MECHANICAL AND FUNCTIONAL ATTRIBUTES OF A TANDEM-SPUN-YARN-FABRIC

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Abstract

Properties of a woven, bottom-weight fabric made with the truly unique core-wrap yarns produced on Southern Regional Research Center's (SRRC) new Tandem Spinning System were examined. The mechanical properties such as tensile, tear, and bursting strengths were satisfactory. When appropriately heat set, without application of any sensitive chemical agent, the fabric exhibited satisfactory levels of durable press and dimensional stability, which were retained permanently even after subsequent wet processing including dyeing and repeated launderings. Flex abrasion resistance, pilling resistance, and air permeability of resin-finished fabric were also acceptable. The fabric had good hand and comfort attributes, as characterized by the Kawabata system. Subjectively, the fabric looked very interesting and was much softer than a typical 100% cotton, ring-spun-yarn fabric, apparently due to the excellent (yarn) core-coverage (about 95%) and the reversal of yarn twist direction in the core and wrap components, which, incidentally, is possible only in tandem spinning. This paper briefly describes the new, totally integrated, tandem spinning system and shows the properties of the fabric made with tandem spun yarns comprised of polyester-staple core (40%) and 100% cotton-wrap (60%).

Introduction

Although absorbent and hence comfortable to wear, pure cotton fabrics are usually deficient in other important functional properties. For example, without a special DMDHEU resin finish, they have a tendency to wrinkle; they shrink with laundering; and they generally are weak and less durable. Although the DMDHEU resin finish improves the wrinkle-resistance and durable-press properties of a cotton fabric, unfortunately, it weakens the fabric and reduces its durability considerably, and to an extent, it also adversely affects the fabric's hand and appearance. Furthermore, formaldehyde, an ingredient of the present DP-resin finish, is now considered to be environmentally sensitive, if not unsafe.

Today, the most common practice in textile manufacturing to produce a mostly-cotton fabric of improved functional performance is to <u>intimately blend</u> cotton with a suitable synthetic fiber in mechanical processing. Compared to a pure, single-fiber type, an intimate fiber blend generally produces a yarn, and hence a fabric, of relatively superior properties. For example, a synthetic fiber such as polyester, being considerably stronger and more uniform than cotton, significantly contributes to the tensile and tear strength abrasion or wear resistance, and hence the overall durability of a cotton-polyester intimate blend. Also, the polyester fiber being thermoplastic and heat setable, once appropriately heat set, imparts permanent dimensional and structural stability to the intimate-blend fabric which, therefore, will not shrink or wrinkle with laundering.

Unfortunately, however, even the intimate-fiber blends, especially those rich in one constituent fiber, do not always exhibit all the desirable fabric functional properties, because the constituent synthetic fibers also have some shortcomings and disadvantages. For example, most synthetic fibers are not absorbent and hence are uncomfortable to wear. They have a strong tendency to pill, which severely affects the fabric appearance. They also are prone to static, which makes them difficult to work with. In other words, the fabrics made with the intimate fiber blends have a few performance problems too. For example, the presence of strong, projecting polyester fibers on the surface of a "polyester-rich" intimate-blend fabric would certainly compromise with the optimum comfort and aesthetics of a 100%-cotton fabric. Also, it would most certainly generate objectionable, unsightly pills on the fabric surface, since the high tenacity polyester fibers have a strong tendency or propensity to pill. Depending on the cotton content, a "cotton-rich" intimate-blend fabric, on the other hand, may still require the special DP-resin finish (which, as stated previously, weakens the fabric and adversely affects its hand and appearance, in addition to posing a possible hazard to human health and the environment) to obtain satisfactory levels of durable-press properties. So, therefore, no viable approach or commercial process is presently available to produce a predominantly-cotton fabric which has all the so-called desirable, ideal properties and is also safe to produce and use.

Scientists at SRRC have been working to develop some new concepts and approaches for producing cotton-rich fabrics that have improved functional properties and are also ecologically benign. In other words, they have been trying to develop new technologies to produce cotton-rich fabrics that, without or with minimum use of any chemically sensitive finishing agent, would provide improved functionality in terms of superior strength and durability, comfort, pill-resistance, dimensional stability, and wrinkle

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resistance (easy-care), when compared to traditional 100% cotton fabrics. The research approach they have adopted to develop these functionally superior and environmentally safe fabrics is to employ the truly unique "core-wrap" yarns that they have recently developed, using their pioneering concept of "strategic-blending" of different staple fibers via "staple-core spinning." They have developed new spinning technologies to produce truly co-axial, synthetic staple-core/cotton-wrap yarns in which the preferentially arranged core material is very uniformly and firmly covered with a sheath of natural fibers. Basically a true, core-wrap, bi-component yarn, as the name implies, is comprised of a central, consolidated core component which is surrounded by an outside wrap component. The core component, usually a strong synthetic fiber, when properly heat set, provides acceptable levels of permanent dimensional stability, wrinkle resistance/recovery, and durable press, while the wrap component, generally 100% cotton, provides the traditional aesthetics, comfort, pilling resistance, and substrate properties of cotton. This core-wrap yarn strategy essentially is a manipulation of different staple fibers in the mechanical processing. It is thus a novel approach to ultimately improving performance and functionality of a predominantly-cotton fabric, which, incidentally, is distinctly different from the traditional chemical finishing approach that has lately been considered to be somewhat detrimental and hence less desirable.

Several spinning systems have been developed at SRRC to produce true core-wrap yarns of strategic blends. The latest (core-wrap) spinning system developed is known as Tandem Spinning. It basically combines two modern spinning methods or technologies in tandem to produce a truly unique, co-axial, torque-balanced, and bi-component core-wrap yarn at extremely high speed. The core usually consists of a high tenacity, thermoplastic fiber such as polyester, and the wrap generally is comprised of 100% cotton. Thus, as indicated earlier, a fabric made with these yarns and then appropriately heat set permanently develops satisfactory levels of dimensional stability and wrinkle resistance, without application of any special chemical finishes. Because of the pure cotton wrap, the fabric also exhibits excellent aesthetics, comfort, and hand. Obviously yarn composition, especially the tenacity and the percentage content of the core material, and the fabric construction/structure also play important roles in determining the ultimate levels of the various mechanical and functional attributes of the end product. This paper briefly describes the new tandem spinning system and shows a few important properties of the fabric made with tandem spun yarns composed of polyester staple-core (40%) and 100%-cotton wrap (60%).

Materials and Methods

Spinning Method

Figure 1 shows a schematic of the tandem spinning system developed at the Southern Regional Research Center. As shown, two entirely disparate spinning technologies, viz., the air jet spinning and the friction spinning, are combined in tandem to continuously produce a truly unique, core-wrap, composite yarn at extremely high speeds. Basically, a low-density sliver of polyester staple fiber is drawn on a conventional 3- or 4-roller drafting system and spun into an integral, air jet spun yarn which continuously feeds without interruption to a friction spinning system, where it is uniformly and almost completely covered with a sheath of cotton fibers delivered from several low-density slivers [8]. The twist directions in the two spinning phases are generally opposite to each other, as shown.

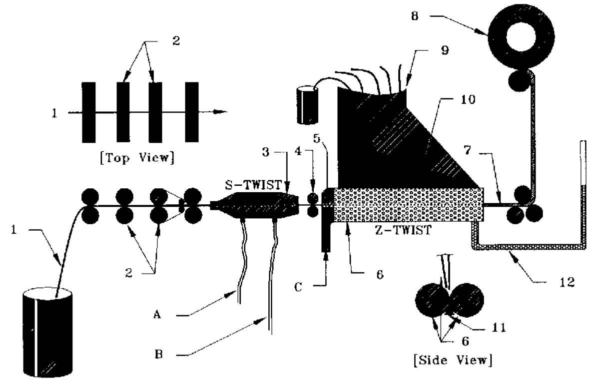

Figure 1. A totally integrated Tandem Spinning System

Yarn and Fabric Production

A prototype version of the integrated tandem spinning system described above was used in the SRRC textile pilot plant to spin sufficient quantities of 65-tex (9/1's) warp and 55-tex (11's) filling core-wrap yarns composed of high tenacity polyester staple-core (40%) and 100%-cotton wrap (60%), using a 2.4 g/m polyester sliver for the core component, and five 2.4 g/m regular carded cotton slivers for the wrap component. Both yarns were spun at 250 ypm and were wound onto cheese-type packages. The yarns were adequately cleared on an Uster Classimat and wound onto 5°-57' cones for further processing. The warp yarn was warped, sized with PVA, and slashed in conventional manner to prepare a loom beam. The warp and filling yarns were woven into a 60 x 42, 2-up, 1-down, right-hand twill fabric on a conventional 132-cm wide fly-shuttle loom equipped with a dobby.

Fabric Preparation and Evaluation

- The woven fabric in greige was heat set at 200°C for 90 secs;
- The fabric was tested at SRRC for various mechanical properties and the durable press and shrinkage characteristics;
- The fabric was pad-batch desized to remove the PVA size;
- It was pad-batch bleached;

- The polyester component of the fabric was dyed with Dispersed Navy D2G in jet at 130°C for 30 min (pH 4.5)
- The cotton component was pad-batch dyed with reactive (Cibacron Blue CR);
- Half the union-dyed fabric roll was finished with a softener only (2.0% silicon, 3.0% high density polymer); and
- The other half roll was finished with the softener plus 5.0% DMDHEU resin (50.0 g/l, 45% solution, pad-dried at 149°C for 60 sec at 108 cm fabric width; pad-dried, cured at 171°C for 60 sec at 108 cm fabric width).

The heat-set and heat-set plus 5%-DP-resin-finished fabric samples were tested according to the standard test methods and procedures. These tests identified selected mechanical, functional, and hand properties such as tensile and tear strengths, abrasion resistance, air permeability, DP-rating, shrinkage, pilling resistance, and certain (kawabata) hand attributes assuming, where applicable, the polyester core as an integral component of the fabric in determining the test "end point."

Results and Discussion

Table 1 shows the properties of the heat set and the heat set + 5% DMDHEU-resin finished fabrics. As indicated, the heat- set-only fabric exhibits a superior DP-rating of 3.4 after 5 HLTD, compared to a DP rating of 3.2 for the heat-set and resin-finished fabric. The shrinkage of both fabrics, although slightly high in the warp direction, is satisfactory and acceptable, considering that the fabrics have a 100% cotton surface and have not undergone any special chemical/mechanical finishing to control shrinkage. As far as the mechanical properties of the fabrics are concerned, the tensile data reveal that the application of 5%-resin finish degrades the breaking strength by only about 8% in the warp direction and about 10% in the filling direction, compared to a typical loss of about 40 to 50% in case of conventional, 100%-cotton fabrics. The breaking elongations of 27% in the warp direction and 20% in the filling direction for the heat-set fabric and, 21% and 18%, respectively for the resin-finished fabric are all exceptionally good. However, it may be noted here that the application of 5% resin finish actually degraded the breaking strains by 22% in the warp direction and 11% in the filling direction. The tear strength, which in many applications is more critical than the tensile strength, is also very good for both fabrics, considering that an equivalent 100%-cotton fabric typically would give a tear strength value of approximately 3 kilograms after the application of a normal DP-resin finish. As expected, the stoll-flex abrasion resistance of the heat set sample is significantly greater than that of the finished fabric, confirming the fact that the special DP-resin finish greatly degrades the surface abrasion resistance, and hence durability, of cotton. The bursting strength of the resin-treated fabric is slightly greater than that of the untreated fabric, apparently due to addition of the resin. The air permeability of both the fabric samples is comparable, presumably due to a relatively low (5%) add-on of the resin.

Table 2 shows various hand attributes of the tandem-spun-yarn-fabric. The applicable range of values for the primary hand qualities is 0-10 and the range for the total hand quality is 0-5. The higher the value of the primary hand quality within the 0-10 range, the greater the intensity of the particular hand (tactile feeling). The higher the total hand value within the 0-5 range, the better the overall hand quality. It can be seen that the fabric mostly gives rather out-of-range values for both the primary and secondary (total hand) qualities for both the winter and summer suiting applications. However, the total hand value of 2.82 may be considered within the reasonable, if not totally acceptable, range for the winter suiting applications. The total hand value (-8.7) for the summer suiting applications is certainly outside the acceptable range . The high bending rigidity perhaps is responsible for the fabric falling outside the hand preference range for the summer suiting applications.

Conclusion

SRRC's tandem spinning system is a viable system for producing a truly unique core-wrap yarn at extremely high production speeds. The yarn produced by the system can be satisfactorily processed in the conventional, downstream processes to produce a fabric without difficulty. The tandem-spun-yarn-fabric, once properly heat set, exhibits satisfactory levels of durable press and shrink resistance without any special chemical finishing. The fabric has acceptable tensile and tear strengths, bursting strength, air permeability, and flex abrasion, which makes it suitable for many textile applications, including apparel.

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Table 1. Properties of a Tandem-Spun-Yarn-Fabric

	Heatset	Heatset + Resin
Tensile Strength:		
Breaking Load (kg)		
warp direction	51.5	47.3
standard deviation	3.4	4.3
filling direction	25.0	22.4
standard deviation	1.5	0.4
Breaking Elongation (%)		
warp direction	27.0	21.0
standard deviation	3.2	2.1
filling direction	20.4	18.2
standard deviation	1.6	0.3
Tearing Strength (kg):		
warp direction	6.3	5.2
standard deviation	0.1	0.1
filling direction	4.1	3.6
standard deviation	0.3	0.2
Bursting Strength (kg):		
meas. value	63.3	67.0
standard deviation	3.4	5.1
Stoll Flex Resistance (cycles)		
warp direction	7,507	6,302
standard deviation	1,052	1,312
filling direction	3,975	2,795
standard deviation	245	283
Pilling Resistance (Rating):		
Air Permeability [(cu.m/min)/sq.m]:		
meas. value	8.1	8.1
std. deviation	0.3	0.2
DP after 5 HLTD (Rating)	3.4	3.2
Shrinkage (%) after 5 HLTD	3.4 X 1.1	3.3 X 0.4

Table 2. Objectively evaluated hand values of a Tandem-Spun-Yarn-Fabric

Hand attribute	**Value of the hand attributes**	
	Men's winter suit	Men's summer suit
Koshi	17.6	19.54
Shari	*	8.5
Fukurami	2.09	3.8
Hari	*	22.9
Numeri	-2.2	*
Total Hand	2.82	-8.7