface integrity (hairiness, diameter) are the basic elements of yarn quality. So, these parameters are examined to evaluate the developed CNHY. U%, CVm%, thin/km (-50%), thick/km (+50%), neps/km (+200%), and hairiness values with standard deviation (SD) of 16^S, 20^S, 30^S and 40^S CNHY at cotton-nylon 80:20 and 90:10 mixing ratio are presented in Table 2.

The CVm, thin, thick, and neps of 16^S yarn count (100% cotton) for any application are 10.23, 0, 3, and 12 at the 25% level, according to Uster® Statistics 2023. Thus, developed 16^S yarn count of CNHY meets the 25% standard of yarn quality. Appearance and surface integrity properties of all CNHY are sufficient to meet the requirements of fashionable cloth. Table 2 also explain that the 90:10 mixing ratio demonstrates superior yarn quality in terms of reducing yarn unevenness, mass variation, and imperfections compared to the 80:20 mixing ratio, particularly in finer yarn counts (30^S and 40^S). The higher cotton content enhances fiber cohesion and alignment, leading to more uniform and defect-free yarn

3.4 Mechanical property

Mechanical properties of CNHY at different mixing ratio are given in **Table 3**. Mechanical properties include CSP, RKM, maximum force to break (F.Max), and elongation at maximum force (E@MF).

Table 3 Mechanical properties of CNHY at different mixing ratio

Cotton-nylon ratio	Count	TPI	CSP	RKM	F.Max (cN)	E@MF (%)
80:20	16^S	17.81	2492	14.33±0.60	519±22	9.42±1.15
	20^S	19.72	2223	14.43±0.75	418±22	9.35±0.68
	30^S	24.88	2056	13.39±0.56	259±11	7.63±0.74
	40^S	29.46	1988	13.70±0.53	198±8	7.15±1.50
90:10	16^S	17.81	2694	16.35±0.56	592±11	8.96±0.74
	20^S	19.72	2532	15.63±0.25	452±7	9.02±0.93
	30^S	24.88	2364	14.83±0.44	286±8	6.96±0.83
	40^S	29.46	2418	15.67±0.76	227±11	6.56±0.41

The mechanical properties of CNHY with two different blend ratios (80:20 and 90:10) were evaluated in terms of the RKM (tenacity in cN/tex) indicates the length of yarn in km at which the yarn will break of its own weight, CSP is the product of the yarn count and its lea strength, F.Max in cN, and E@MF in %. Table 3 demonstrates that for each count, the RKM and CSP values were higher at an 80:20 ratio compared to a 90:10 ratio. Cotton fiber may be crucial in this scenario since it underwent two rounds of processing—carding and another procedure that caused the fibers ruptured. CSP values were decreased with increasing the yarn count for each ratio. The reason for this phenomenon is that there is fewer amounts of fibers in a higher yarn count in the cross section. The results are demonstrated that the 90:10 cotton-nylon blend outperformed the 80:20 blend in terms of strength (RKM and F.Max), which indicates that a higher proportion of nylon increases the tensile strength of the yarn cause the nylon fiber is known ability to enhance durability and strength in blended yarns due to its higher tensile properties compared to cotton. In addition, the 80:20 blend ratio of CNHY has been shown higher elongation than 90:10 blend ratio just because of increasing the content of stretchable nylon fiber in yarn crossection.

Breaking force vs. elongation scatter plot diagram of 16^S, 20^S, 30^S, 40^S count of NCHY at the cotton-nylon 80:20 and 90:10 ratio are shown in Fig. 3. There are no abnormal deviations in the scatter diagrams. All breaking points are concentrated to center with small variation. Maximum B-Force (682 cN) and maximum tenacity (18.49 cN/Tex) was observed in 16^S CNHY at 90:10 mixing ratio and highest elongation (%) was exhibited in 16^S CNHY at 80:20 ratio according to Fig. 3. Elongation (%) is higher at 80:20 ratio compared to 90:10 ratio. This is occurred due to presence of more nylon fibers in the yarn crossection.

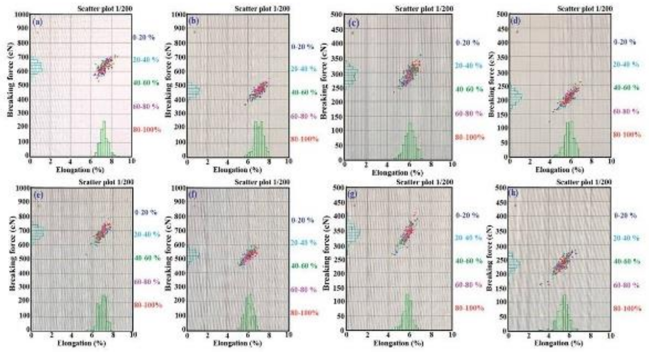

Fig.3 Scatter plot diagram of (a) 16^S, (b) 20^S, (c) 30^S, (d) 40^S count at the cotton-nylon 80:20 ratio and (e) 16^S, (f) 20^S, (g) 30S, (h) 40^S count at the cotton-nylon 90:10 ratio

Stoke diagram for breaking force of 16^S, 20^S, 30^S, 40^S count at the cotton-nylon 80:20 and 90:10 ratio are given in **Fig. 4**. Stoke diagram for breaking elongation of 16^S, 20^S, 30^S, 40^S count at the cotton-nylon 80:20 and 90:10 ratio are given in **Fig. 5**. There were 200 observations performed for each test in order to monitor any deviations or unacceptable problems that may have developed. There are no unpleasant or unexpected features in the diagram.

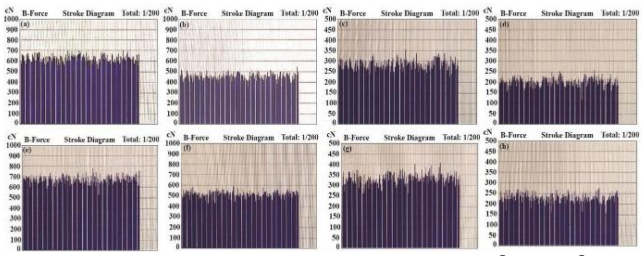

Fig.4 Stroke diagram for breaking force of (a) 16^S, (b) 20^S, (c) 30^S, (d) 40^S count at the cotton-nylon 80:20 ratio and (e) 16^S, (f) 20^S, (g) 30 S, (h) 40 S count at the cotton-nylon 90:10 ratio

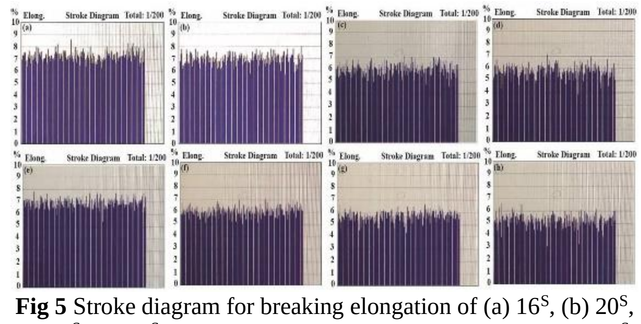

Fig 5 Stroke diagram for breaking elongation of (a) 16^S, (b) 20^S, (c) 30^S, (d) 40^S count at the cotton-nylon 80:20 ratio and (e) 16^S, (f) 20^S, (g) 30^S, (h) 40^S count at the cotton-nylon 90:10 ratio

4. Conclusions

Yarn count of 16^S, 20, 30^S, and 40^S have been successfully developed using existing short staple spinning process at cotton-nylon mixing ratio of 80:20 and 90:10. U%, CVm%, thin, and thick values of CNHY were slightly decreased at cotton-nylon mixing ratio 90:10 for each yarn count. On the other hand, CSP, RKM, and E@MF (%) values were slightly higher at cotton-nylon mixing ratio 90:10 for each yarn count. For 16^S, 20^S, 30^S, and 40^S yarns, CSP values were 2492, 2223, 2056, and 1988; RKM values were 14.33, 14.43, 13.39, 13.70; E@MF (%) values were 9.42, 9.30, 7.92, 9.60 at an 80:20 nylon-cotton mixing ratio and CSP were 2694, 2532, 2364, 2418; RKM were 16.35, 15.63, 14.83, 15.67; elongation (%) were 8.96, 9.02, 6.96, 7.02 respectively at nylon–cotton 90:10 ratio in this study. With this, CNHY will be able to expand its current yarn product lines and increase their attractiveness for use in stylish fabrics.

5. Acknowledgement

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NOMENCLATURE

B/D : Breaker draw frame
CNHY : Cotton-nylon hybrid yarn
CSP : Count strength product (Ne×lbs)
CVm : Co-efficient of mass variation
D : Denier
F.Max : Force maximum
F/D : Finisher draw frame
ktex : Killotex
RKM : Reisskilometer
^{s} : Yarn count in English system (Ne)
SD : Standard deviation
TPI : Twist per inch
U% : Unevenness (%)