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Research Article

Effect of Some Navels on Properties of Cotton/Nylon66 Blend (1 : 1) Rotor Spun Yarn and Wrapper Formation: A Comparison between Rotor and Ring Spun Yarn

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Use of nylon/cotton blend yarn in military uniform is common and due to advantages in its fabric in comparison to 100% cotton fabrics, capabilities of military uniforms have been improved. In this study the effects of navel type on properties of (50%-50%) nylon/cotton blend yarn and wrapper formation were investigated and compared with similar ring spun yarn. Rotor spun yarn was produced on a single head laboratory rotor spinning machine with four navels (smooth, spiral, 3 grooved, and 4 grooved) and ring yarn was produced on a zinser 319 ring spinning machine. Test result showed that navel type has a significant effect on yarn strength and strength of smooth navel yarn was maximum. Elongation of a 100% cotton rotor spun yarn is more than similar ring yarn, but it was not observed in cotton/nylon blend. Yarn irregularity and imperfections varied significantly with navel type and for rotor yarns were more than the ring yarn. Navel type had significant effect on yarn hairiness but it didnot have an effect on yarn abrasion significantly.

1. Introduction

The use of blended yarn has increased significantly these days. Blending is used as a means of substituting a less expensive fiber for a highly priced one and to produce yarns with qualities that cannot be obtained by using one type of material alone.

El-sheikh [1] reported that the properties of blended yarns depend on their constituent fibers and also showed that blended yarn's tenacity decreases as the percentage of high tenacity fiber is increased. Kemp and Owen [2] investigated the stress/strain characteristics and cotton fiber breakage for a series of nylon/cotton blended yarns at strain above the breaking strain of all cotton and also studied the strength and mechanical behavior of nylon/cotton blended yarn and they found that a dependence exists between the behavior of the two fiber types. Gibson et al. [3] worked on military uniform and reported that nylon/cotton blend is used as an outer shell in different version of military chemical protective uniforms. And some researchers [4–6] worked on battle dress uniforms (BDU) and found that nylon/cotton blend is more suitable than those of any other blends. Kong et al. [7] reported that by adding 2–4% elastan yarn (lycra) through the nylon/cotton fabrics, the ability of extension of these kinds of fabrics can be increased up to 50% and it is appropriate for military uniforms. Javadiyan et al. [8] worked on seven different nylon/cotton blend ratios and reported that by increasing the nylon fiber blend ratio, the yarn elongation, abrasion resistance, tensile work of rupture, and hairiness significantly increase, whereas yarn tensile modulus decrease.

Navels differ in their material, forms, number of grooves, existence of fluted inserts, length of ceramic parts, and grooves [9]. Smooth navels often give better yarn characteristics; the yarn is more resistant to rubbing and has good heat conductivity and generally less false twist; grooved navels can operate at lower twist levels; the running performance is better because of the greater false twist effect but hairiness does increase; ceramic navels with 4–6 grooves have proved advantageous in the spinning of blended yarns and fibers that are not strongly sensitive to heat [10]. The configuration of

Table 1: Properties of fibers.

No	Fiber	Blend ratio	Length (mm)	Linear density (fineness)
1	Cotton	50%	Effective 28	0.15 tex (3.8 micronaire)
2	Nylon66	50%	Cutting 38	0.17 tex (1.5 den)

the navel has quite a considerable effect on both spinning stability and yarn appearance [11]. Nawaz et al. [12] reported that the effect of draw-off navel type and yarn count was highly significant while for yarn evenness, the effect of yarn count and rotor diameter was highly significant, whereas the effect of draw-off navel was at par. Erbil et al. [13] worked on the effect of navel type on hairiness of rotor-spun blend yarn and reported that the form and structure of navel have an important effect on hairiness, except the number of notches.

The work reported here is concerned about the evaluation of the quality and mechanical properties of five different nylon/cotton blends of yarn that are particularly used in military uniforms, apparel and textile industry.

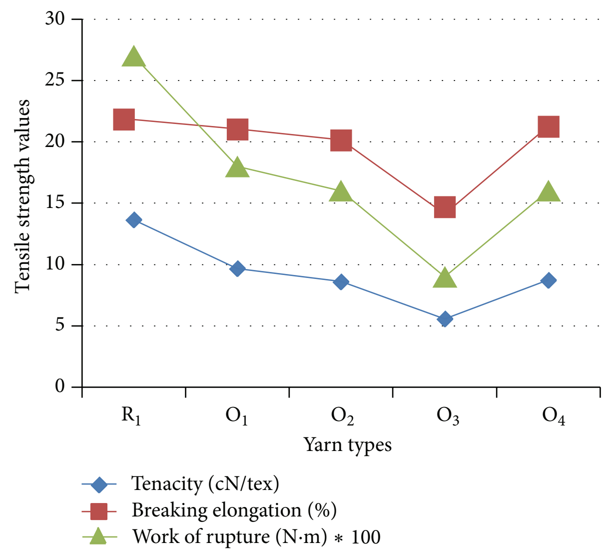


Figure 1: Effect of navel type on tensile properties of nylon/cotton rotor spun yarn.

2. Materials and Method

Nylon66 and Cotton have been used in the present investigation (Table 1). Cotton and nylon66 fibers in carded sliver were prepared. The carded sliver in the same proportion passed through two stages of drawing processes and created 4.5 Ktex nylon/cotton blend sliver and then the blended sliver feed to flyer frame for making 528 tex roving. Finally, draw sliver and roving were produced on a RU04 rotor spinning (Shubert & Salzer) with four different navels (smooth, spiral, 3 grooved, and 4 grooved) and Zinser 319 Ring spun machine respectively, to produce yarn of 20 Ne (29.5 tex).

Spindle speed, nominal count, and twist were 6700 rpm, 20 Ne, and 637 T.P.M, respectively. Also the speed of rotor, opening roller, take-up roller, and feed roller was 49300 rpm, 9200 rpm, 71.3 m/min, and 0.48 m/min, respectively.

The codings of the four different rotor spun yarns and ring spun yarn (witness yarn) are listed in Table 2.

All the samples were tested for the following: tensile strength, evenness, hairiness, and abrasion resistance.

2.1. Tensile Strength. Yarn tensile properties (tenacity, breaking elongation, and work of rupture) were determined on a SDL tensile tester with a jaw speed of 1 m/min and a test length of 50 mm, and 30 tests were conducted for each yarn.

2.2. Evenness. The irregularity and yarn imperfection (thick, thin, nep, and CV%) were measured by using a Keisokki uster over a length of 1000 m of yarn speed at 25 m/min and 5 tests were conducted for each yarn. The degree of sensitivity of the thinness, thickness, and neps was −50%, +50% and +280% respectively.

2.3. Hairiness and Abrasion Resistance. A SDL hair tester was used to determine the hairiness with a testing speed of 20 m/min and a test length of 30 m for 5 samples (totally 150 m); only hairs with a length greater than or equal to 3 mm were measured. The yarn abrasion resistance was measured by using a SDL yarn abrasion tester. A abradant (P1200) was used and 30 tests were conducted for each yarn sample. All tests were conducted under the standard laboratory conditions (22 ± 2°C and 65±% r·h).

2.4. Scanning Electron Microscopy (SEM). Wrapper formation of the samples was observed by scanning electron microscopy (VEGA TESCAN, Czech Republic). Samples were fixed in SEM holders and coated with a thin layer of gold prior to SEM investigation.

2.5. Analysis of Data. The data was analyzed statistically by using CRD (complete random design) method for the interpretation of data. Analysis of variance (ANOVA) and Duncan test were provided at α value of 0.05%. All statistical analysis steps were performed on SPSS software.

Table 3 shows test results for the properties of yarn quality. A summary of ANOVA statistical results is tabulated in Tables 4, 5, and 6. As shown in these tables, the effect of navel type on yarn physical properties is almost statistically significant.

3. Results and Discussion

3.1. Tensile Properties. The effect of navel type on nylon/cotton blended rotor spun yarn tensile properties is illustrated in Figure 1.

From the test result in Tables 3 and 4 and Figure 1, we can observe that navel types have statistically significant difference according to tensile properties. Duncan test revealed that the highest and the lowest yarn tenacities were recorded for R_1 (13.6 cN/tex) and O_3 (5.7 cN/tex), respectively. These

Table 2: Navel types.

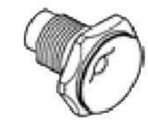
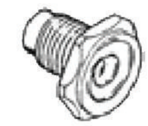
Navel type	Yarn code	Properties	Processed material	Spinning system	Navel design
—	R_1	—	—	Ring	—
KN	O_1	Ceramic, Smooth	Cotton and blend	Rotor	
KS	O_2	Ceramic, Spiral	Cotton and blend	Rotor	
K3KK	O_3	Ceramic, 3 grooved, short	Cotton and blend	Rotor	
K4KK	O_4	Ceramic, 4 grooved, short	Cotton and blend	Rotor	

Table 3: Test result for yarn quality properties.

Yarn type	Tensile strength			Evenness				Hairiness	Abrasion resistance
	Tenacity (cN/tex)	Breaking elongation (%)	Work of rupture (N·m)	CV%	Thin (−50%) per Km	Thick (+50) per Km	Nep (+280) per Km		
R_1	13/65	21/80	0/27	13/94	0	18	8	6	6/87
O_1	9/68	21/05	0/18	16/13	8	34	2	1/9	8/53
O_2	8/62	20/16	0/16	14/60	6	48	4	3	8/50
O_3	5/58	14/13	0/09	17/83	38	70	33	7/6	5/77
O_4	8/74	21/27	0/16	17/05	16	74	2	1/7	8/20

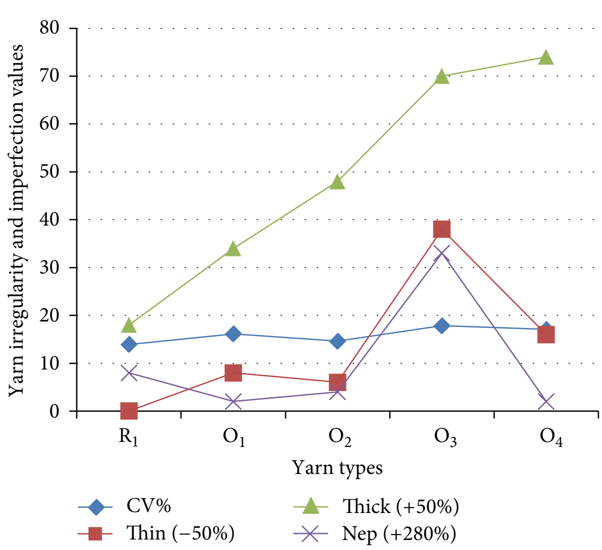


Figure 2: Effect of navel type on yarn irregularity and imperfection of nylon/cotton rotor spun yarn.

values were nonsignificant for O_2 and O_4. Also between the navel types, smooth navel (O_1) has the highest value.

Figure 1 and Duncan test indicated that the highest and the lowest yarn breaking elongations were recorded for R_1 (21.8%) and O_3 (14.13%), respectively; also there is a significant difference between R_1, O_2 and O_3, and these values were non-significant for the others (Table 4). In contrast with breaking elongation for 100% cotton in written text book [14], the breaking elongation in nylon/cotton rotor spun yarn with all navel types (except 3 grooved) is lower than similar ring spun yarn.

Figure 1 and Duncan test showed that the highest and the lowest yarn works of rupture were recorded for R_1 (0.27 N·m) and O_3 (0.087 N·m), respectively. There is no significant difference between O_2 and O_4.

3.2. Evenness. The effects of navel type on nylon/cotton blended rotor spun yarn irregularity (CV%) and imperfection are shown in Figure 2. From the test results in Table 3 and Figure 2, it is clear that navel type has statistically significant

Table 4: A summary of ANOVA statistical result (Duncan test) for tensile strength*.

Yarn type	Tensile Strength														
	Tenacity					Breaking elongation					Work of rupture				
	R_1	O_1	O_2	O_3	O_4	R_1	O_1	O_2	O_3	O_4	R_1	O_1	O_2	O_3	O_4
R_1	—	+	+	+	+	—	−	+	+	−	—	+	+	+	+
O_1	+	—	+	+	+	−	—	−	+	−	+	—	+	+	+
O_2	+	+	—	+	−	+	−	—	+	−	+	+	—	+	−
O_3	+	+	+	—	+	+	+	+	—	+	+	+	+	—	+
O_4	+	+	−	+	—	−	−	−	+	—	+	+	−	+	—

*At 5% confidence limit, "+" means statistically significant and "−" means statistically in-significant.

Table 5: A summary of ANOVA statistical result (Duncan test) for evenness*.

Yarn type	Evenness																			
	CV%					Thin					Thick					Nep				
	R_1	O_1	O_2	O_3	O_4	R_1	O_1	O_2	O_3	O_4	R_1	O_1	O_2	O_3	O_4	R_1	O_1	O_2	O_3	O_4
R_1	—	+	−	+	+	—	−	−	+	−	—	−	−	+	+	—	−	−	+	−
O_1	+	—	+	+	+	−	—	−	+	−	−	—	−	+	+	−	—	−	+	−
O_2	−	+	—	+	+	−	−	—	+	−	−	−	—	+	+	−	−	—	+	−
O_3	+	+	+	—	+	+	+	+	—	+	+	+	+	—	−	+	+	+	—	+
O_4	+	+	+	+	—	−	−	−	+	—	+	+	+	−	—	−	−	−	+	—

*At 5% confidence limit, "+" means statistically significant and "−" means statistically insignificant.

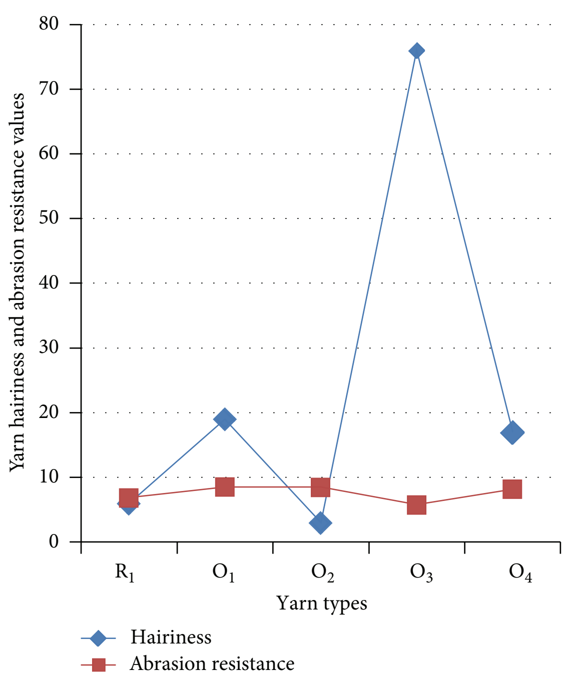


Figure 3: Effect of navel type on hairiness and abrasion resistance of nylon/cotton rotor spun yarn.

difference at the level of 0.05 according to yarn irregularity and yarn imperfection.

Figure 2 and Duncan test revealed that the highest and the lowest yarn CV% were O_3 (17.82) and R_1 (13.93), respectively. It is found that in 3 grooved navels, the highest yarn irregularity was obtained. Also between the navels, spiral navel has the lowest CV%. In contrast with result for 100% cotton yarn, rotor spun yarns have more CV% than similar ring spun yarn.

As shown in Figure 2, in thin point, there is no significant difference among spun yarn except 3 grooved yarns; also among navels, spiral navel has the lowest thin point but in thick point; it is found that 4 grooved navel has the highest and ring yarn has the lowest one. Fibers in surface layer of rotor spun yarn partially evaded from twisting operation in spinning process that resulted in yarn taking lower twist; thus, few fibers participated in yarn strength and lead to creating the thick points.

As shown in Figure 2 and Duncan table revealed that the highest and lowest yarn neps were O_1 and O_3, respectively, and there is no significant difference between R_1, O_2, O_4, and O_1. The high amount of irregularity of 100% cotton rotor spun yarn is attributed to the high amount of short fiber content as well as to the relative short effective length of cotton fiber compared to nylon66; it is deduced that the wrapper fibers existing around the yarn body are an undesired factor which in turn increases the yarn irregularity.

3.3. *Hairiness.* Figure 3 shows the effect of navel type on nylon/cotton blended rotor spun yarn hairiness. Test result shows that 4 grooved navel has the lowest and 3 grooved navel has the highest hairiness. Also Duncan test revealed that there in no significant difference between O_1 and O_4 but other navels and ring spun yarns differ significantly from each other.

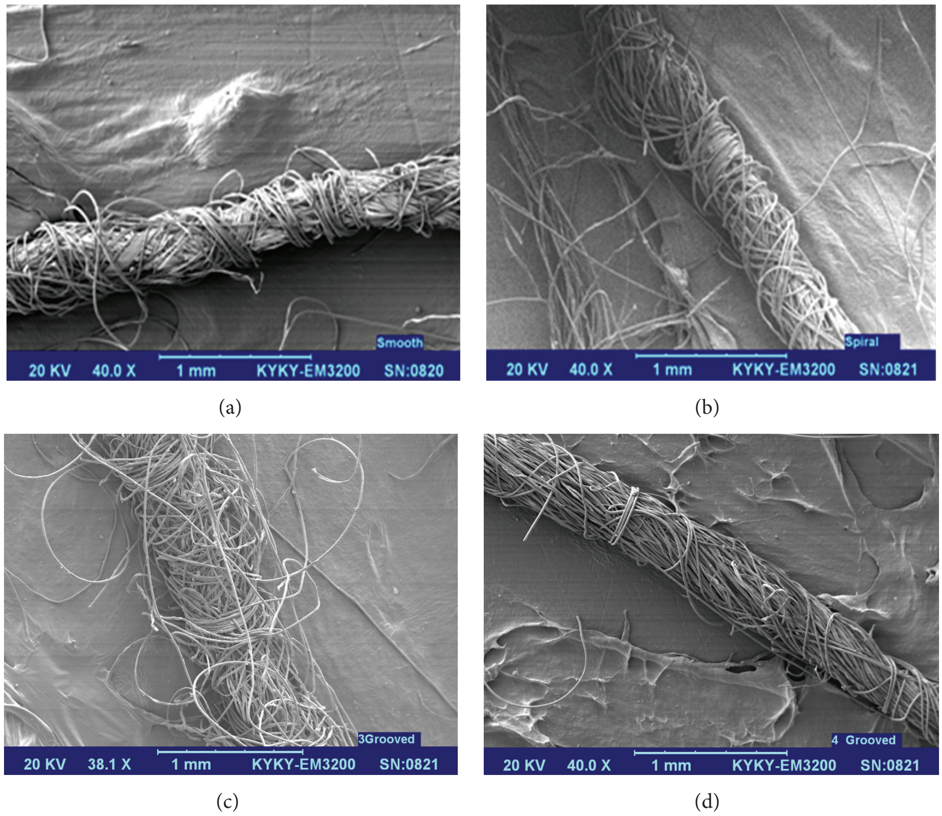


FIGURE 4: Effect of navel types on wrapper formation (a) smooth navel, (b) spiral navel, (c) 3 grooved navel, (d) 4 grooved navel.

TABLE 6: A summary of ANOVA statistical result (Duncan test) for hairiness and abrasion resistance*.

Yarn type	Hairiness					Abrasion resistance				
	R_1	O_1	O_2	O_3	O_4	R_1	O_1	O_2	O_3	O_4
R_1	—	+	+	+	+	—	+	+	–	+
O_1	+	—	+	+	–	+	—	–	+	–
O_2	+	+	—	+	+	+	–	—	+	–
O_3	+	+	+	—	+	–	+	+	—	+
O_4	+	–	+	+	—	+	–	–	+	—

*At 5% confidence limit, "+" means statistically significant and "–" means statistically in-significant.

3.4. Abrasion Resistance. Effect of navel type of nylon/cotton blended rotor spun yarn is shown in Figure 3; it is found that all navel types (except O_3) have higher abrasion resistance than ring spun yarn. According to Figure 3 and Duncan table, it is clear that the highest and the lowest abrasion resistances were recorded for smooth and 3 grooved navels, respectively. And there is no significant difference between O_1, O_2 and O_4.

3.5. Wrapper Formation. Figure 4 shows the effect of navel types on wrapper formation. Hajilari et al. [15] worked on wrapper types and classified them into four group as follows.

First group is loose and concentrated wrapper fiber; second is loose and distributed wrapper fiber; third, tough and concentrated wrapper fiber; fourth, tough and distributed wrapper fiber.

As shown in Figure 4, smooth navel has considerable effect on wrapper formation and this type of navel has the most wrapper density compared to the others (i.e., the third group, tough and concentrated). Spiral and 4 grooved navels have tough and distributed wrapper fiber but as it is clear from Figure 4, 4 grooved navel yarn is more oriented than smooth and spiral navel yarns. It is clear that the fiber orientation and parallelization of 3 grooved navel yarn is too low due to existing loose and distributed wrapper fibers and it is a potential reason for deteriorating yarn quality. As we observed in all physical tests, a physical property of this yarn was the worst.

4. Conclusions

Test result shows that navel types statistically have significant effect on tenacity and smooth navel has the highest value. According to the result of breaking elongation of 100% cotton rotor spun yarn, cotton rotor yarn has more elongation than similar ring yarn but in nylon/cotton blend it was not observed (except 3 grooved navel). Also navel type has considerable effect on yarn irregularity and imperfection; in contrast with written result for 100% cotton yarn, the higher CV% of nylon/cotton rotor spun yarn was obtained and generally, yarn imperfection of rotor spun yarn is more than similar ring spun yarn. In contrast with this subject that says that 3 grooved navel has lower yarn bulk and hairiness than 4 grooved navel [16], in nylon/cotton blend these properties were not obtained. Navel types havenot significant effect on yarn abrasion resistance and all types of navels (except 3 grooved) have more abrasion resistance than ring yarn. Totally it is found that in yarn irregularity and breaking elongation tests, the effect of initial material is more than the effect of yarn structure and also 3 grooved navel is not appropriate for nylon/cotton blend. The SEM investigation also shows the effect of navel types on nylon/cotton rotor yarn and among these yarn, 4 grooved navel was more oriented than the others.

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