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NOTES

White Speck Consistently Quantified by Image Analysis

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INTERPRETIVE SUMMARY

On darkly dyed fabrics, undyeable clusters of undeveloped cotton fibers appear as white specks or streaks on the surface of the fabric, resulting in a product that cannot be marketed as first quality. This white speck problem resulted in an estimated annual loss of $200 million to the textile industry.

Much of the evaluation of white speck has been performed subjectively. Image analysis, an objective means to quantify this problem, has been used in a variety of areas, from the medical field to tolerance testing in manufacturing. Han and coworkers at Clemson pioneered its use for white speck detection.

After evaluation of three image analysis systems, we selected a Microimage Video Systems color camera, an Imaging Technologies frame grabber, a personal computer with a second monitor, and the Optimas software.

A black-and-white video image was captured by a color camera and observed on a monitor. The software to analyze the image was run on a personal computer. Using the software, the operator determined the threshold, which included the gray level range that the white speck comprised. The threshold was unique to the particular fabric due to factors such as cotton cultivar and dye uptake. Tungsten flood lighting gave the most realistic images, which were consistent regardless of the time the same sample was viewed.

Two sets of cotton fabrics were used and tested on several dates. One set of tests involved eight plain-weave fabrics that each had distinct visual levels of white speck content. The other set was comprised of 35 filling-face sateen fabrics, with a range of white speck content. To generate the white speck content of a fabric, 24 images of 7.5-by-10 cm yielded statistically significant data. The operator manipulated the fabric so that 24 consecutive images were analyzed per fabric. The system and technique demonstrated no significant differences between dates of testing. From this study, we believe we have a reliable means of quantifying white speck content of finished fabrics.

ABSTRACT

White specks are undyeable, undeveloped fiber communities on dyed and finished cotton (*Gossypium hirsutum* L.) fabrics. These specks currently are not quantifiable for comparison purposes. In order to remove the subjectivity from dye defect classification, image analysis was evaluated as a means to accomplish white speck detection. Of the wide variety of imaging software that exists, the Optimas system was best suited for this application. Two sets of cotton fabrics were evaluated for their white speck content. One study involved eight plain-weave fabrics, each with visually distinct levels of white speck content. This study was used primarily to identify the system, software, and technique best suited for white speck quantification. The second study verified the system, software, and technique using 35 filling-face sateen fabrics. Compared with the eight fabrics, the 35 had subtle differences in white speck levels. The imaging system was consistent on several dates of testing.

White specks on finished-dyed fabrics are defined as small undyeable, undeveloped, or extremely immature fiber clusters that appear white on the surface of a darkly dyed fabric, or as non-uniform streaks in the fabric. Unfortunately, these defects are not detected until after dyeing, resulting in a fabric that cannot be marketed as first quality. In recent years the U.S. textile industry has lost an estimated $200 million annually due to dye defects

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(Goynes et al., 1996). Typically, fabrics are evaluated for their white speck content in a subjective manner. Thus, it is imperative to find a means to objectively quantify an acceptable fabric with respect to white speck content.

Based on the versatility of image analysis, it seemed appropriate to try to use it to evaluate fabric white speck. Such a technique developed by Han has proven successful at counting white specks (Han et al., 1998). Several imaging systems are commercially available, servicing a wide variety of applications from the medical field to tolerance testing in manufacturing. As might be expected, not all imaging software and systems are suitable for the macroscopic white speck detection. Many systems are capable of defining trends and providing consistent relative rankings, but not all are capable of yielding the same white-speck content every time the fabric is tested.

MATERIALS AND METHODS

Image Analysis System

Three image analysis systems were evaluated for their ability to quantify the white speck content of fabrics. Of the three systems studied, only Optimas was consistent and will be discussed in further detail.

Image analysis for this study was done[1] using the Optimas 5.2 software on a Gateway 2000 P5-75 computer complete with a dual monitor setup, including a Sony Trinitron RGB Monitor and an Imaging Technologies frame grabber. A Microimage Video Systems RGB/YC/NTSC color camera, placed approximately 46 cm above the fabric was used to extract the image and set at an F-stop of 4. Four tungsten 120 V, 300 W flood photography lights were used for uniform lighting on the fabric. These lamps were placed 30.5 cm on either side of the camera and 28 cm above the fabric surface (Fig. 1). All data analysis was performed on the Gateway computer while the frozen live image was viewed on the RGB monitor.

The image was converted to black-and-white and focused. With the current lighting scheme, a contrast

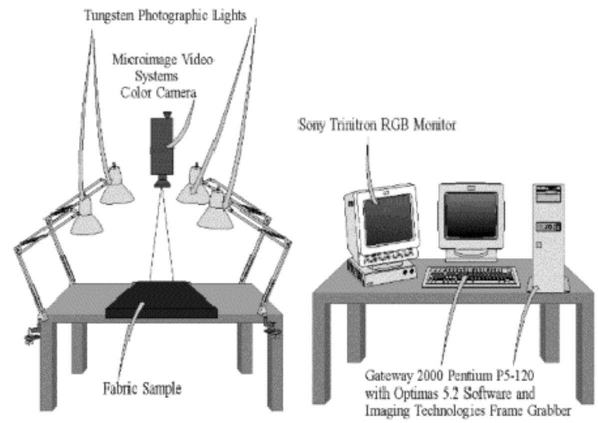

Fig. 1. Typical setup of the equipment used to perform image analysis on cotton fabric .

of 120 and a brightness of 217 produced an analyzable image, which may be altered to accommodate any desired lighting level. The calibration remained constant throughout testing. With the camera at the indicated height above the sample, one pixel was approximately 0.171 mm in width and 0.175 mm in height with an aspect ratio of 0.98. The area or region of interest, identified as ROI in the software, was set at 77.5 cm^2 for a 10- by-7.5-cm area to be analyzed.

A minimum boundary length of one pixel was established to exclude random noise in the foreground from being interpreted as white specks. Boundaries were placed such that if two pixels were adjacent, they were counted as one. Once the parameters were set, the equipment was allowed to equilibrate for about 1 h to allow for stabilization of the lighting. Tests then were performed consecutively under the same conditions so that reliable comparisons and correlations could be formulated.

The percent white is defined as the area of the white specks detected divided by the region of interest. Thresholding dictates what was detected as white and, thus, contributed to the percent white of the sampled area. The threshold was based on a scale from 0 to 255, which highlighted the areas being detected; ranging was from 70 - 255 up to 108 - 255, depending on the fabric. This highlighted the white specks based on the lighting and camera settings, the fabric content, construction, and dye uptake, as well as the amount of white speck visually apparent.

The Optimas software provides an automatic thresholding macro that can be used as a guide for

[1]Use of a company name or product name does not imply approval or recommendation of the product to the exclusion of others that may also be suitable.

setting. The threshold for each fabric was determined by using several sample areas from the fabric to be tested with different impacts of white-speck content. The threshold was adjusted in each section to highlight the white specks as best as possible without overestimating the white speck and detecting false positives, often referred to as noise. The optimal threshold was selected to ensure that the white specks were being highlighted on the RGB monitor at the proper size. Once set, the threshold remained constant for the analysis of each fabric.

In the initial study with eight fabrics, 30 regions of interest of each fabric were analyzed for a total area of 2322 cm^2 per fabric. The operator manipulated the fabric sample sequentially so the same area was not tested more than once. This technique was repeated for each fabric analyzed and the data were sent to a spreadsheet.

Eight Fabric Study

Eight fabrics were produced from four cotton fiber cultivars: Deltapine, DP90; Stoneville, STV825; Acala EA-C30, experimental cotton bred to mature early, and EA-C32, an Acala cotton. Two of the four lots for each cultivar were single-carded using the Mark IV card. The other two lots were tandem-carded using the Mark IV tandem card. It was found that the tandem card was set improperly, resulting in an increase in dye defects. Due to the varietal and carding differences, the eight fabrics had visually different levels of white speck. Both 30/1 and 40/1 yarns with a 3.8 T.M. were ring spun. Plain-weave fabrics were woven from 30/1 warp yarns and 40/1 filling yarns for all cultivars to produce eight fabrics of 100% experimental yarns (Bel et al., 1993; Bel-Berger et al., 1996).

Three USDA-ARS Southern Regional Research Center employees familiar with the study ranked the eight fabrics in order of appearance of white speck. The fabric that appeared to have the lowest level of white speck impact was ranked No. 1, the fabric with the next lowest white speck content was ranked 2, and so on until the fabric with the highest white speck content was ranked 8.

Thirty-five Fabric Study

The 26 leading variety study (Agricultural Marketing Service, 1993) involved 26 bales of cotton collected and processed on modern textile processing equipment at the USDA-ARS Cotton Quality Research Station, Clemson, SC.

We used a total of 35 fabrics. The bulk of them were from the 26 AMS leading cultivars, plus five additional cultivars that were harvested from the same rain-fed field in Stoneville, MS, and processed identically to the 26 cultivars, which means they were single-carded on a Truetzchler Card. In addition, four of the 26 AMS cultivars also were combed.

Filling yarns, 36/1 ring spun, were produced and woven into a 5-harness filling faced sateen with a common combed warp, 30/1 yarns. The experimental yarns gave approximately 85% surface coverage (Bel-Berger et al., 1996, 1997). The fabrics were analyzed using image analysis and visually ranked as with the eight fabrics. The visual impact of the fabric white-speck content ranked No. 1 of the sateens was similar in visual impact to the No. 1 ranking of the plain-weave fabric. The actual percent white values as detected by image analysis were different for different types of fabric, despite the same visual ranking. This difference is due, in part, to the fabric construction, because sateens are more reflective. Although the level of calibration established in the eight-fabric study allowed visual rankings as high as No. 8, none of the 35 fabrics had white speck levels greater than No. 6.

Dyeing Procedure

The fabrics of both studies were finished with a 0.1% Prechem 70 (IVAX Industries), 0.3% T.S.P.P. boiloff, a caustic scour of 1.1% Prechem SN, 1.1% Mayquest 80 (IVAX), 0.1% Prechem 70 and 0.7% sodium hydroxide, caustic soda, followed by the same boiloff procedure. The fabric was then bleached with 0.1% Prechem 70, 0.5% Mayquest BLE, and 3.0% peroxide, Albone 35 (DuPont), followed by an acid scour with 0.1% acetic acid and dyed with 2% Cibacron Navy F-G Blue, 0.5% Calgon, 8% sodium chloride, 0.8% Na_2 Co_3, soda ash, and 0.5% Triton X-100 (Rohm and Haas Co.). All chemicals were determined from the weight of the bath, except for the Cibacron dye, which was based on the weight of the fabric. This dye has a high propensity for highlighting white specks in finished fabrics (Bel et al., 1993).

Statistical Analysis

The 30 images for each of the eight fabrics for each date were included in the analysis of variance (ANOVA). The goal was to determine whether the testing dates were significantly different for each fabric, thus indicating inconsistency. Three independent variables were studied: fabric, date, and fabric by date; and one dependent variable, percent white. Three types of post hoc tests – Duncan, Scheffe, and Tukey (Mendenhall and Beaver, 1994) – were performed to note statistical differences in the dates of testing as well as the fabrics, to indicate the technique's reliability. The means of 2, 3, up to 30 fabrics were plotted as percent white versus number of replications to indicate the minimum number of images needed to produce the percent white mean. To verify the minimum number of images required per fabric, ANOVA was performed on a data set containing 30 images and a data set containing 24 images to see if the means were significantly different.

For the 35 fabrics, 25 images for each fabric were used in the ANOVA. There were two dates of testing for the 35 fabrics to verify the consistency of the technique and system. Due to the larger size of the data set of the 35 fabrics, the means of 2, 3, up to 24 fabrics were plotted as percent white versus number of replications. This graphical technique verified the minimum number of images needed to produce the percent white mean.

The validity of the technique was checked by comparing image analysis data to visual rankings of the white speck content determined by three panelists. A regression analysis was performed on the percent white and the visual rankings to study this relationship. The percent white used in the regression was the mean of all of the replications for each fabric: 30 samplings for four dates yielding 120 observations that were used to calculate the mean for the eight fabrics. Due to the two types of fabrics, a regression analysis was performed for each study individually.

RESULTS AND DISCUSSION

The parameter percent white was used as a measure of white speck content instead of the number of white specks because percent white better represented the visual impact of the white speck content of the fabric. White specks appeared in a variety of sizes, and a fabric that had fewer but larger specks had a worse appearance than a fabric with more small white specks. The Optimas software was consistent.

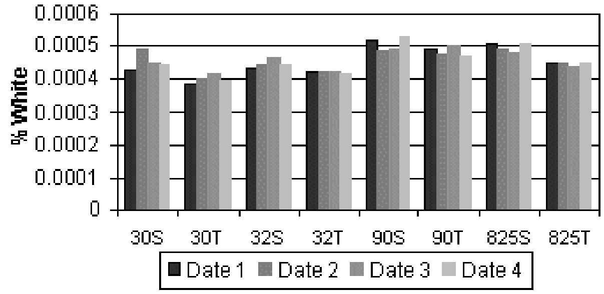

Fig. 2. Percent white values of the initial eight cotton fabrics at four test dates, as determined by image analysis equipment.

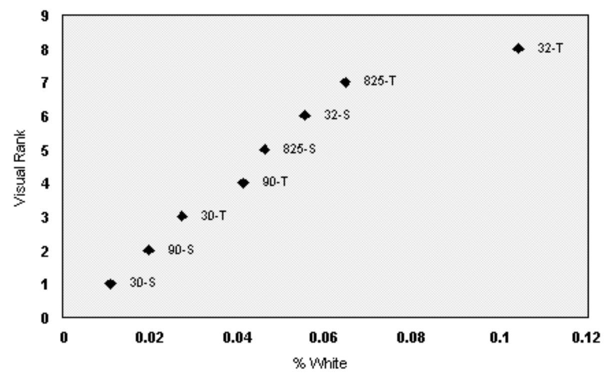

Fig. 3. Percent white vs. visual rank for the initial eight cotton fabrics assessed by the image analysis equipment and used as the basis for ranking the 35 that were later tested. The numbers used in the illustration refer to the cultivar used - 30 and 32, Acala EA-C30 and EA-C32; 90, Deltapine DP90; and 825, Stoneville STV-825. The "S" and "T" refer to single and tandem carding of the fibers.

Eight Fabric Study

The percent white means for the eight fabrics were not statistically different for each date of testing (Fig. 2). The fabrics were identified by the number in their name, followed by an S or T for different treatments. In Fig. 2, the daily percent white values for each of the fabrics had very little variation. The average percent white for each of the eight fabrics remained the same for each test date. This indicated that the image analysis system and technique were measuring the white speck content consistently. Regression analysis of the visual rankings and the percent white values of the eight fabrics verified that

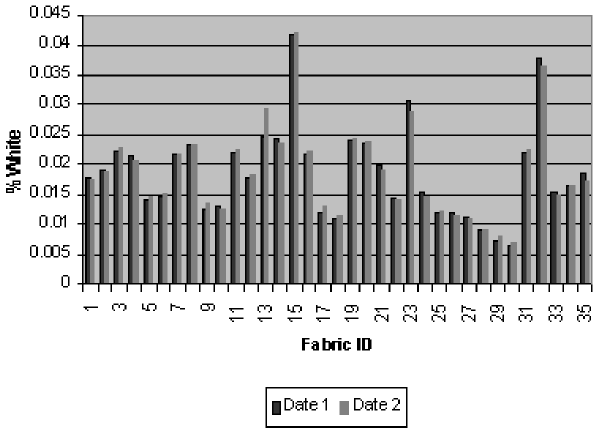

Fig. 4. Percent white values of 35 cotton fabrics at two test dates, as determined by image analysis equipment.

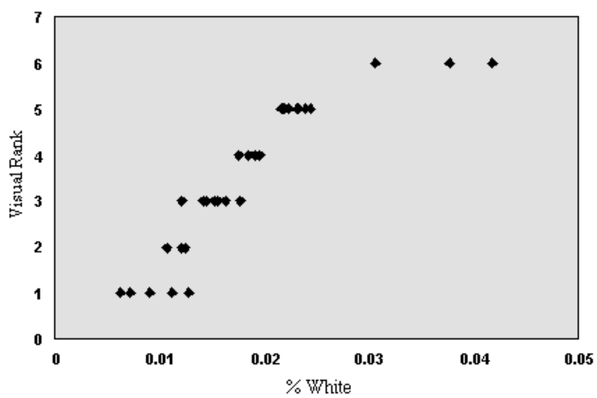

Fig. 5 Relationship between the percent white and the visual ranking of the 35 cotton fabrics, as determined by image analysis equipment.

the image analysis system and technique were measuring the white speck content as shown in Fig. 3.

Thirty-five Fabric Study

To confirm that the system and technique were consistent, 35 fabrics were tested for white speck content on two dates, utilizing the same procedure used for the eight fabrics. Fig. 4 shows that the percent white averages were nearly identical for the two testing dates. The filling face sateen was more reflective and required different thresholds than for the plain weave fabrics. To compensate for this reflectiveness, the thresholds were set to minimize this noise. There was some compromise between the noise level and the white speck detection of the sateens. The lower the level of noise, the smaller the white specks that could be detected. Because none of the 35 fabrics had white speck levels that had the visual impact of ranking 7 or 8 of the eight-fabric study, the 35 fabrics were ranked visually into six groups. The group with the least white speck content, ranked 1, to 6, the group with the highest white speck content, correlating in visual impact to the 1 and 6 ranking of the plain weave fabrics. As the percent white increased, the visual ranking increased (Figure 5).

Statistical Results

The image analysis system was able to quantify the level of white speck content, not merely indicate the trends from one test date to another. The dates of testing were not significantly different from each other as determined by ANOVA for both the eight fabrics and the 35 fabrics. For each set of fabrics, the percent white values are not statistically different, regardless of the date of testing.

In the graphical technique, the percent white means stabilized at 24 replications, for the most variable fabric. For the eight fabrics, ANOVA demonstrated that the results from 24 images per fabric were not statistically different from the results from 30 images per fabric. ANOVA and the graphical technique demonstrated that 24 images on a particular fabric were sufficient for white speck detection.

The validity of the proposed analysis system was tested by comparing the visual rankings of the eight fabrics with the mean of all replications of each test date for each fabric. A regression analysis of rank and percent white of the eight-fabrics and of the 35 fabrics demonstrated that the white speck content detected with image analysis matched the subjective visual rankings, by both increasing.

CONCLUSIONS

Image analysis is a tool that permits a consistent, objective means of quantifying the appearance of a finished fabric for white speck content.

Of the imaging systems and software studied, the Optimas system was best suited for white speck detection. The Optimas 5.2 software utilized in conjunction with the outlined technique, proved to be a repeatable, reliable means of quantifying white speck content of finished fabrics. Lighting was critical and the tungsten flood lighting consistently illuminated the fabric in a realistic manner.

Twenty-four replications for each fabric provided repeatable, statistically sound means for white speck content. The reliability was checked by ANOVA of the test dates of each fabric; the test date proved not to be significant in its effect on percent white for each fabric. The white speck content of a particular fabric remained the same regardless of when it was tested. The validity of the system and technique was checked by a regression analysis of the visual rankings of the fabrics and the percent white averages of the fabrics.

Because the visual rankings correlated with the percent white of the fabrics, the image analysis system and technique, we conclude that the procedure was, indeed, measuring white speck content of the fabrics.

The two sets of fabrics, plain and sateen, were different in the visual impact of the white speck due to the reflectance of the two weaves, and required two different ranking scales.

This research identified a system that was appropriate for white speck detection and a technique for consistently generating realistic data. The subjectivity of determining these dye defects was replaced by objective quantitative data that can be used for comparative purposes. This tool also provided a means to study varietal, harvesting, and processing effects on the dye-resistant neps.

This technique, while consistent across time, still requires operator involvement to move the fabric and to determine the threshold. In addition, uniform lighting is essential. In future research, to alleviate these problem areas, more will be studied on automatic thresholding and scanning the fabric into images to ensure uniform lighting.

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