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TEXTILE TECHNOLOGY

Pilot Study to Examine the Relationship between AFIS Fiber Properties and White Speck Occurrence

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ABSTRACT

Cotton containing dead and/or immature fibers is a major concern in the dyeing and finishing of textile products. In an un-dyed state, entangled fiber clusters are generically classified as neps. It is only after the application of dye, when some neps remain un-dyed, that the more specific classification of "white speck" is used. The high volume instrument (HVI) fiber property measurement system is important in marketing and general quality assessment of the cotton crop; however, HVI is not precise enough to address immature/dead fiber content. The objective of this pilot study was to examine the relationship between the AFIS (Uster's Advanced Fiber Information System) fiber properties and white speck occurrence on dyed yarn. Relationships between key fiber properties, such as length, nep count, and maturity, and the occurrence of white specks were investigated. Ten bales of cotton with a range of micronaire values were sampled (10 samples per bale) and analyzed using AFIS with 3 replications of each counting 3,000 fibers. Each sample was then processed into yarn and dyed using the same procedure. White specks were quantified on dyed yarn using a white speck yarn counting method. This preliminary study demonstrated a promising relationship between the AFIS fiber properties and the white speck occurrence. Fiber fineness and fiber nep per gram were highly correlated with white speck occurrence on the dyed yarn.

The American Society for Testing and Materials (ASTM, 1999, p. 43) defines a fiber nep as "a tightly tangled knot-like mass of unorganized fibers". In most cases, fiber neps consist of at least five or more fibers with the average number being 16 or more (Hebert et al., 1988). Immature fibers are finer and have a higher propensity to form neps than more mature fibers (Hebert et al., 1988). In an un-dyed state, entangled fiber clusters could be generically classified as neps. It is only after the application of dye, when some of the neps remain un-dyed, that the more specific operational definition of "white speck" is used.

Many factors, including cultivar (genotype), growing conditions, harvesting, ginning, and textile processing, contribute to the occurrence of white specks on yarn/fabric. The effect of environmental components, such as temperature and rainfall, leads to high maturity differences. The maturity and variability of each fiber determine the fiber processing characteristics (Bradow and Davidonis, 2000). The mechanical processes from harvesting to textile construction significantly influence the occurrence of white specks on yarn or fabric (Bel-Berger and Von Hoven, 1997). Increased drying and cleaning during ginning and opening processes lead to fiber breakage, more neps, and decreased spinning efficiency, which consequently results in poor yarn and fabric quality. The influence and variability of both biological and mechanical factors on white speck occurrence creates a complex phenomenon.

Current commercial fiber testing with High Volume Instrumentation (HVI 900-A, Uster Technologies; Knoxville, TN) is important in cotton marketing; however, it does not directly measure the immature fiber content. HVI measures fiber properties, such as micronaire, length, strength, color, uniformity, and trash content. Micronaire is an index that is the result of fiber fineness and maturity. Since micronaire is related to the inverse of the specific surface of cotton, coarse immature cotton and fine mature cotton could have the same micronaire but result in different yarn white speck counts. Therefore, HVI micronaire may not be a good candidate for assessing immature fiber content. Conversely, the Advanced Fiber Information System (AFIS-Pro, Uster; Knoxville, TN) can measure length, fineness, maturity distributions, and trash content. From these four main measurements, 20 different cotton fiber

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parameters can be obtained by AFIS-PRO. AFIS measures individualized fibers by using an air stream that moves the fibers through a set of optical sensors to be counted and characterized (Frydrych and Matusiak, 2002). There have been few studies that examined the relationship of white specks to fiber properties on dyed fabric. Bel-Berger and Xu (2006) found that fiber properties, such as neps and maturity, influence fabric white speck levels. Once the white speck is on the yarn, it is highly likely to appear on the fabric. An accurate and repeatable system to quantify white specks on dyed yarn (Simonton et. al, 2005) has made it possible to explore causal factors of white speck occurrence. This study investigated the use of AFIS fiber measurements as indicators of white speck occurrence on the finished dyed yarn.

MATERIALS AND METHODS

Ten bales of cotton were selected for this study. All the bales were commercial bales of Texas cotton picked with a stripper. The cotton cultivar(s) is unknown. The micronaire values measured by HVI of these bales are provided in Table 1. Each bale was separated into approximately 10 equal layers. A sample was taken by collecting from multiple locations in each layer. Before textile processing, the physical characteristics of the cotton samples were measured with AFIS-PRO (Table 2). Three AFIS replications of 3,000 fibers were performed for each sample. Each bale layer was blended one at a time by laying out each sample in front of the four Hunter feed hoppers (James Hunter Machine Co.; Mauldin, SC) starting with hopper 1 and moving to hopper 4. After reaching hopper 4, the process was repeated until the sample was totally allocated to all four hoppers. From the Hunter hoppers the sample passed through a Rieter mono-cylinder beater type cleaner (Rieter Textile Systems; Spartanburg, SC), then through a Rieter ERM saw tooth cleaner (Rieter Textile Systems), and collected in an AMH blending hopper (Automatic Material Handling; Charlotte, NC). All samples were opened, cleaned, and blended using the same protocol. After blending, the cotton was carded with a Trutzschler 903a card (American Trutzschler; Charlotte, NC). Card settings and parameters were as follows: production rate, 40 kg/h; flat setting (0.001 mm), 11-10-10-9-9-9; flat speed, 180 mm/min; cylinder speed 500 rpm; linker-in speed, 97%. At the end of carding process 50 g of card sliver was collected from each sample for AFIS testing (Table 3).

After carding, the processes were performed as follows: breaker drawing (Rieter RSB 851 Drawframe; Rieter Textile Systems; Spartanburg, SC), finisher drawing (American Trutzschler HSR 1000; Charlotte, NC), roving using Saco Lowell Rovematic SF-3H (Saco Lowell; Greenville, SC) with Suessen HP-A410 Drafting (Suessen; Süssen,Germany), and finally ring spinning a 24.6/1 tex yarn on a Suessen

Table 1. Micronaire for cotton by layers from each bale

Layers[z]	Bales									
	1	2	3	4	5	6	7	8	9	10
1	4.35	3.30	5.05	4.10	4.70	3.35	4.00	4.00	3.85	5.05
2	4.30	3.30	5.00	4.10	4.65	3.40	4.00	4.00	3.90	5.05
3	4.35	3.30	5.00	4.15	4.60	3.35	3.95	4.00	3.90	5.10
4	4.30	3.25	5.05	4.10	4.60	3.30	3.90	3.95	3.95	5.05
5	4.30	3.30	5.00	4.10	4.60	3.30	3.75	3.90	4.05	5.10
6	4.35	3.30	5.00	4.10	4.60	3.30	3.55	4.00	4.00	5.05
7	4.50	3.30	5.10	4.15	4.60	3.30	3.55	3.95	4.05	5.10
8	4.40	3.30	5.05	4.15	4.60	3.30	3.60	4.00	4.05	5.10
9	4.40	3.25	5.10	4.10	4.60	3.30	3.50	3.95	4.05	5.10
10	4.30	3.30	5.05	4.00	4.50	3.35	3.55	4.00	4.00	5.10
Avg.	4.36	3.29	5.04	4.11	4.61	3.33	3.74	3.98	3.98	5.08
Std. Dev.	0.06	0.02	0.04	0.04	0.05	0.03	0.20	0.03	0.07	0.02

[z] Each bale was separated into approximately 10 equal layers. A sample was taken by collecting from multiple locations in each layer.

Fiomax 1000 (Suessen). The winding process took place after spinning for package dyeing using a Morton Package Dye Machine Model 77-132-1 (Gaston County Dyeing Machine Co.; Gastonia, NC). The dye used for the yarn was a mixture of three reactive dyes; (1) 0.016% Drimarine Yellow K-2R Reactive Yellow 125 (Clariant Corp.; Charlotte, NC), (2) 3.6% Intracon Brilliant Blue VS-RW Reactive Blue 19 (Crompton and Knowles; Reading, PA), and (3) 2.7% Intracon Navy Blue VS-HR Reactive Blue 89 (Crompton and Knowles). The resulting color was a dark shade of Navy blue (Simonton et al., 2001).

After the dyeing process, an Alfred Sutter yarn board winder (Alfred Sutter; New York, NY) was used to wind samples onto 178 mm wide by 279 mm long by 3.2-mm thick, black, rigid paper yarn boards. Each sample was used to fabricate yarn boards containing a minimum of 200 meters per board. Each board was labeled with an "A" and "B" side. Five yarn boards were created for each layer of every bale. Total sampling for each bale was 50 yarn boards. Each sample board was digitized with a 118 dots per centimeter (300 dpi) resolution in gray scale (256) with a Hewlett Packard Scan Jet model 7400c flat bed scanner (Palo Alto, CA) connected to a Dell model 530 computer (Round Rock, TX) equipped with a 1.7 GHz Xeon processor. The scanner parameters were set to minimize or totally disable several automatic features contained in the scanner software that were designed to optimize images. Images were examined by the software package, Counting Apparatus for Trash and Impurities (CATI; version 6, CIRAD Laboratories; Montpellier, France), to count white specks on dyed yarn. Using the protocol previously developed by Simonton et al. (2005), the number of white specks on the yarn were counted.

Table 2. AFIS fiber properties for each bale of cotton

AFIS fiber property	Bales								
	1	2	3	4	5	6	8	9	10
Nep size (µm)	719	719	701	720	692	715	708	708	708
Nep by weight (g)	362	564	236	412	299	528	488	458	354
Fiber length by weight (mm)	21.281	23.702	24.134	22.356	23.622	24.426	23.495	22.818	22.945
Fiber length by weight coefficient of variance (%)	38.00	37.25	30.31	35.13	31.55	35.41	35.82	35.63	34.60
Upper quantile fiber length by weight (mm)	26.458	29.443	28.283	27.157	27.915	29.879	28.677	27.724	27.788
Short fiber content by weight (%)	15	12	6	11	7	10	10	11	10
Fiber length (mm)	16.459	18.495	20.904	18.165	19.988	19.651	18.847	18.377	18.762
Fiber length by number coefficient of variance (%)	54.14	53.14	39.40	48.09	42.58	49.24	49.79	49.32	47.52
Short fiber content by number (%)	36	31	17	28	20	26	28	28	27
Fiber length 50% (mm)	30.315	33.452	32.317	31.187	31.852	34.044	32.893	31.797	31.733
Total trash (count/g)	632	352	431	772	346	399	504	511	504
Trash size (µm)	368.80	376.25	403.82	367.75	376.67	368.68	365.55	365.40	393.90
Dust (counts/g)	491	277	323	604	267	315	398	404	383
Trash count by weight	140	75	108	168	79	84	105	107	121
Visible fiber matter (%)	2.183	1.374	2.068	2.689	1.340	1.610	1.823	1.812	2.241
Seed coat nep size (µm)	1054	1085	1135	1064	1099	1047	1089	1120	1096
Seed coat nep by weight	34	35	28	38	22	39	27	27	29
Fiber fineness (millitex)	177	157	187	174	179	159	162	164	176
Fiber maturity	7.572	8.470	5.588	7.600	7.050	8.735	7.793	7.585	7.338
Immature fiber content (%)	0.865	0.843	0.936	0.885	0.899	0.861	0.882	0.884	0.899

Table 3. AFIS fiber properties for each sliver of cotton

AFIS fiber property	Bales								
	1	2	3	4	5	6	8	9	10
Nep size (µm)	620	601	622	614	601	611	599	603	633
Nep by weight (g)	68	130	59	80	65	137	100	93	70
Fiber length by weight (mm)	20.963	22.538	22.784	21.505	22.835	23.106	21.886	21.480	23.233
Fiber length by weight coefficient of variance (%)	38.30	40.87	34.24	37.61	34.21	39.17	37.87	39.18	33.89
Upper quantile fiber length by weight (mm)	26.120	28.677	27.644	26.662	27.576	29.151	27.085	26.780	28.075
Short fiber content by weight (%)	16	16	10	14	10	13	14	15	9
Fiber length (mm)	16.620	17.196	18.948	17.230	19.008	18.076	17.475	16.891	19.448
Fiber length by number coefficient of variance (%)	51.05	55.67	45.36	49.82	44.80	52.84	50.35	52.25	44.26
Short fiber content by number (%)	35	37	25	32	25	32	32	35	23
Fiber length 50% (mm)	30.201	32.961	31.589	30.776	31.581	33.460	31.352	31.013	32.080
Total trash (count/g)	26	46	23	36	17	29	36	33	28
Trash size (µm)	281.10	214.27	304.67	256.50	208.10	245.97	233.30	246.00	317.07
Dust (counts/g)	23	44	19	32	16	27	34	30	23
Trash count by weight	3	2	4	4	1	2	2	2	5
Visible fiber matter (%)	0.044	0.045	0.054	0.056	0.018	0.040	0.042	0.056	0.063
Seed coat nep size (µm)	756	712	833	798	555	777	528	661	825
Seed coat nep by weight	8	6	9	8	3	8	3	4	15
Fiber fineness (millitex)	179	159	186	176	181	161	167	166	186
Fiber maturity	8.400	10.240	7.453	9.010	8.090	9.607	8.567	9.060	7.253
Immature fiber content (%)	0.864	0.815	0.896	0.859	0.883	0.836	0.869	0.856	0.902

The relationship between AFIS fiber properties and white speck count was analyzed. The coefficients of determination (R^2) of white speck counts versus AFIS fiber properties for each bale were examined. First, white speck count and cotton sliver AFIS fiber properties were investigated. Since the carding process influences fiber properties (such as neps), the correlation of sliver fiber properties and white speck count would be expected to be higher than bale fiber properties and white speck count. Second, white speck count and bale fiber properties were analyzed. Third, all bales were tested for differences in means for white speck count, maturity, fineness, nep per gram, and immature fiber content. Finally, stepwise multiple regression analyses performed on both bale and sliver fiber to identify fiber properties that might predict the white speck count on dyed yarn.

RESULTS AND DISCUSSION

Fiber properties among the bales are presented in Tables 2 and 3. Fiber properties of bales 8 and 9 and bales 3 and 10 were similar. The rest of the bales were different in one or more fiber properties, such as maturity, nep per gram, immature fiber content, fineness, and total trash. White speck count is discrete in nature and was derived using a counting technique, so it was assumed that the distribution would be non-normal and at best Poisson in nature (Hayter, 1996). With an assumption of non-normal distribution, it was necessary to transformation the analysis to conduct an analysis of variance. Since the counting variances are not homogenous, the data was stabilized using a square root transformation. The square root transformation is commonly used to stabilize variance and improve the normal approximation of the distribution (Box et al., 1978; Krifa et al., 2002). Square root transformation is adequate when the variance is proportional to the mean, which is the case for Poisson distributions (Box et al., 1978). The square root of white speck count for bales 1 through 10 (not including bale 7) are 5.72, 16.17, 5.18, 7.24, 5.39, 15.23, 12.11, 12.90, 5.05, respectively.

Variability in fiber properties among and within all bales was tested. Between bales variability was tested by a *t*-test for independent samples and was significant at $P = 0.05$. Within bale variability was tested by a *t*-test, and layers for each bale were not significantly different for AFIS fiber properties. Bale 7 had high within bale variation on white speck count (Fig. 1) and micronaire (Table 1); therefore, it was considered an outlier and not included in the data analyses.

Fiber properties and white specks. The results of the regression analysis for the nine remaining bales are presented in Tables 4 and 5. Six variables for the bale fiber (neps per gram, upper quartile length, fiber length 50%, fineness, immature fiber content, and maturity) were significantly correlated with white speck count (Table 4). Nine variables for the sliver fiber (neps per gram, length by weight CV%, length by number CV%, short fiber count by number, total trash, dust, fineness, immature fiber content, and maturity) that were significantly correlated with white speck count (Table 5). Only neps per gram, fineness, immature fiber content, and maturity were significantly correlated for both bale and sliver fiber. Of the four variables, fineness had the highest *F*-values for bale

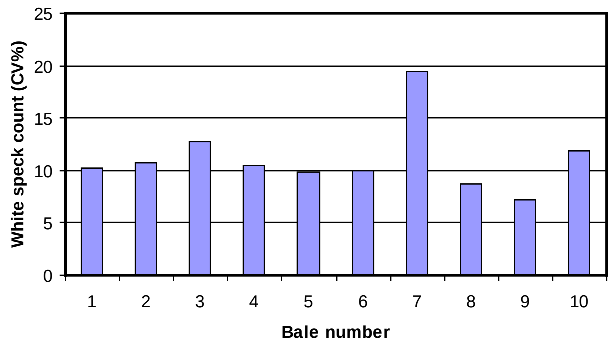

Figure 1. Percentage coefficient of variation (%CV) of white speck counts for all bales.

Table 4. Results of regression analysis of fiber properties for bale cotton with white speck count

Bale fiber property	Adjusted R^2	df Residual	F	P
Nep size (µm)	-0.052	1	0.606	0.462
Nep by weight (g)	0.840	1	43.143	0.000
Fiber length by weight (mm)	0.042	1	1.352	0.283
Fiber length by weight coefficient of variance (%)	0.146	1	2.372	0.167
Upper quantile fiber length by weight (mm)	0.477	1	8.282	0.024
Short fiber content by weight (%)	-0.094	1	0.315	0.592
Fiber length (mm)	-0.141	1	0.013	0.913
Fiber length by number coefficient of variance (%)	0.160	1	2.522	0.156
Short fiber content by number (%)	-0.023	1	0.822	0.395
Fiber length 50% (mm)	0.499	1	8.975	0.020
Total trash (count/g)	-0.012	1	0.905	0.373
Trash size (µm)	0.162	1	2.542	0.155
Dust (counts/g)	-0.047	1	0.640	0.450
Trash count by weight	0.147	1	2.378	0.167
Visible fiber matter (%)	0.170	1	2.641	0.148
Seed coat nep size (µm)	-0.087	1	0.359	0.568
Seed coat nep by weight	0.038	1	1.316	0.289
Fiber fineness (millitex)	0.898	1	71.216	0.000
Fiber maturity	0.503	1	9.109	0.019
Immature fiber content (%)	0.416	1	6.695	0.036

fiber (71.2) and sliver fiber (169.8). This was followed by neps per gram with an *F*-value for bale fiber of 43.1 and for sliver fiber of 72.9.

Upper quartile length was significant for bale fiber but not for the sliver. Percentage coefficient of variation for both length categories was significant in sliver fiber but not bale fiber. This would indicate that fiber breakage occurred during the processing of the fibers in the top 25% of the length distribution. This is further supported by short fiber content by number being significant in the sliver fiber but not in bale fiber.

The broken fibers after the carding process influenced the fineness and maturity ratio values. Bale 1 had the least change in maturity ratio, and bales 2 and 6 showed a decrease in maturity ratio. It appears that short fiber content increased in bales 2 and 6 but did not change in bale 1. Fiber breakage was significant for bales 2 and 6 but not bale 1. Examining the significant variables that are common in both bale and sliver fiber (neps per gram, fineness, immature fiber content, and maturity) made it easy to highlight the importance of their individual differences and influences over white speck count.

The coefficient of determination (R^2) for fiber neps per gram on white specks was 0.86 for the bale and 0.91 for the sliver (Fig. 2). It appears that in this sample set of bales, neps per gram in both bale and sliver fiber have the greatest effect on white speck count on dyed yarn. The relationship between fiber fineness and white specks had coefficients of determination (R^2) of 0.91 in the bale and 0.96 in the sliver (Fig. 3). As seen in the regression graphs, fiber fineness in this data set also played a role in the occurrence of white specks in dyed yarn.

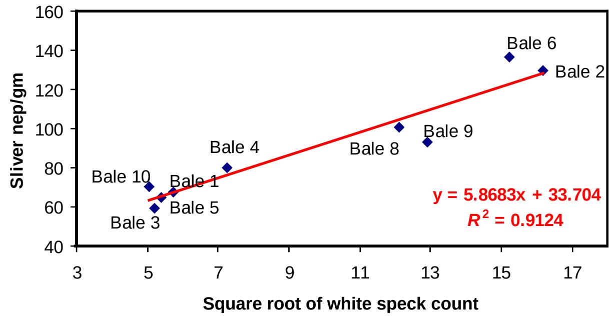

Figure 2. Regression analysis of the square root of white speck counts and fiber neps g^{-1} in the sliver by bales.

Table 5. Results of regression analysis of fiber properties for sliver cotton with white speck count

Sliver fiber properties	Adjusted R^2	df Residual	*F*	*P*
Nep size (µm)	0.306	1	4.525	0.071
Nep by weight (g)	0.900	1	72.954	0.000
Fiber length by weight (mm)	-0.142	1	0.004	0.951
Fiber length by weight coefficient of variance (%)	0.666	1	16.937	0.004
Upper quantile fiber length by weight (mm)	0.119	1	2.083	0.192
Short fiber content by weight (%)	0.291	1	4.279	0.077
Fiber length (mm)	0.108	1	1.964	0.204
Fiber length by number coefficient of variance (%)	0.696	1	19.322	0.003
Short fiber content by number (%)	0.425	1	6.913	0.034
Fiber length 50% (mm)	0.246	1	3.617	0.099
Total trash (count/g)	0.438	1	7.245	0.031
Trash size (µm)	0.240	1	3.530	0.102
Dust (counts/g)	0.535	1	10.202	0.015
Trash count by weight	0.043	1	1.363	0.281
Visible fiber matter (%)	-0.138	1	0.031	0.865
Seed coat nep size (µm)	-0.075	1	0.445	0.526
Seed coat nep by weight	0.050	1	1.417	0.273
Fiber fineness (millitex)	0.955	1	169.828	0.000
Fiber maturity	0.720	1	21.540	0.002
Immature fiber content (%)	0.691	1	18.923	0.003

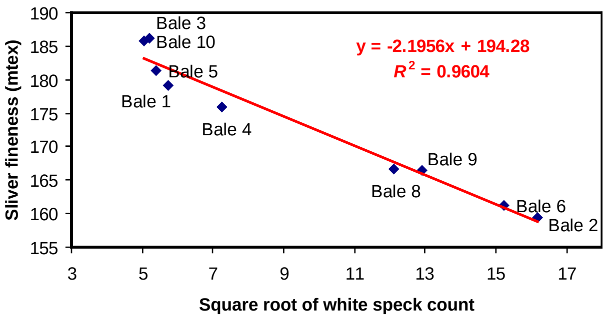

Figure 3. Regression analysis of the square root of white speck counts and cotton fineness in the sliver by bales

The coefficients of determination (R^2) for immature fiber content cotton on white specks were 0.57 for the bale and 0.75 for the sliver (Fig. 4). The predictive value of immature fiber content appears to rise when taken in sliver form. AFIS nep size through the mechanical process illustrated an increase in the immature fiber clusters that turn into white specks on the carded fabric (Bel-Berger et al., 1997). Large neps through carding process were either removed or divided into a number of small neps, which had a more significant effect on white speck content in dyed yarn. It also indicates that even though immature fiber content was statistically significant, high variability of immature fiber content eliminates its use as the sole variable for predicting white specks in dyed yarn. The relationship between fiber maturity and white specks had coefficients of determination (R^2) of 0.49 in the bale and 0.73 in the sliver (Fig. 5). The increase in R^2 of immature fiber content from bale fiber to the sliver suggests that the card influenced maturity by removing some part of the fiber distribution, which affects maturity readings in the sliver. It could be easy to remove large nep clusters when you have mature cotton; however, with the immature cotton it would be easy to break these large neps into smaller ones instead of removing them.

Stepwise multiple regression. Multiple regression analysis revealed a relationship between fiber properties and white speck counts. Using the regression model, it was possible to determine if more than one predictor for white speck occurrence. Using stepwise multiple regression analysis, the number of predictors was reduced, but the outcome

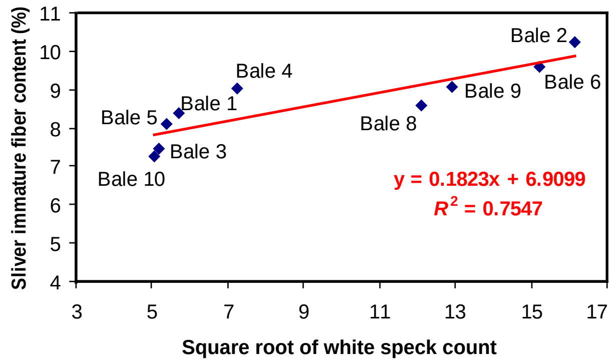

Figure 4. Regression analysis of white speck counts and cotton immature fiber content in the sliver by bales

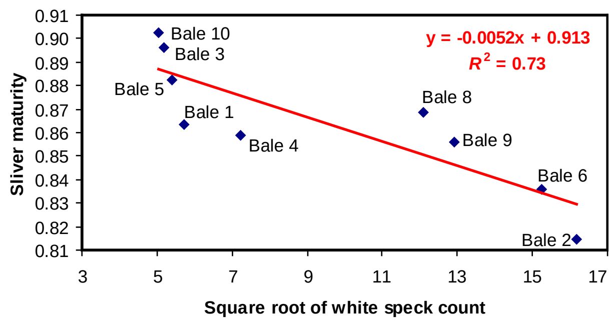

Figure 5. Regression analysis of white speck count and cotton maturity in the sliver by bales

was efficiently predicted. Bale cotton fiber fineness and immature fiber content were the main predictors for white speck count on dyed yarn. The correlation between the observed white speck values and calculated white speck values from the equation obtained from the stepwise multiple regression analysis of bale fiber had an R^2 of 0.93 (Table 6). There seems a very clear relationship between white speck count and fiber fineness and immature fiber content (Fig. 6). The coarser fiber with less immature fiber content had a reduced number of white speck counts on dyed yarn. For the sliver, stepwise multiple regression analysis identified fineness, nep per gram, and immature fiber content as the predictors for white speck count (Table 6). As a result of this analysis, coefficient of determination (R^2) between the observed and calculated white speck values was 0.97 (Fig. 7). These high coefficients of determination need to be confirmed with a larger sample size, since this

Table 6. Predictive equations for number of white specks from multiple regression analysis

Regression equations		Adjusted R^2	F	P
Bale cotton	White specks = 126.4 – 0.6 fiber fineness – 2.15 immature fiber content	0.93	55.497	0.00013
Sliver cotton	White specks = 82.2 – 0.4 fiber fineness + 0.1 neps/gram - 0.9 immature fiber content	0.96	71.06	0.0279

was a very small sample set and limited variability in maturity between some bales. This low level of variability may have not been enough to estimate the residuals in the stepwise regression model, so the high coefficients of determination may be related to very small sample size.

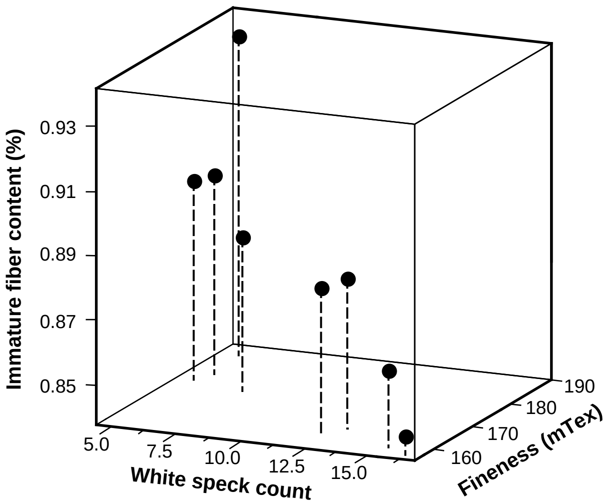

Figure 6. White speck versus cotton fineness and immature fiber content in the bale by bales

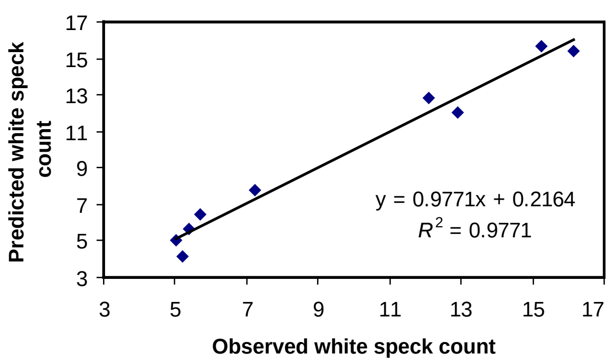

Figure 7. Regression analysis of predicted white speck count and observed white peck count based on cotton fiber properties in the sliver.

For this study, AFIS fiber properties, fineness, nep per gram, and immature fiber content seem to have the most promise as influential indicators that could be used in the formulation of a predictor model or algorithm for white speck occurrence in yarn. Depending on these fiber properties the opening and carding process both removed or generated short fibers. Bale 1 showed no increase in percentage short fiber content by number when immature fiber content went from 7.5 to 8.4%, while bale 9 had increase in percentage short fiber content by number and immature fiber content went from 7 to 9 %. AFIS testing may be indicating a bias, since during AFIS testing there is fiber breakage. Bales 4 and 9 have the same maturity ratio, but different fineness values and the more breakage in bale 9 than in bale 4. Bale 9 shows higher nep per gram than bale 4 and this may be the explanation of higher white speck count in bale 9.

CONCLUSIONS

It is important to estimate potential white speck occurrence in the bale before the yarn and fabric formation processes. It seems that fineness, nep/gm, and immature fiber content could be used as variables to form the basis for a model used to predict the white speck potential from a bale of cotton based on AFIS test results. There were some problems with this pilot study that will have to be addressed in the future. These problems were small sample size and possible bias in the AFIS fineness and maturity results. Future research with a much larger data set could be used to create a model or algorithm for the prediction of white specks based on AFIS test results. It would be worth including other test measurements, such as maturity and length distributions, since mean values derived from distributions could be leading to bias.

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