

TEXTILE TOPICS

International Textile Center

Texas Tech University Lubbock, Texas USA

International Textile Center Welcomes Students for New Session of Texas International Cotton School

On Monday, August 21st, students and cotton industry experts from five countries and six U.S. states converged on the International Textile Center campus as the 26th session of the Texas International Cotton School began.

The school is a cooperative effort between the Lubbock Cotton Exchange and the International Textile Center at Texas Tech University. The program comprises hands-on instruction of all phases of cotton production, harvesting, ginning, classing, testing, preparation and processing. Students also undergo in-depth training in many phases of marketing, futures, indexing and other functions along the cotton value change.

For more information or to apply to the next session of the Texas International Cotton School, visit us at <http://www.texasintlcottonschool.com>.



Front Row—Raina King, Texas Tech University; Valerie Countiss, USDA-FAS, Washington D.C.; Brenda Hewitt, Wells Fargo, TX; Barbara Boren, Executive Director, Lubbock Cotton Exchange; Kristi Jordan, PCCA, TX; Melanie Beauchamp, PCCA, TX; Judy Teas, TICS. Second Row—Niaba Teme, Texas Tech University; Billy Faulk, Swift Galey Mills, North Carolina; Warwick Murray, Rabobank, Australia; Gary Wu, First Cotton Ltd.; Mahmood Ullah Gazi, Dulamia Mills, Bangladesh; Brett Underwood, Trinity Cotton, TX; Jaime Cantu, Graduate Asst., ITC-TTU. Third Row—Todd Straley, United Cotton Growers, TX; Mike Stephens; Matthias Knappe, UNCTAD/WTO ITC. Not Pictured—Md. Nomair Wasif, Al-Hamd Industries, Pakistan; Tyrone Wong, Pvt. Tyfountex, Indonesia.

*Sharing
current research
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World Cotton Research Conference-4 Issues Final Announcement and Call for Papers



With the Fourth convocation of the World Cotton Research Conference less than a year away, Organizing Committee members proudly announce the publication of the Official Announcement and Call for Papers.

Online Registration and Paper Submission have begun at <http://www.wcra4.org> and a downloadable copy of the Announcement is available at that web address. Parties interested in submitting papers for presentation or attending WCRC-4 are urged to register early. Pre-registration with the ICAC website does NOT guarantee registration.

We hope you'll join us in Lubbock on September 10-14, 2007 for WCRC-4, as we explore Cotton, Nature's High Tech Fiber.

Compact Spinning Effect on Cotton Yarn Quality: Interactions with Fiber Characteristics

Mourad Krifa and M. Dean Ethridge

The following is a reprint, by permission, of an article in the Textile Research Journal (TRJ 76(5): 388-399).

The evolution of spinning technology has generally altered the relationships between fiber properties and yarn quality. Different spinning processes will likely involve different fiber-machine interactions, which alters the optimum combinations of fiber properties.

For several decades, development efforts in ring spinning were focused on improving the existing technology and incorporating automation and process-linking capabilities. The basic design of a ring spinning machine remained largely unchanged until the introduction of the compact (or condensed) ring spinning technology, beginning in the late 1990s.

Compact spinning offered the potential to create a near-perfect yarn structure by applying air suction to condense the fiber stream in the main drafting zone, thereby virtually eliminating the spinning triangle [1, 2, 10, 17, 21-23]. The qualitative improvements inherent to this enhanced yarn structure have been extensively documented in the literature [1-4, 10, 14-17, 21-23]. Compact spinning has been shown to significantly improve yarn tensile properties and reduce its hairiness. Both characteristics are crucial for yarn performance in downstream manufacturing operations.

Research previously conducted by the authors [15, 16] has focused on the application of compact spinning on short-to-medium staple cottons. Results showed that, beyond the overall yarn quality improvements, some interactions are likely between compact spinning and raw fiber properties. Comprehending such interactions is critical for determining the combinations of fiber properties needed to obtain best results with compact spinning. The present research was done to investigate the spinning/fiber-property interactions proper to the compact system, again with a focus on short-to-medium staple cottons.

MATERIAL AND METHODS

Thirty-five cotton bales were selected based on a wide range of the well-known fiber properties. Table I contains summarized fiber analysis results. In order to ensure the representativeness of the raw fiber properties measurement, each bale was divided into ten layers, with fiber samples taken from each layer and tested on HVI (High Volume Instrument, 4 replications for Micronaire, 4 for color, and 10 for length and strength) and AFIS (Advanced Fiber Information System, 3 replications of 3000 fibers each).

We processed the selected bales on both conventional (Suessen Fiomax 1000, 45 mm rings) and compact (Suessen Elite E-1, 42 mm rings) ring spinning frames into 22.7 tex (26 Ne) warp twist

Table I: Main fiber properties of the selected bales (HVI and AFIS measurements on raw cotton).

Fiber properties	Min.	Max.	Average
HVI			
Micronaire	2.8	5.1	4.1
Upper Half Mean Length (UHML, mm)	24.9	30.8	27.7
Length uniformity (%)	79.1	84.2	81.6
Strength (g/tex)	23.9	33.6	29.1
Elongation (%)	4.5	9.4	6.8
AFIS			
Mean length by number (Ln, mm)	16.2	21.7	19.0
Short Fiber Content by number (SFCn, %)	18.2	36.8	26.9
Mean length by weight (Lw, mm)	20.5	26.8	23.7
Short Fiber Content by weight (SFCw, %)	5.5	15.4	9.7
Upper Quartile Length by weight (UQLw, mm)	25.3	32.1	28.6
Maturity Ratio (MR)	0.82	0.95	0.88
Fineness (mtex)	156	190	171
Standard Fineness (Std. Fin., mtex)	181	203	194

yarn ($\alpha_m = 127$). The yarn was produced from the same lots of roving, having been prepared in identical conditions. Total spinning draft was 26 and preliminary draft was 1.22. We ran both frames at 32 m/sec traveler speed, with 2/0 semi-round wire travelers and 63° Shore front-top-roll cot hardness.

After proper conditioning (65% RH, 21° C), we tested all yarn samples on the following instruments:

- Uster® Tester 3 (UT3) for evenness and hairiness,
- Uster® Tensorapid for single-end tensile properties,
- Zweigle G566 hairiness tester.

We tested ten bobbins from each sample on each instrument, with 400 m per bobbin on the evenness tester and 100 m per bobbin on the Zweigle hairiness tester. The single-end tensile test consisted of 100 individual breaks per bobbin.

As mentioned above, the effects of fiber stream condensing on yarn properties are well documented in the literature. Therefore, we will only provide a brief overview of the main effects observed in our experimentation. We will then place the primary focus on relationships among yarn hairiness, tensile properties, and fiber characteristics.

RESULTS AND DISCUSSION

Table II contains the average values and ranges of the main yarn properties. Note that yarn hairiness is characterized both by the H index, as measured by the UT3, and the Zweigle S3 parameter (number of protruding hairs exceeding 3 mm in projected length per 100 m yarn).

As expected, yarn results showed a highly significant effect of the spinning process (conventional vs. compact) on tensile properties and hairiness. No significant effects were observed on yarn non-uniformity (mass CV %) or evenness

Table II: Average values and ranges of yarn properties
Compact vs. conventional ring spun yarn.

Spinning process Yarn Properties	Conventional Yarn			Compact Yarn		
	Average	Min.	Max.	Average	Min.	Max.
Mass CV %	16.38	13.69	19.05	16.16	14.24	18.45
Thin /km	33	2	125	33	4	108
Thick /km	292	88	672	257	112	609
Neps200 /km	198	78	372	177	68	399
Elongation (%) ^a	6.33	5.17	7.80	6.90	5.66	8.40
Tenacity (cN/tex) ^a	15.90	12.24	20.66	16.85	13.17	21.22
Work to break (cN.cm) ^a	591.4	429.3	757.7	658.1	494	861.8
H (UT3 hairiness index) ^a	5.01	4.21	6.08	4.42	3.96	5.03
S3 (hairs >3mm / 100 m) ^a	611	265	1425	214	77	485

^adifference is significant at $\alpha=0.001$

imperfections. These results are globally in agreement with the previous research we conducted [14-16] and with the literature, although slight improvements of yarn mass variation (CV %) were

reported in some cases [3, 4], and were attributed to improved control over fiber losses at the exit of the drafting system of the spinning frame.

In order to determine the nature of the fiber-process interactions, we first test whether the spinning processes (categorical predictor variable) and fiber properties (continuous predictors) interact to influence yarn properties (that is, whether the regression slopes relating fiber and yarn properties differ across the spinning processes). We then examine the changes in the distributions of yarn properties, hairiness in particular, with regard to the spinning processes and to fiber properties.

YARN HAIRINESS

Hairiness of staple yarns is due to the protrusion of fiber ends and loops from the yarn core [18, 20, 25]. Its critical importance as a measure of yarn surface integrity has been extensively documented in the literature. In general terms, it is known to be highly dependent on fiber blends and spinning processes, as well as on spinning conditions (speeds, machine design...) for a particular process [5, 8, 9, 11, 19]. In ring spinning of cotton fiber, yarn hairiness is greatly influenced by the geometry of the spinning triangle [13, 25] and by various fiber properties, among which the most commonly cited are length (length distribution) and fineness [6, 18, 24, 26].

As previously stated, we measured yarn hairiness using two methods: the Uster® Tester (UT3), and the Zweigle G566 hairiness tester. Each instrument provides a hairiness parameter: H (expressed as the total hair length per yarn centimeter, and hence unitless) and S3 (expressed as the number of protruding hairs exceeding 3 mm per yarn unit length), respectively. In addition to the S3 index, the Zweigle tester provides a hair length distribution (number of hairs in different length categories). At this point, we shall consider the two indexes. The hair length distribution will be examined in the next section.

Table III contains simple correlation coefficients between hairiness (H and S3) and fiber properties. The results corroborate the significant influence of fiber length parameters and, to a lesser

Table III: Simple correlation coefficients between conventional and compact yarn hairiness parameters and fiber properties (critical r value at $\alpha = 0.05$ is 0.33).

Yarn hairiness / Fiber properties	Yarn hairiness (UT3)		Yarn hairiness - Zweigle S3	
	Conventional	Compact	Conventional	Compact
HVI				
<i>Micronaire</i>	ns ^b	ns	ns	ns
<i>UHML (mm)</i>	-0.86	-0.62	-0.70	-0.42
<i>Uniformity (%)</i>	-0.89	-0.82	-0.46	ns
AFIS^a				
<i>Ln (mm)</i>	-0.87	-0.69	-0.49	ns
<i>SFCn (%)</i>	0.71	0.59	ns	ns
<i>Lw (mm)</i>	-0.91	-0.67	-0.62	-0.38
<i>SFCw (%)</i>	0.80	0.64	0.36	ns
<i>UQLw (mm)</i>	-0.85	-0.59	-0.69	-0.39
<i>Std. Fin. (mtex)</i>	0.41	ns	0.34	ns

^aAbbreviations are as in Table I ^bns: non significant at $\alpha = 0.05$

extent, fineness parameters. There are substantial differences in the correlation coefficients depending on the hairiness parameter considered and on the spinning process (conventional vs. compact). The correlation coefficients observed for compact yarn are consistently lower than those obtained for the conventional one. The Zweigle S3 parameter shows a greater difference between the two spinning processes. Conventional yarn S3 is related to most fiber length parameters and shows a slight but significant correlation with standard fineness. Compact yarn merely shows rather low correlations with HVI Upper Half Mean Length (UHML), AFIS mean length (Lw) and AFIS Upper Quartile Length (UQLw). Clearly, compact spinning altered the relationships between yarn hairiness and fiber properties. We examine the nature of this alteration using the homogeneity of regression slopes model.

Based on the results shown in Table III, HVI length parameters were selected as continuous predictors in the homogeneity of slopes model and tested for interactions with the spinning process. The results of the analysis are reported in Table IV for both hairiness parameters. It should be noted that substitution of HVI results by length parameters obtained on AFIS® produced analogous results.

Table IV reveals that for UT3 hairiness index, both staple length and length uniformity show highly significant F values. Yet, only staple length shows a significant interaction with the spinning process (i.e., “process*length” interaction term). For the Zweigle S3, length uniformity is not significant in the model and only the terms involving staple length show significant F values (“length” and “process*length” terms).

Table IV: Homogeneity of slopes model, yarn hairiness as affected by the interaction between the spinning process and HVI fiber length characteristics.

Effect	Degr. of Freedom	UT3 Hairiness				Zweigle S3			
		Sum of Squares	Mean Square	F value	Prob. >F	Sum of Squares	Mean Square	F value	Prob. >F
Process^a	1	6.058	6.058	207.31	<.001	2756699	2756699	111.18	<.001
Length	1	5.914	5.914	202.39	<.001	852986	852986	34.40	<.001
Uniformity	1	2.009	2.009	68.74	<.001	12286	12286	0.49	0.484
Process*Length	1	0.795	0.795	27.20	<.001	382826	382826	15.44	<.001
Process* Uniformity	1	0.006	0.006	0.21	0.650	1085	1085	0.044	0.835
Error	64	1.870	0.029			1586931	24796		

^aProcess: 2-level categorical predictor (conventional vs. compact).

According to the significant interactions shown above (process*length), the magnitude of variation of yarn hairiness among spinning processes appears to be dependant on the value of fiber length. In other words, the effectiveness of the compact system in reducing yarn hairiness is dependent upon the staple length being spun.

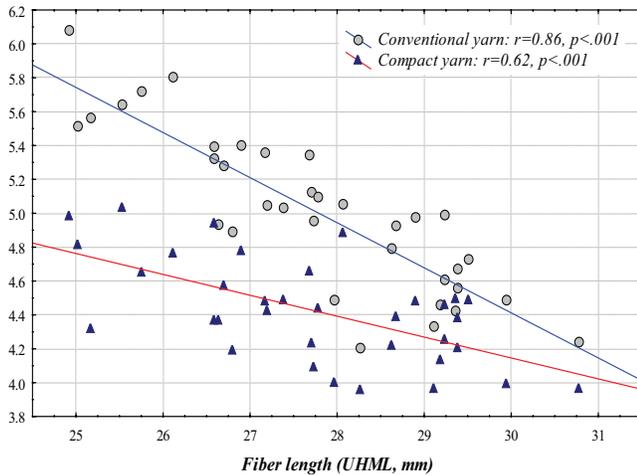


Figure 1. Conventional and compact yarn UT3 hairiness index vs. fiber UHML.

The interactions detected through the homogeneity-of-slopes model can be visualized by plotting the data and comparing the regression slopes. This is done for UT3 hairiness in Figure 1. It shows that while the difference between conventional and compact yarns appears substantial for shorter staple length values, the two regression lines converge at the high end of the length axis. The scatter plots relating length Uniformity and UT3 yarn hairiness (Figure 2) show similar trends. According to the non-significant “process*uniformity” interaction effect (Table IV), this trend is likely to be due to the relationship between staple length and length uniformity. It should also be kept in mind that, although no significant interactions were detected among other fiber properties (e.g., Micronaire), these may affect the dispersions of the scatter-plots shown in Figures 1 and 2.

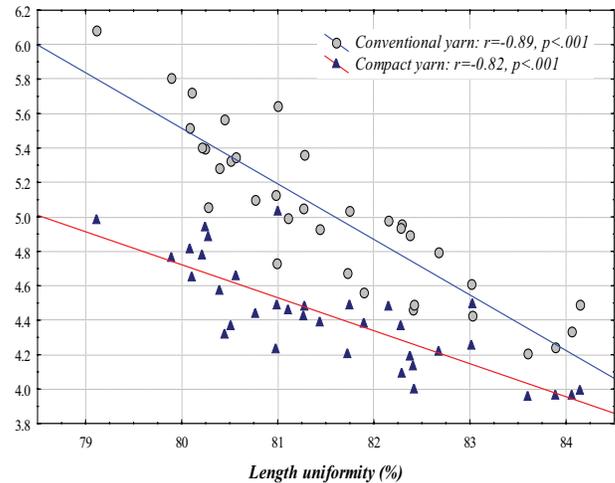


Figure 2. Conventional and compact yarn UT3 hairiness index vs. length uniformity.

The heterogeneous regression pattern described above suggests that despite the overall significant effect, the differences in yarn hairiness between the two spinning processes might be non-significant for some range of staple length or, more generally, for some combinations of those fiber properties influencing yarn hairiness (e.g., length and uniformity). Indeed, one relevant question related to the heterogeneity of slopes problem is whether there exists a “region of non-significance” associated with some values of the continuous predictor variables.

To explore this issue, we used the “Johnson-Neyman” technique. Huitema [12] presents this technique as an alternative for the analysis of covariance when the hypothesis of homogeneity of regression slopes is not satisfied. Huitema states that heterogeneity of slopes presents interpretation problems because the magnitude of the treatment

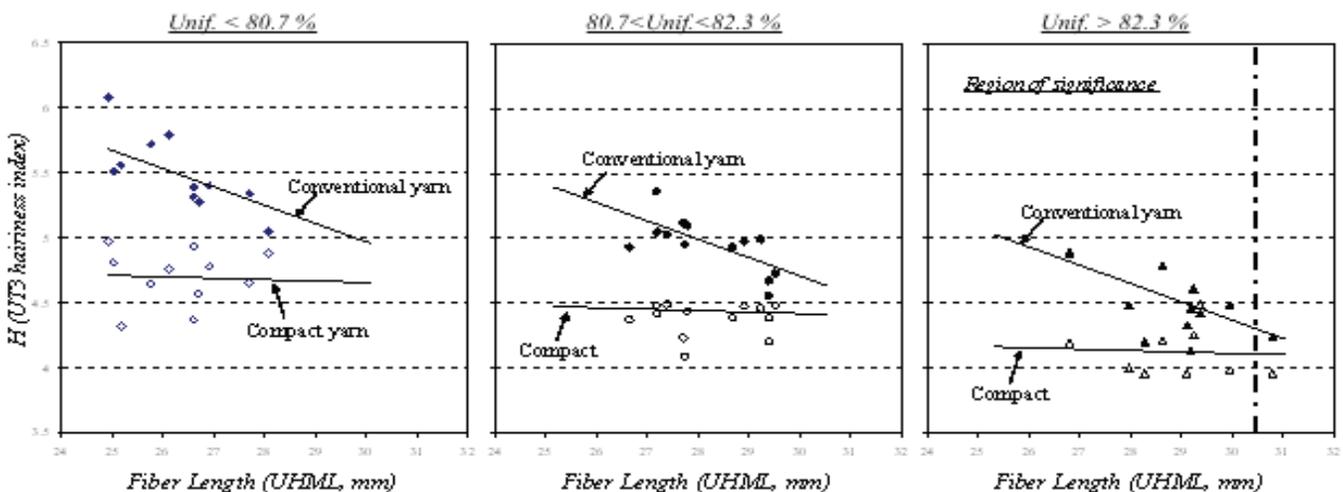


Figure 3. Conventional and compact yarn hairiness index as a function of staple length and uniformity.

effect (categorical factor or group) is not the same at different levels of the continuous predictor. The purpose of the Johnson-Neyman technique is to identify the values of continuous predictor that are associated with a significant group effect. The author introduces computation approaches for various cases, including the one we have in hand; i.e., with a two-level categorical factor and two continuous predictors.

Figure 3 shows the combined effect of staple length and length uniformity on yarn hairiness, as expressed by the homogeneity-of-slopes model, along with results of the approach suggested by Huitema. For readability purposes and to allow a 2-D representation, we show the results for three distinct intervals of uniformity index.

Figure 3 reveals the nature of the relationships between yarn hairiness and HVI length parameters (UHML and uniformity), for both conventional and compact yarns. It is apparent that higher length uniformity resulted in lower hairiness for both yarn types. On the other hand, the interaction involving staple length appears more complex. Indeed, the relationship length-hairiness shows a significant negative slope (-0.14) for conventional yarn and a slope not significantly different from zero for compact yarn.

The significance limits (i.e., value of staple length beyond which the difference between conventional and compact yarn hairiness is non-significant) were estimated according to Huitema [12]. The estimated significance limit ranged between 29.8 and 30.6 mm depending on the uniformity level. We reported the estimated significance limit for the high uniformity interval in Figure 3 (broken vertical line); the estimates obtained for the other two uniformity intervals are beyond the staple ranges covered by the experimental data (25.1 to 28.1 mm for uniformity < 80.7 and 26.6 to 29.5 mm for 80.7 < uniformity < 82.3) and are not shown on the graph. Figure 3 shows that only the sample with the longest length falls within the non-significance region when considering the range of 35 bales treated here. It should be stressed that these estimates are based on the current range of samples and that any extrapolation (to substantially longer staples, for

instance) is not advised.

Application of the same model to Zweigle S3 data resulted in slightly lower significance limits (i.e., differences in S3 levels between conventional and compact yarns were non-significant beyond UHML values lower than the estimates obtained for UT3 H index.) This is probably related to the nature of the two parameters, S3 being a count of long hairs only (>3 mm) and having a higher variability.

Figure 4 shows S3 significance limit estimates for a larger sample of 104 cotton bales. Note the decrease of UHML significance limit for higher uniformity levels. Six of the 104 tested bales (the six longest bales) are in the non-significance region; that is, have combinations of UHML and uniformity values that resulted in a non-significant S3 difference between conventional and compact yarns.

As a practical matter, the significance limit as such does not represent the most important information obtained from the data. Of more interest is the global pattern itself. While conventional yarn hairiness is significantly affected by both length and uniformity, the UT3 H parameter for compact yarn varies somewhat with uniformity levels, but is insensitive to staple length variation (within the tested range). Thus, the value added to the yarn by using compact spinning was higher for shorter-stapled cottons than for longer ones. For the longer cottons (bales in the vicinity of the significance limit of Figure 4), low hairiness

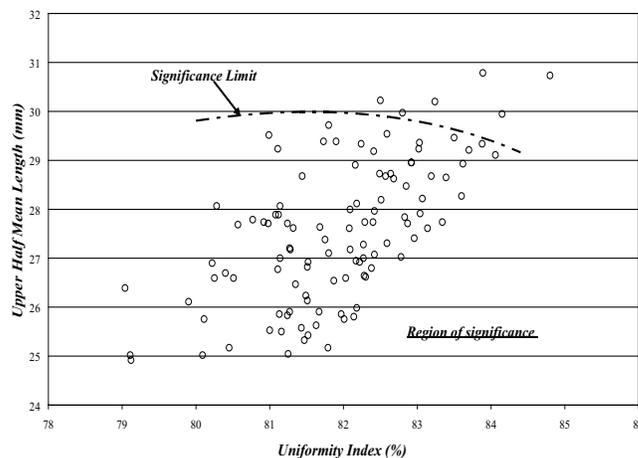


Figure 4. Significance limit estimated according to Huitema [12] – the bales with staple and uniformity values beyond the significance limit show non-different conventional and compact yarn S3 levels.

levels could be achieved on the conventional frame and the use of compact spinning had virtually no effect on yarn hairiness. These results could have critical implications for identifying the best alternatives offered by compact spinning, since using the technology with a comparable range of cottons (such as the bales close to the significance limit of Figure 4) and for a similar application (preparation, yarn count, twist) may lead to very limited benefits for the spinner.

Naturally, these results are limited to yarn hairiness. It is undoubtedly a crucial parameter for yarn performance in number of downstream processes such as sizing, weaving and knitting, where yarn failure is more likely to be caused by abrasion than by longitudinal traction. But it is not the only major criterion determining yarn value that may be affected by compact spinning. We discuss yarn tensile properties in a subsequent section, after we conclude the hairiness discussion by a brief consideration of the protruding hair length distribution.

PROTRUDING HAIR LENGTH DISTRIBUTION – ZWEIGLE HAIRINESS TESTER

Hair length distribution is well documented in the literature [5-8, 20, 24]; It has been shown to have an exponential or an almost-exponential pattern. Barella and Manich [7, 8] fit two (in some cases three) exponential segments to the hair length distribution of various yarn types. The different segments are substantiated by the variation of the exponential fit parameters over different ranges of hair length categories (slope change of the hair length frequency distribution curve on a semi-logarithmic scale). We shall use this fit for purpose of graphical representation (Figure 5, Figure 6). Further discussion of the exponential fit for the different yarn types, with the particularities proper to compact yarn, should be treated as a separate matter.

We report in Figures 5 and 6 the two-exponential-segments approximation, as suggested by Barella and Manich [7, 8], applied to conventional and compact yarns spun from two selected

cottons with different levels of staple length and uniformity. (Graphs are plotted using a semi-logarithmic scale.)

Both figures show that the relative decrease in the number of protruding hairs engendered by compact spinning is greater for the longer hair categories than for shorter ones. More importantly for our purposes, it is apparent that the shift in the entire hair length distribution was greater for the short cotton (Figure 5) than for the longer one (Figure 6). This corroborates the results obtained when we considered hairiness parameters (H and S3) in the previous paragraph. It is to be noted, however, that in addition to the differences in

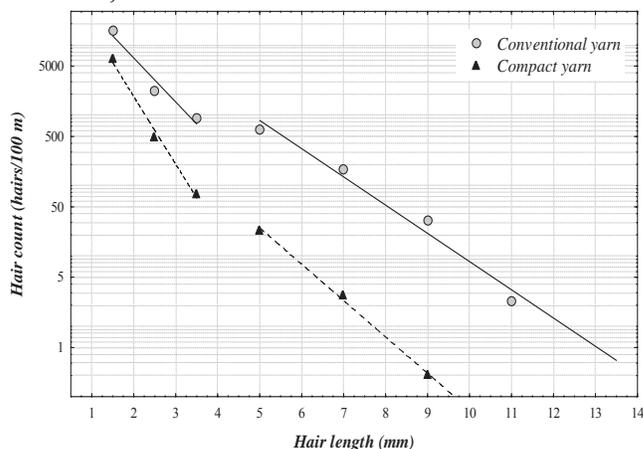


Figure 5. Alteration of hair length distribution with compact spinning – Example 1: UHML = 25.1 mm, Uniformity = 79.1%.

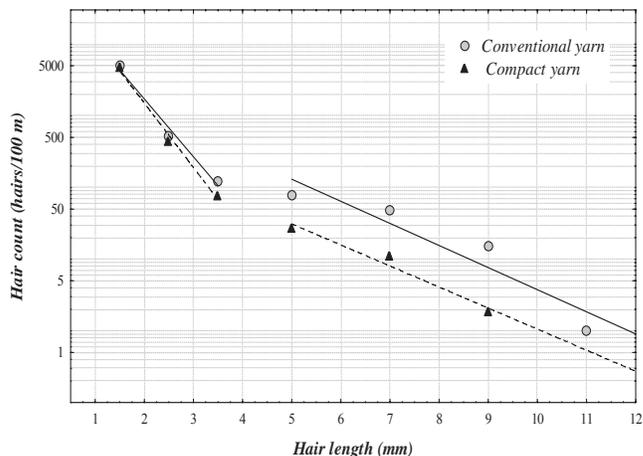


Figure 6. Alteration of hair length distribution with compact spinning – Example 2: UHML = 30.8 mm, Uniformity = 83.9%.

length parameters, the two cottons depicted in Figures 5 and 6 also differed in fineness and maturity. As previously mentioned, these properties are likely to affect the changes in hair length distribution shown above, although neither fineness nor maturity were part of the interactions revealed

in the previous section (Table III, Table IV). Nevertheless, the effectiveness of compact spinning in altering the hair length distribution (thus, its effectiveness in reducing yarn hairiness) appears to vary considerably depending on fiber properties.

The two examples shown in Figures 5 and 6 represent significantly different behaviors. Obviously, intermediate cases exist among the wide range of samples tested and the alteration of hair length distribution changed gradually to cover the whole spectrum from one extremity (short, non-uniform cotton) to the other (long, uniform cotton). A useful representation of this wide range of behaviors is shown on Figure 7, where the numbers of hairs detected on compact yarn (in the different length categories) are plotted against those detected on conventional yarn (in the corresponding length categories).

Five different cottons, with a range of length and uniformity levels, are simultaneously plotted on the figure. Each data point in the plot has the number of hairs detected on conventional yarn as abscissa and the number of hairs of the same length category detected on compact yarn as ordinate. The corresponding length categories are reported on the figure.

It is made clear on Figure 7 that the relative decrease in hair numbers due to the resort to compact spinning was most remarkably observed for the low-frequency long hair categories (>3mm). The shorter hair categories, on the other hand, show no significant difference between conventional and compact spinning, as the data points lay in close proximity to the equality line. Therefore, resort to compact spinning tends to significantly decrease the number of hairs that are known to be detrimental to the yarn performance and appearance (long hairs, sometimes referred to as secondary hairiness), while preserving the short hairs, which are important for imparting the desired softness and wear-comfort to the fabric.

A key issue related to the results shown in Figure 7 is the inter-cotton variability, particularly in the range of long hairs, and its relationship to the fiber attributes proven to be involved in the interactions discussed earlier (length, uniformity). For the shorter cottons, the experimental data

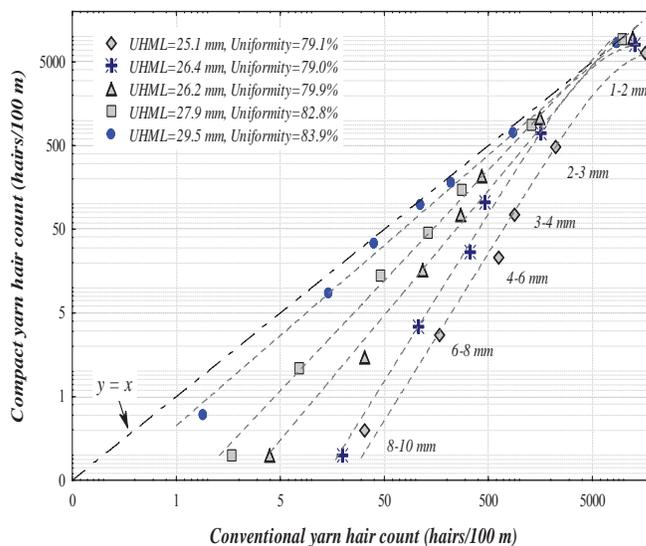


Figure 7. Hair length distribution – Compact vs. conventional yarn for a selected set of bales with different length and uniformity levels.

points diverge considerably from the equality line. As we consider longer and more uniform cottons, the divergence decreases and the points are closer to the equality line, which means that the change in hair length distribution was less for the longer cottons. Over the entire range of cottons tested, we observed that compact spinning resulted in an average reduction of 65% of the protruding hairs longer than 3 mm. However, as a result of the inter-cotton variability illustrated on Figure 7, the percentage reduction of the number of hairs longer than 3 mm ranged from 9 % to 94% (Only 4% of the observations were below 20% and the median was approximately 70%). Yet, the percentage reduction in hairs shorter than 3 mm averaged only 16%.

Given this pattern, it appears that only cottons producing a conventional yarn with an important number of hairs in the long hair categories (>3 mm) will exhibit a clear hairiness decrease with compact spinning. These are more likely to correspond to shorter and less-uniform cottons. Longer and more uniform cottons, on the other hand, will have few hairs in the longest categories even with conventional ring spinning. Therefore, resort to compact spinning with these cottons cannot significantly reduce yarn hairiness.

YARN TENSILE PROPERTIES

Our results show that yarn tensile properties were also significantly improved with compact spinning (Table II). We examined yarn tensile properties analogously to hairiness data. We report the simple correlation coefficients between yarn tensile properties (Uster® Tensorapid single-end measurement) and fiber characteristics (HVI and AFIS measurement) in Table V.

Unlike hairiness parameters, yarn tensile properties do not show sizable differences between the correlations obtained for conventional and compact yarns. According to the coefficients of Table V, breaking strength and work-to-break measurements of compact and conventional yarns appear to be about equally correlated with fiber strength, standard fineness, and all measured length parameters (UHML, Uniformity, mean lengths, UQL, short fiber content...). As for yarn elongation, it shows moderate correlations with Micronaire, fiber elongation and length parameters, with apparent differences between conventional and compact yarns.

Figure 8 illustrates the relationship between yarn strength and HVI fiber length for both conventional and compact yarn, presented analogously to the scatter plots previously shown

Table V: Simple correlation coefficients between conventional and compact yarn tensile properties and fiber characteristics (critical r value at $\alpha = 0.05$ is 0.33).

Yarn property Fiber properties	Strength (cN/tex)		Elongation (%)		Work to break (cN.cm)	
	Conventional	Compact	Conventional	Compact	Conventional	Compact
HVI						
<i>Micronaire</i>	ns ^b	ns	-0.44	-0.46	-0.42	-0.40
<i>UHML (mm)</i>	0.81	0.81	ns	0.44	0.68	0.71
<i>Unif. (%)</i>	0.66	0.64	0.48	0.58	0.76	0.75
<i>Strength (g/tex)</i>	0.87	0.87	ns	ns	0.44	0.44
<i>Elongation (%)</i>	-0.72	-0.75	0.48	ns	ns	Ns
AFIS^a						
<i>Ln (mm)</i>	0.71	0.73	ns	0.45	0.64	0.69
<i>SFCn (%)</i>	-0.48	-0.52	ns	-0.34	-0.45	-0.51
<i>Lw (mm)</i>	0.82	0.82	ns	0.44	0.69	0.73
<i>SFCw (%)</i>	-0.60	-0.62	ns	-0.35	-0.51	-0.56
<i>UQLw (mm)</i>	0.83	0.83	ns	0.42	0.68	0.71
<i>Fineness (mtex)</i>	-0.33	ns	ns	ns	-0.39	-0.34
<i>Std. Fin. (mtex)</i>	-0.84	-0.83	ns	ns	-0.48	-0.43

^a Abbreviations are as in Table I. ^b ns: non significant at $\alpha = 0.05$.

for hairiness data (Figure 1). Despite a slightly perceptible difference in the regression-line slopes, there were no statistically significant interaction effects for yarn strength. Application of the homogeneity of slopes model to all measured yarn tensile properties (strength, elongation, work to break) with the key fiber characteristics shown in Table V did not reveal any significant interactions. It appears, therefore, that yarn strength and elongation improvement due to compact spinning was homogenous throughout the range of samples tested. In other words, resort to compact spinning resulted in an overall increase of yarn strength and elongation mean values that is statistically independent of fiber properties.

COMPACT YARN ADDED VALUE

Reduced yarn hairiness and improved tensile properties are the key benefits of the compact system. Of these two critical aspects of compact yarn quality, only hairiness improvement is significantly affected by the choice of raw cotton (at least in the short to medium staple range treated in our research). Some combinations of raw fiber properties are not adequate for full utilization of the compact capabilities to reduce hairiness. Since comparable hairiness levels are achievable with

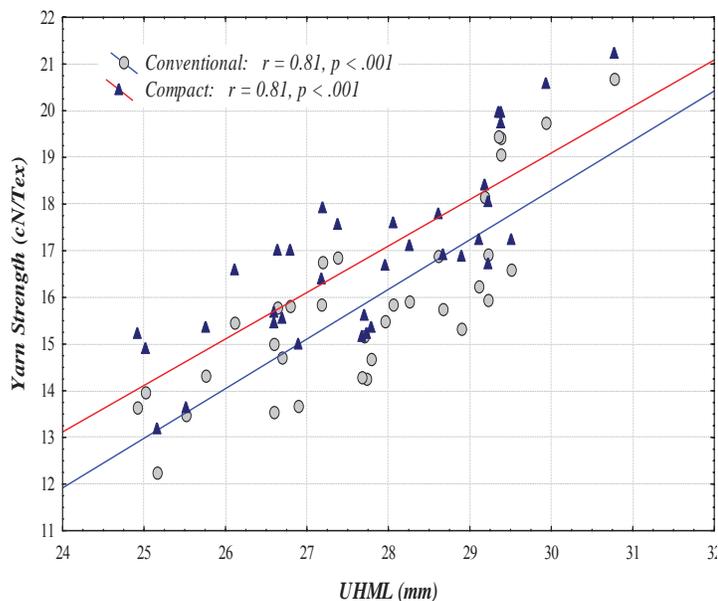


Figure 8. *Conventional and compact yarn single-end strength vs. fiber UHML.*

some cottons on the conventional system, only tensile properties may be significantly improved. A relevant question raised by these results, therefore, is when the application of compact spinning is of interest to the spinner, with due consideration taken of the production costs related to the compact technology.

To answer this question, it is necessary to (1) fully assess the value added to compact yarns with respect to performance in downstream processes, and (2) weigh the advantages of the compact system among the numerous alternatives spinners have to produce a yarn with given specifications. We do not attempt an in-depth analysis of these issues, but we will share some tentative implications.

It is well established that during downstream processing (weaving, knitting), the yarn is stressed in a variety of ways and, as previously stated, its failure is more likely to be caused by abrasion and fatigue than by longitudinal traction. Therefore, factors such as hairiness may rival the importance of yarn strength and elongation in determining the processing performance of yarns. However, compact technology offers various alternatives other than its use with the same raw material and in the same conditions to produce a better yarn. These alternatives notably include the possibility of altering the process to increase its productivity (lowering the twist or shortening the preparation process for example) or using lower cost raw fiber while

maintaining yarn quality [3, 4, 14]. It appears, based on the results to date, that the latter alternative is more advantageous to the spinner dealing with coarse-to-medium yarn counts (carded spinning of short-to-medium stapled cottons). Indeed, reducing the raw fiber staple not only allows lowering the production cost while maintaining yarn quality, but also guarantees a better utilization of the compact technology capabilities, since these appear to be more optimally exploited with short cottons than with longer, higher cost ones.

Research is currently underway to fully examine these aspects. Objectives include: (1) Further analyzing compact yarn mechanical characteristics based on the distributions of its tensile properties (in addition to the parameters treated here) and on the occurrence of weak places; (2) Establishing whether the interactions exposed in the present research would significantly affect other aspects of yarn performance in further processing (e.g. abrasion resistance); and (3) Examining the effects of altering the processing conditions (e.g. twist reduction, yarn counts...) on the fiber-process interactions revealed in this research. Results will be reported in a sequel to the present paper.

CONCLUSIONS

Using a wide range of short-to-medium stapled cottons, we evaluated the advantages offered by compact spinning technology in carded yarn production. Our experimental results revealed that, in addition to the overall improvement of yarn hairiness and tensile characteristics, some interaction effects exist that impact the effectiveness of compact spinning in reducing yarn hairiness.

Compact spinning achieved maximum yarn hairiness reduction when using short, non-uniform cottons. For longer staples and higher uniformity levels, hairiness reduction was non-significant; therefore, the value added to the yarn by resort to compact spinning was rather limited in that regard. It seems likely that other fiber properties (fineness, for instance) interacted with staple length and uniformity. However, their effect was not clearly

shown with the present range of samples.

By examination of the protruding hair length distribution, measured using the Zweigle G566 hairiness tester on both conventional and compact yarns, it was shown that compact spinning mainly altered the number of the long protruding hairs; the reduction of hairs longer than 3 mm averaged 65%, against an average reduction of 16% of the hairs shorter than 3 mm. However, compact spinning alteration of the protruding hair length distribution varied considerably depending on cotton samples, with shorter and less uniform cottons generally showing larger shifts in the distribution. As a result, the percentage reduction of hairs longer than 3 mm ranged between 9% and 94%, with some cottons (corresponding to the longest and most uniform in the tested range) showing non-significant, or at best limited, differences between conventional and compact yarn hairiness.

The implications of these interactions are critical to the spinner because depending on raw fiber selection, the value added to the yarn by using compact technology may not be sufficient to justify and compensate for investment and production costs.

In addition to its effect on hairiness, compact spinning resulted in a significant improvement of yarn tensile properties (strength and elongation). Unlike hairiness, however, no interaction effects were detected for tensile properties and the increase of average strength and elongation appeared statistically homogenous over the entire range of cottons tested.

Further analysis of yarn tensile properties, with consideration of parameter distributions and occurrence of weak places, along with other measures of yarn performance (abrasion, fatigue), is ongoing in order to determine if interactions similar in nature to those encountered for hairiness also exist for these critical parameters. Current research also includes evaluation of the performance of compact technology in producing carded yarn of different counts with altered processing conditions, particularly twist. Results covering these issues will be reported in a future publication.

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