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QUANTIFICATION OF WHITE SPECKS

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Abstract

Prior work demonstrated that dyed yarn offered a promising media for the quantification of white specks, (Simonton et al., 2001). It is a logical assumption that white specks appearing on the surface of dyed yarn will also appear, to a certain degree, on the surface of cloth made from that yarn. The first step in exploring the use of dyed yarn for white speck quantification was the development of a methodology based on human inspection for both yarn and cloth. This research expanded the original work to include multiple operators.

Introduction

Immature fibers are finer in structure, due to their lack of secondary wall development and have a higher propensity to form neps than do 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 neps remain un-dyed, that the more specific classification of "white speck" is used. The combination of low dye retention and high reflectivity, gives the white speck its' characteristic light shinny appearance on the surface of dyed cloth or yarn.

Current commercial fiber testing, based on average fiber properties, was not designed to measure or detect the presence of immature fibers in the small quantities that have been determined to be detrimental to dyed finished fabric quality, (Zellweger Uster, 1999). It has been estimated that even in fabric with severe white speck contamination the percentage of white speck fibers (by weight) is most likely less than 0.10% of the total fibers, (Watson, 1989). These amounts would be too small to have significant effects on the average fiber properties as measured by current commercial test instruments, but are substantial enough to negatively impact the commercial value of the fiber to the end user.

The main focus of this research was to perform foundational work toward the development of human inspection methodologies that could be used for the quantification of white specks. The work involved the comparison of within and between operator counting repeatability when using dyed yarn and dyed knits for counting white specks. It was hypothesized that operator repeatability would be improved when using dyed yarn as compared to using dyed knit cloth. In order to determine the least variable human inspection count media a comparison of operator-to-operator and reading-to-reading variability were made using both yarn and knits.

Procedures and Instrumentation

Fifteen yarns were selected for comparison. These were taken from an inventory of commercially spun 30/1 Ne 100% cotton ring spun yarn. The selection criterion was based on prior knowledge gained during the pilot study phase of this research that indicated the yarns contained varying degrees of white speck contamination, (Simonton et al., 2001).

Direct Blue 80 was selected based on the work of Smith (1991). Smith categorized dyes by their ability to cover immature fibers. The Direct Blue 80 dye was found to be sensitive to immature fiber (white specks), (Smith, 1991). The same dye was utilized for both yarn and knits.

A Leslie Hubble CAC 60-5 VeriVide light cabinet was used as a source of standard lighting. The VeriVide light cabinet was equipped with both artificial daylight (D75) and cool white (CW) light sources. It was found during the pilot study that the operator's ability to detect white specks was improved if both D75 and CW light sources were simultaneously illuminated, (Simonton et al, 2001). Based on this experience, both light sources were utilized. The lower work surface of the VeriVide light cabinet was equipped with an adjustable viewing platform. The platform helped to insure accurate repetitive sample placement. The angle from the light source to sample was set by the operator to achieve their best visual differentiation between the white specks and the adjacent yarn or knit, (Boynton, 2000).
A Model 44 Chavis yarn winder was used to place the fifteen yarn samples onto individual stainless steel dye tubes for dyeing. After winding, they were package-dyed, in a single batch, using a 15-package capacity Gaston County Package Dye Machine Model 702 RFC.

After the dyeing process, an Alfred Sutter yarn board winder was used to wind samples onto 7” wide by 11” long by 1/8” thick black rigid cardboard yarn boards. The Alfred Sutter yarn board winder was set to place 16 equally spaced wraps per inch on each board for a horizontal distance of 5.75 inches. With this setup each board had 28.11 linear yards of yarn per board viewing side, for a total of 56.22 linear viewing yards per yarn board.

Five replications of each dyed yarn sample were made. This gave a total of 75 yarn boards, each having “A” and “B” sides. The “A” and “B” designations were arbitrary designations for the purpose of preventing the operator from reading the same side twice. Five replications yielded a total of 281.1 linear yards of yarn on the face of the boards per sample yarn.

The board “reading” process involved placing each sample into the viewing box of the VeriVide light cabinet. The operators positioned each board in the viewing box with the aid of an adjustable viewing platform. After positioning the board the operator used a counting technique that traversed from left to right, then right to left, while moving from top to bottom. A pointed probe was used to help the operator maintain focus while counting. Three separate operators, on side “A” first and then on side “B”, counted white specks. Each operator performed readings on three separate occasions. With three operators making three readings on all 75 boards a total of 675 data points were collected.

The fifteen sample yarns were used to knit individual single knit jersey fabric. A Model F.A.K. Lawson Hemphill Fiber Analysis Knitter, equipped with 20 needles per inch, was utilized to produce single knit jersey tubes. Five replications of each of the 15 yarn samples were made giving a total of 75 knit tubes. The knit tubes were sub-labeled with A, B, C, and D sides. The “A”, “B”, “C”, and “D” designations were arbitrary designations for the purpose of preventing the operator from reading the same side twice. “A” side was designated, as the outside front and “B” side was the outside back of the knit tube. “C” and “D” sides were obtained by turning the tube inside out. “C” was the inside front opposite “A” and “D” was the inside back opposite “B.” Each knit tube was also marked with a white 4” orientation line located under the sample number on the “A” side.

The knit tubes were simultaneously dyed using a Gaston County 90 liter capacity Laboratory Dye Beck. After the dyeing process all knit tubes were transferred to the VeriVide light cabinet for “reading”. A 4” by 9” template, made from 3/16” black foam board, was placed inside of each knit tube before viewing. This gave a total of 36 square inches per side. With four sides being viewed per sample reading a total of 144 square inches were viewed. The operator, first on the “A” side and then on the “B” side, counted white specks. The knit sample was then turned inside out and placed back onto the template. Once the template had been placed inside of the knit tube, the orientation line on the “A” side, as seen from the “C” side, was used to achieve correct alignment. The three operators used for the yarn segment of this study repeated three separate readings each on all knit samples for a total of 675 data points.

Analysis

The limited number of samples (15) was not adequate for determining the distribution of the data collected. The combination of the data being discrete in nature and being obtained with a counting technique suggest a non-normal distribution. With a non-normal distribution assumption, it was necessary to select the appropriate non-parametric statistical tools for the analysis.

A Wilcoxon Match Pairs Test for dependent samples was used to examine the difference between each operator’s three readings. The results of this test are contained in Table 1. When comparing each operator’s readings only 1 of the 9 possible yarn readings was significantly different while 7 of 9 possible knit readings were significantly different at an alpha of 0.05.

Coefficient of variation was used to compare each operator’s reading-to-reading variation for both count medias. CV% were expressed by the following formula:

$$CV\% = (s / m) * 100 \tag{1}$$

where:

- s - Standard deviation for each sample between readings 1,2,3 for each count media,
- m - Average of readings 1,2,3 for each count media.

The results of this comparison are contained in Table 2. It can be seen that in two out of the three operators within operator variability was less for yarn than it was for knits. In the third operator there was not an appreciable difference between yarns and knits as measured by CV%. A summary comparison of yarn and knit CV% can be seen in Figure 1.

Operator reading-to-reading performance was examined by a direct comparison between the three readings. The same technique was used for both yarns and knits. The comparison was accomplished by utilizing the following formulas:

$$((R1 - R2)/R1)*100 = \% \text{ difference Reading 1 to Reading 2} \quad (2)$$

$$((R2 - R3)/R2)*100 = \% \text{ difference Reading 2 to Reading 3} \quad (3)$$

$$((R3 - R1)/R3)*100 = \% \text{ difference Reading 3 to Reading 1} \quad (4)$$

The results of these comparisons can be seen in Figures 2 and 3. When visually compared, operators 1 and 2 had a lower percent difference reading-to-reading for yarn than they did for knits. Operator 3 was more variable reading-to-reading than the other operators for yarn and approximately the same for knits. Upon review it was found that the first reading for operator 3 skewed the comparisons. When only the percent difference reading 2 to reading 3 was used operator 3 was in the same percent difference range as the other operators for yarn and about the same for knits. This difference suggested some type of training inadequacy or other variable that was not accounted for.

A Spearman R rank order correlation was used to examine the proportionality between operators. The average correlation between operators when reading knits was 0.87 and 0.98 for yarn. The correlation between yarn and knits was 0.84. The difference between yarn and knit correlation further support the view that yarn is the less variable count media.

Conclusion

Test results demonstrated that dyed yarn was a more stable counting media for the quantification of surface white specks than dyed knit FAK tubes when using multiple operators. In comparison to FAK knit cloth, yarn was less variable reading-to-reading and operator-to-operator. When each operator's individual readings were compared, the difference between yarn and knit variability became most apparent.

When comparing dyed yarn and dyed knit cloth, as the counting media, dyed yarn displayed lower coefficient of variation between operator readings. In general, this would indicate that an operator would be expected to have a tighter counting range, on multiple readings, for yarn than they would for knits when counting white specks.

A grant from the Texas Higher Education Coordinating Board for calendar years 2002 and 2003 will allow this work to be expanded. Future plans include; validation of the manual visual techniques with multiple yarn counts and colors, development of image-analysis techniques, and systemic exploration of the white speck phenomenon.

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Table 1. Wilcoxon Test for Significance; Significantly Different Reading-to-Reading.

	Operator 1		Operator 2		Operator 3	
Reading	Knits	Yarn	Knits	Yarn	Knits	Yarn
R1 to R2	Yes	No	Yes	No	Yes	No
R2 to R3	Yes	No	Yes	No	No	No
R3 to R1	No	No	Yes	Yes	Yes	No

Alpha = 0.05.

Table 2. Direct Comparison of Reading-to-Reading Operator CV%.

	Operator 1		Operator 2		Operator 3	
Sample	Knit (CV%)	Yarn (CV%)	Knit (CV%)	Yarn (CV%)	Knit (CV%)	Yarn (CV%)
1	3.91	0.52	1.69	3.06	5.90	1.57
2	8.63	1.74	2.11	2.23	6.18	1.12
3	4.72	0.50	2.60	0.32	2.41	0.59
4	0.41	0.81	5.22	0.76	3.31	4.89
5	2.20	2.05	6.63	.092	2.77	2.78
6	5.22	1.38	6.37	0.94	4.28	4.56
7	0.62	2.35	2.47	1.29	1.58	1.99
8	3.11	1.67	2.86	2.54	3.73	6.86
9	2.90	0.61	3.54	0.72	1.49	2.19
10	4.00	0.41	4.76	1.85	6.02	4.05
11	6.78	0.40	4.56	2.21	2.95	5.49
12	1.46	3.07	6.37	2.96	4.60	2.58
13	4.44	0.70	4.07	0.52	3.02	7.34
14	1.50	0.84	2.97	1.54	3.59	4.59
15	2.20	0.83	2.46	0.82	3.00	6.65
Average	3.47	1.19	3.91	1.51	3.65	3.82

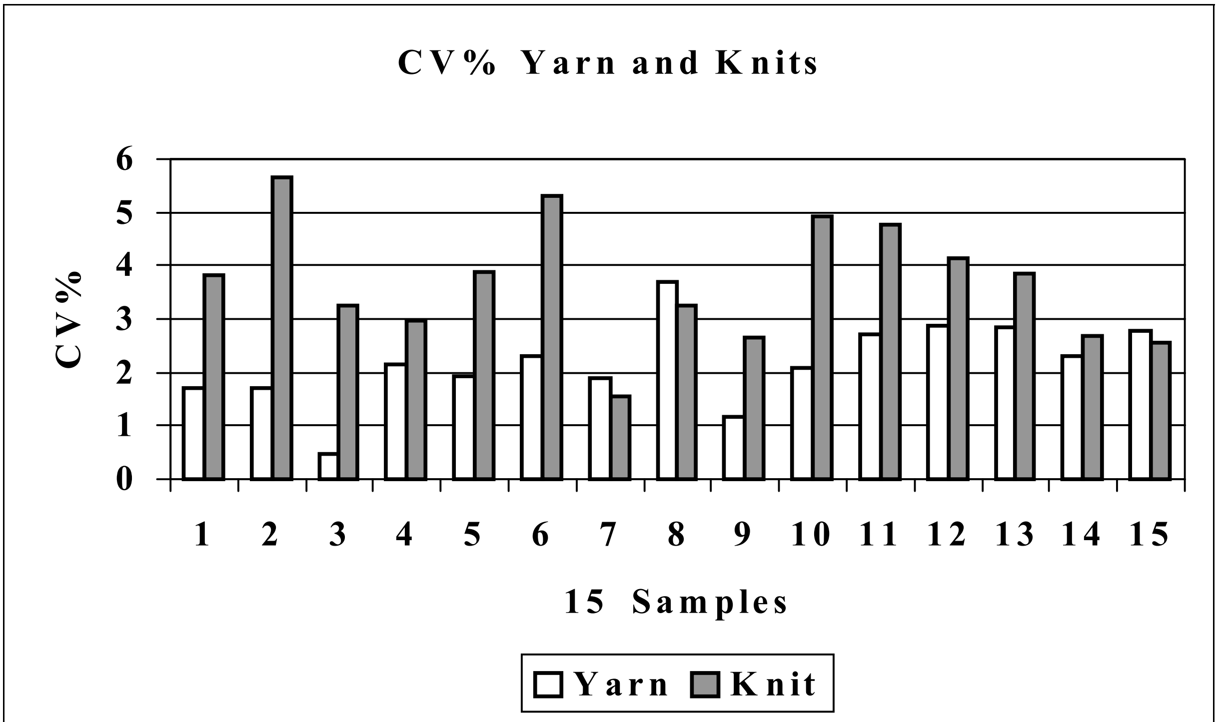

Figure 1. Yarn Knit CV% Comparisons.

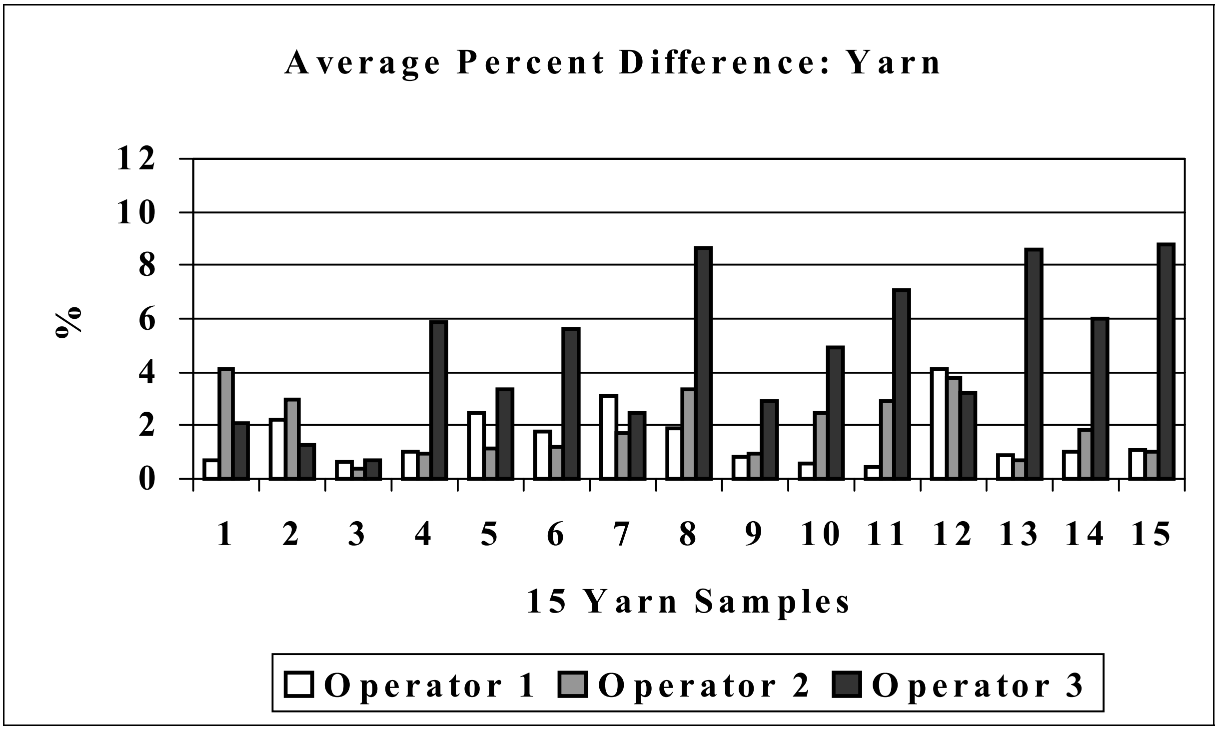

Figure 2. Average Percent Differences Reading-to-Reading for Yarn.

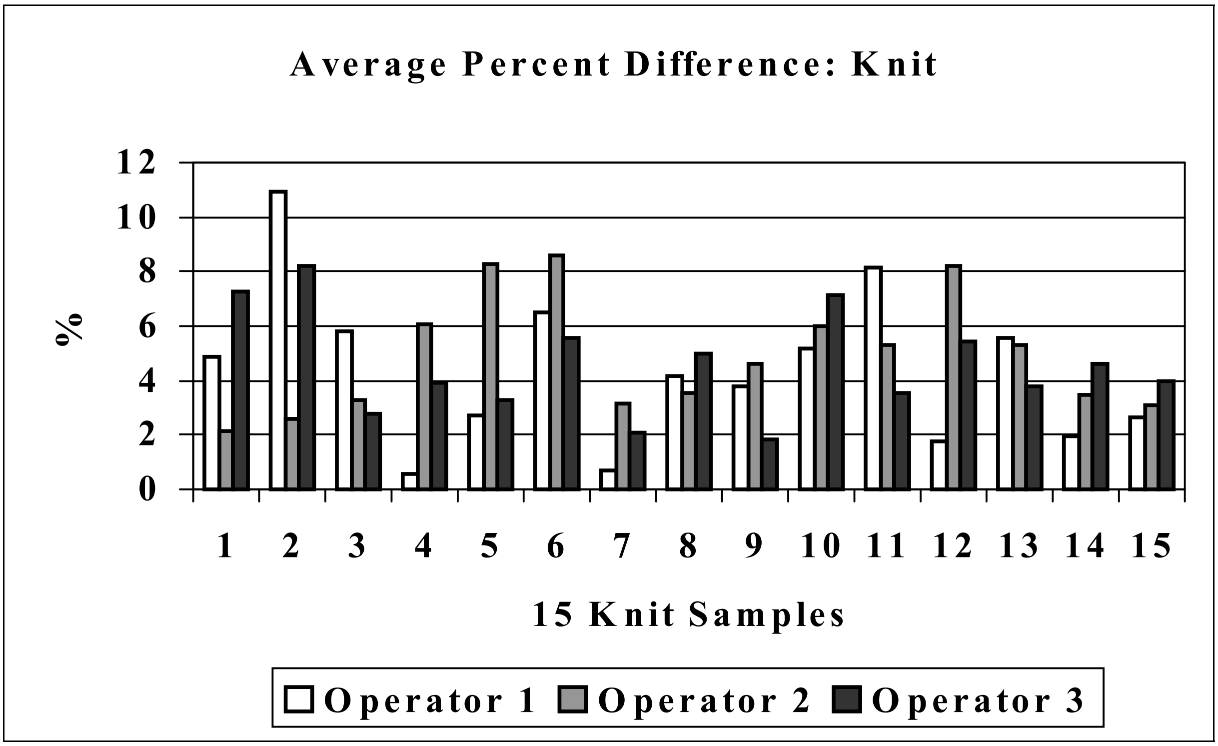

Figure 3. Average Percent Differences Reading-to-Reading for Knits.