A POLYETHYLENE STAPLE-CORE/COTTON-WRAP DUCK FABRIC FOR MILITARY TENTAGE

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Abstract

The US Army is interested in a flame-resistant, 10 oz/sq yd, duck fabric, preferably cotton or predominantly cotton content for tents. One of the most important specifications and perhaps the most difficult to attain is the FR-finished fabric's tear strength of at least 6 lbs. Although by selecting a strong, long staple, combed cotton, it is possible to meet the required tear strength in the greige fabric, it is extremely difficult to retain the same strength level in the FR-finished fabric. By applying ARS core-spinning technology developed at SRRC and using only 10% (by weight of the yarn/fabric) gel-spun polyethylene (PE) staple fiber (only in the yarn core), we have been able to produce an almost 100%-cotton-surface fabric that meets the required military specification of tear strength in the filling direction and considerably exceeds it in the warp direction. This paper briefly describes various processes involved in converting fibers into a FR-finished fabric and properties of the yarns and fabrics produced.

Experimental Procedures

Yarn Production and Preparation

Raw materials used were a) 1 1/8" Acala cotton and b) 1.5 denier, 1.5" long, gel-spun polyethylene (Dyneema) fiber produced by DSM High Performance Fibers, The Netherlands. The cotton was opened and cleaned in Superior and Fine Cleaners. The cleaned cotton and PE were appropriately blended using weigh pan blenders and a conveyor belt. The blend ratio was 70% cotton and 30% PE. The fiber blend was processed on an Hollingsworth card producing a 60 gr/yd sliver at about 60 pounds per hour. The card sliver was drawn (two passages) on a Versamatic DF, producing a 55 gr/yd sliver at about 400 ft/min. The drawn sliver was converted into a 2.0-hank, 0.9 tpi, roving (to be used as the core material in subsequent core spinning) on a Rovematic. Using similar mill equipment and procedures, a quantity of 2.0-hk, 100% cotton roving (to be used as the sheath material in core spinning) was also produced. Applying the ARS-patented, core-wrap ring spinning technology (developed at SRRC and exclusively licensed to HTT-International, NJ), bi-component yarns of 14/1's warp and 15/1's filling containing PE inside and 100% cotton on the outside were produced on a modified ring spinning frame. Both the yarns were spun with a TM of about 4.0 using two, 2.0-hank cotton rovings for the wrap and a 2.0-hank, 70/30 cotton/Dyneema intimate-blend roving for the core, thus resulting in a fiber blend ratio of 90% cotton and 10% PE (only in the yarn core) in the composite yarns. Using standard test procedures, equipment and conditions, the yarns were mainly tested for tensile breaking strength. Both the yarns were two-plied on a twister, using a TM of 4.0. The warp yarn was appropriately beamed on a loom beam and the filling yarn was wound onto cones suitable for weaving.

Weaving

Using 52 ends/inch in the reed and 32 picks/inch, a 10-oz/sq. yard, 40"-wide, duck fabric was woven on a Draper, X-P, loom. The greige fabric was tested for certain physical and mechanical properties according to standard test procedures.

Finishing

The greige fabric was boiled off and caustic scoured by conventional procedures. The scoured fabric was made flame-retardant with a standard formulation of Retadol (30% solids solution, by weight of the fabric). The wet pick up of the FR-treated fabric was 70%. The treated fabric was ammoniated (1 yd/min); oxidized (1% H_2O_2 based on weight of water) for 30 minutes; rinsed twice for ten minutes each; padded; and dried for 2 min at 190 F. Because of the sensitivity of PE to temperatures above 200 F, the fabric was not subjected to any (wet) processing condition or treatment above this critical temperature. Using standard test procedures, the scoured as well as FR-finished fabrics were tested for tear and tensile strengths, abrasion resistance, and fire retardancy.

Results and Discussion

Table I shows the tenacity (tensile breaking strength per unit yarn tex) of the 100% cotton (control) yarn and the 90:10 cotton:PE-core yarn. As seen, an addition of only 10% PE dramatically increases the single-strand breaking strength by more than 33%. Similar increases are also observed in the skein breaking strengths (CxS products) of both the warp and fill yarns.

Tables II, III and IV show some important physical and mechanical properties of the greige, scoured, and FR-finished fabrics, respectively. The tensile breaking strength of the greige fabric made with the core yarns is 56% greater in the warp direction and about 53% in the filling direction, compared to those of the 100% cotton (control) fabrics. Indeed, just a ten percent content of Dyneema (PE) in the fabric remarkably improves the latter's tensile strength. The fabric tear strength (which, incidentally, in this particular fabric application is more important and critical than the

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tensile breaking strength) is even more impressive. For example, the tear strength is 140% higher in the warp direction and 115% greater in the filling direction.

As seen in Tables III and IV, the tensile and tear strengths of the scoured and FR-finished fabrics are also considerably higher than those of the equivalent, 100% cotton fabrics. In fact, they all meet or exceed the required military specifications. The breaking elongation of the core-yarn fabrics is significantly greater than that of the cotton control fabric. The FR properties of the finished core fabric are marginally acceptable. However, we expect some further improvement (especially in the char length) by increasing the (solids) level of FR treatment to 35% and by better controlling the FR-treatment process, which perhaps was not optimized in the present study. A fine denier, gel-spun polyethylene staple fiber is a new fiber, and, as such, we really do not yet have an adequate information on its optimum mechanical processing and chemical finishing. However, we are trying to learn more about this rather unique and interesting fiber. At any rate, the very first experimental fabric made with this fiber on commercial machinery and equipment has met the required, critical property of tear strength. The flex abrasion of the core-yarn fabric is almost three times greater in the warp direction and about four times in the filling direction than the corresponding values of the equivalent all-cotton fabrics. The flat abrasion resistance of the two types of fabrics is comparable.

Conclusion

Although the drafting of Dyneema® polyethylene staple fiber poses certain difficulties in mechanical processing, the fiber, especially in blend with cotton, can be reasonably processed on typical cotton processing machinery and equipment and converted into either cotton-rich or polyethylene-rich blend slivers and rovings which, in turn, can be used as the core material on the SRRC core-spinning process. Considering the marriage of a unique new fiber and a relatively new core spinning technology, the resultant core-spun yarns are reasonably satisfactory. The yarns do not pose any significant problem in weaving. The woven fabric finished with FR treatment meets or exceeds the Army's stringent requirement of tear strength. Future research with the latest, improved Dyneema fiber which is about 25% stronger than the present fiber is expected to give even better results.

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Table I. Properties of cotton/Dyneema® staple-core and 100% cotton yarns.

Property	Fiber content (Cotton/Dyneema®)	
	100 C	90 C/10D
Yarn strength[1]		
Single-strand (g/tex)		
14/1	15	20
15/1	15	19
Skein (csp)[2]		
14/1	2258	3000
15/1	2346	2895

[1] Yarns for weaving were 2-plied (i.e., 14/2 warp, 15/2 filling).
[2] Cotton count (Ne) x bkg. strength (lbs).

Table II. Properties of greige fabrics made with cotton/Dyneema® staple-core and 100% cotton yarns.

Property	Fiber content (Cotton/Dyneema®)	
	100 C	90 C/10D
Fabrics:		
Weight (oz/sq. yd)	8.99	9.30
Thread count (w x f)	55 x 35	56 x 35
Breaking strength (lbs.)		
Warp	144	225
Filling	89	136
Tearing strength (lbs.)		
Warp	11.1	26.7
Filling	6.6	14.2

[3] Above the capacity of the test instrument.

Table III. Properties of scoured fabrics made with cotton-covered Dyneema® staple-core yarns and 100% cotton yarns.

Property	Fiber content (Cotton/Dyneema®)	
	100 C	90 C/10D
	D	F
Weight (oz/sq. yd)	8.25	8.55
Thread count (w x f)	56 x 33	56 x 32
Breaking strength (lbs.)[1]		
Warp	161	251
Filling	109	153
Elong. at break (%)		
Warp	13.7	17.8
Filling	16.8	18.2
Tearing strength (lbs.)[2]		
Warp	15.1	12.3
Filling	6.3	9.1
Flex abrasion (cycles)		
Warp	683	3037
Filling	715	3194
Flat abrasion (cycles)	1890	2537

[1] Grab break.
[2] Elmendorf tear.

Table IV. Properties of FR-treated fabrics made with the cotton-wrapped Dyneema® staple-core yarns and the 100% cotton yarns.

Property	Fiber content (Cotton/Dyneema®)	
	100 C	90 C/10D
Weight (oz/sq. yd)	9.40	9.35
Thread count (w x f)	49 x 34	48 x 32
Breaking strength (lbs.)[1]		
Warp	162	219
Filling	136	166
Elong. at break (%)		
Warp	13.9	18.0
Filling	5.8	5.2
Tearing strength (lbs.)[2]		
Warp	4.5	7.8
Filling	3.9	5.8
Flex abrasion (cycles)		
Warp	212	609
Filling	575	2156
Flat abrasion (cycles)	3658	3561
Char length-wrap (in.)	3.3	5.0
Oxygen index	.34	.31