MICROSCOPIC TRACKING OF WHITE-SPECK DEFECTS FROM BALE TO FABRIC

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Abstract

Structures of materials that compose "white speck" defects on cotton fabrics are the same as that of undeveloped cotton fibers that contain only primary wall, or primary wall and very thin layers of secondary wall. Bundles of these unseparated, very immature fibers are found on undeveloped seed, or motes. Such undeveloped seed and fibers are harvested along with normal seed. Microscopic examinations were made of samples from various stages of processing to determine whether the compressed fiber bundles were removed during any process or were carried with the normal fibers through yarn and fabric production. Samples were examined from bale cotton, chute cotton, card sliver, yarns, and fabrics to determine the presence of undeveloped fiber bundles. In lots where defects were found in bale cotton, they were also abundant in all samples.

Introduction

Defects that appear on dyed cotton fabrics as white or light specks render fabrics unsuitable for commercial use, and the comprehensive nature of the problem causes heavy financial loss to the textile industry. These small white dots on fabrics that have been dyed dark colors, cannot be identified with the naked eye, and can only be assumed to be materials that did not dye in the same manner as did the body of the fabric. Examination of these undyed defects using microscopical techniques identified them to be composed of bundles of undeveloped fibers such as those produced by undeveloped seed or motes (1). Fibers that have developed only primary wall structures before boll opening do not separate, or "fluff," when the boll opens and fibers dry. Because the fibers have no individual rigidity, they remain in the configuration in which they developed in the boll, and exist as inseparable clumps rather than individual fibers.

Cotton fiber wall thickness is greatly dependent on maturity, or the width of the fiber wall as related to its maximum width capability. Other factors such as variety, and growing conditions also influence the thickness of the fiber wall. For the lack of more definitive terminology, we have come to refer to thick-walled fibers as mature, and thin-walled fibers as immature. We are able to look at fiber cross sections within a given sample and point out those that we consider mature and those that we consider immature. However, all immature fibers are not equally immature. Many have very thin walls, and others have wall thicknesses approaching those considered mature (2). It is expected that harvested fibers will contain a portion of immature fibers, and that these should not adversely affect the quality of the product. However, there are immature fibers whose development was halted before significant amounts of secondary cellulose layers were deposited. Because development can be halted at any step of fiber growth, many stages of "maturity" can be found in most fiber samples. Wall thicknesses in fibers considered to be "immature" can range from a thin layer of secondary wall to walls several microns thick. There is no fiber maturity definition that includes a required wall thickness. Therefore, fibers whose secondary wall development allows them to separate into individual fibers on boll opening but has not reached maximum thickness are immature. Whether these fibers cause dye defects depends on whether their walls have developed sufficient cellulose to accept a great enough quantity of dye that they are perceived as dyed rather than white. Very immature fibers whose development has allowed them to separate and act as individual fibers rather than masses, often blend with more mature fibers and do not present a perceptible defect. Those that remain as cohesive fiber mats because of undeveloped secondary walls do not blend and become visible after dyeing. Although fibers in white defects and those from motes have the same apparent structure, the passage of these compressed mote fiber bundles from seed through ginning, cleaning and mill processes to become an integral part of the fabric structure had not been documented. For this study, samples from the bale, chute, card sliver, yarn, and fabrics were dyed, and examined for presence of undyed defects. Selected defects were prepared for electron microscopy, and structures of those removed from each processing stage were compared.

Materials and Methods

Four cotton varieties were used in the overall white speck defect study. However, for this study of progression of defects through processing steps, no attempt was made to evaluate varietal differences microscopically since the emphasis was on whether the processing equipment removed the defect materials. Speck counting procedures were carried out, and have been reported earlier (3). The bale cotton was processed in the mill at the USDA, ARS, SRRC, New Orleans, LA. The first sample was taken from the bale fiber before opening and cleaning. The second sample was taken after the opening and cleaning processes, from the chute area. The final fiber sample was taken after carding. Both single and tandem carding was carried out on all varieties. Samples of yarn before weaving were taken, and from areas of the resultant plain weave fabric.

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Fiber webs from each processing stage were dyed with CI Direct Red 81 (3, 4) to show locations of undyed defects. Yarn dyeing was carried out by wrapping yarns on perforated metal cylinders, which were immersed in a Cibacron Royal Blue FB dye bath in an Ahiba Polymat automatic dyeing machine. Samples were dyed for 45 min at 60° C, then boiled for 2 min in a solution of Tide, and rinsed.

Fabrics were dyed for 45 min at 60°C in a Cibacron Navy Blue FG dye bath using the SRRC pilot plant dye jig. After dying, material was first cold rinsed, then rinsed at 70°, then again in cold water. Rinsed fabric was run through a two-roll padder, then through a tenter frame at 90°C.

White defects were selected by observing dyed webs or fabrics using a low power, widefield stereo microscope. Defects or small sample swatches were mounted on sample stubs for scanning electron microscopy, and sputter-coated to suppress charging in the microscope.

Results and Discussion

Although the morphological structure, as shown by SEM, of masses of fibers that are found on motes is visually the same as that of those found on fabric surfaces, there are subtle differences. Because dyed fabrics have received treatments, both chemical and physical in the processing steps that produce the fabric from the seed fibers, some differences are to be expected. The changes that are most often found are 1.) that the mass of undeveloped fibers may become tangled in loose, more mature fibers, and 2.) the mass appears to have been flattened or pressed into the surface of the fabric. Because of the entanglement in more mature fibers, it is sometimes proposed that the defect materials are composed only of separated fibers that have been entangled in the processes that lead to production of yarns. This view proposes that cleaning and carding procedures would remove masses of undeveloped fibers and that they would not be carried through to the final fabric. The other visual difference, flattening or compression of the mass is likely due to pressure from squeezing and/or rolling procedures. Such flattening makes the mass more reflective, and spreads it so that it may cover more than one yarn area. This flattening visually increases the impact of the defect on the fabric surface.

Determining progression of the undeveloped fiber bundles through the various processing stages is important because their presence in samples from each stage of the processing shows definitively that cleaning equipment does not remove all of them and that they comprise the same materials that appear on fabric surfaces. Following the changes that occur in their appearance from one processing step to another also provides information on how processing affects them before they reach the fabric.

Because it is visually difficult in undyed materials to distinguish fiber bundles that contain potential "white speck" materials from other types of fiber neps, it is necessary to dye all materials before examination. Dyeing procedures must be carried out very carefully, because laboratory dyeing processes are more efficient than commercial processes, and even "white speck" bundles often pick up some dye in the laboratory. They are thus more difficult to distinguish without use of microscopes capable of high magnifications and great depths of field. Therefore, great care is necessary both in dyeing processes and in selection of defects.

Samples from all processes up to yarn spinning were taken from dyed mats. These mats, dyed with Direct Red 81, were deep pink, and undeveloped fiber masses were white or very light pink. There was very little difficulty in finding undyed masses in bale cotton lots taken before the opening and cleaning line. Undyed defects were evident in samples from all four varieties studied. Size of the mass varied, but usually appeared quite similar to the masses found still connected to undeveloped seed from the boll. Samples taken from the chute area after opening and cleaning but before carding were very similar to those from bale cotton.

The greatest differences in defects were found to occur during the carding processes. A process for counting white defects in webs was set up, and though all data have not been completed, counts and visual inspection indicate that a single carding process reduced the number of defects. Defects were still easily found in dyed webs, however. Some undeveloped fiber clumps, when examined by scanning electron microscopy were found to be entangled in more mature fibers. This mixing of dyed and undyed fibers produced a defect that appeared to be lightly dyed rather than white.

Unexpectedly, tandem carding increased the number of white defects. Microscopical examination of these defects indicated that they often appeared to be pulled or stretched, and probably were separated or broken into more than one particle in some cases. Thus, while the amount of white speck material did not increase, separation of single defects into two or more defects, and stretching of smaller defects into longer defects produced the visual appearance of more white speck material.

Examination of yarns for white defects was very difficult. Because of the difficulty in detecting true white speck defects in undyed materials, it was necessary to dye the yarns before examination. Additionally, even though several white speck defects may be found in a square cm of fabric, the yarns to which these defects are attached may be several meters in length, and may have no other defects in this length. Therefore it may be necessary to examine several meters of yarn to find obvious white speck defects. Even at a low magnification using a widefield microscope, the process is very tedious and time consuming. Additionally, the defect may occur on either side of the yarn, and will not likely be found by examining only one surface. Sections of yarn containing observed defects were cut from the yarn and mounted for SEM study.

SEM examination of these defects in yarns showed that they were pads of extremely immature, undeveloped fibers, sometimes with more mature fibers wrapped around them. Some defects were found to be only lightly attached to the yarn surface, and some were embedded within the twisted yarn structure. Those that were on the surface were the most obvious white speck defects.

Detection of potential white defects on the surface of undyed fabrics is difficult because there are many types of defects on these surfaces. Dark specks, those that contain plant parts are very obvious. These are largely removed in scouring and bleaching processes and are not associated with the white speck problem. It is difficult to differentiate which of the remaining fiber defects will become white specks. It is not until the fabric is dyed that the white defects become evident. In dyed fabrics the white speck defects were readily detected. Small swatches of fabric were examined using scanning electron microscopy to determine composition and structure of the materials composing them. At these increased magnifications it becomes obvious that these defects are the same as those seen in previous fiber and yarn structures.

Summary

The problem directly addressed by this research is the source of undyed specks on fabric surfaces. Tracking of these cotton fiber cell-wall bundles through various textile processing steps provides direct visual evidence that their source is undeveloped, unseparated fibers from undeveloped seed. In every example studied, the undyed defect consisted of bundles of these fibers. No differences in the fiber structure of defects in each processing stage were found. Processing does affect the nature of the defect in some instances, such as tearing or spreading of the bundle during repeated carding, and entanglement of more mature fibers around the undeveloped fiber bundles. Microscopic studies provide conclusive evidence that undeveloped fiber bundles carry through processing to become defects on the fabric surface. These fibers have not developed sufficiently to have significant amounts of secondary wall cellulose to accept dyes used with cellulosic fibers, or to provide sufficient wall integrity to exist as individual fibers.

It is probable that some of the white appearance of the undeveloped fiber defects is due to differences in reflectance between the fabric surface and the flat defect. The undeveloped fibers themselves are flat and ribbon-like, and most bundles also have a very flat surface. Defects on fabric surfaces appear to be more reflective than those on yarns. This is possibly due to compression of the defect into the fabric surface during fabric rolling and squeezing procedures.

One problem consistently encountered in this study was the inability to discern white speck defects before dyeing. Because of this, unusable fabrics are not detected until final processing, and thus the financial impact of the problem is increased. During this work, observations with low-power light microscopy using special lighting processes have indicated that it may be possible to predetermine the presence of white speck defects in undyed yarns and fabrics. If this procedure proves useful, it may provide a means to evaluate samples for white speck materials early in processing.

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