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Microscopic Determination of Cotton Fiber Maturity

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The textile cotton fiber is a natural product and its physical structure and properties depend on its complete development. The fiber develops from the outer primary wall inward. Completely developed, or mature, fibers have thicker secondary walls than do undeveloped or immature fibers. Since properties and value of harvested fibers are determined by degree of maturity, methods for determining this property are required. There are several indirect methods for measuring fiber maturity, but direct determinations can be made only by microscopic processes. Historically, assessments of degree of maturity have been made on individual samples using light microscopy. Immature and mature fibers can be distinguished by viewing the fibers longitudinally while mounted in oil on a glass slide. Immature fibers appear flat and ribbon-like, while those that are mature are rounded and tubular. Mature and immature fibers can be readily determined, however, degree of maturity is difficult to access. The method is subjective, being dependent on the judgment of the observer as to which fibers fall in each classification. A dyeing method developed by Goldthwait [1], referred to as “differential dyeing”, utilizes variations in structures of mature and immature fibers to distinguish wall thickness. The mixed dye contains Diphenyl Fast Red 5BL Supra, and Chloratine Fast Green BLL. Mature fibers dye red and immature fibers green. The red dye molecule is more easily stripped from the immature fibers, leaving them predominantly green, while it remains in the structure of the mature fiber. Figure 1 shows cross sections of fibers dyed using this process.

The scanning electron microscope (SEM) permits direct observations of whole fibers, therefore, it presents an opportunity to observe differences in fiber maturity as well. Gradations in fiber wall thickness can easily be seen while observing whole fibers, but are even more evident when cut bundles of fibers are viewed (Figure 2). Variations in thickness can be determined ranging from very thin walled fibers to those that are completely mature. Thin-walled fibers create problems in dyeing and processing. Not only do they fail to accept dyes as well as do mature fibers, they can produce other defects in textiles as well. If development of fibers on a seed is terminated when only the extremely thin outer layers have been produced, these undeveloped fibers remain clustered together and do not blend with other fibers on harvesting. They form undyeable neps, or white specks on dyed fabrics. Such a clump of fibers is shown by the Goldthwait dye test in Figure 3. When such clumps of fibers are carried into yarns and fabrics, they form undyeable defects on fabric surfaces. Such a defect formed from ribbon-like fibers is shown in figure 4a at low magnification, and in 4b at magnification that reveals the undeveloped fibers in the bundle. Ability to determine the presence of large numbers of such defect-forming fibers prior to processing is a high priority for the textile industry.

Recent progress in development of an image analysis measurement of fiber maturity offers promise of greater objectivity [2]. This method requires embedding and sectioning of bundles of fibers whose parameters are analyzed using a CCD camera with a light microscope.

[1.] C. F. Goldthwait, H. O. Smith, and M. P Barnett, Textile World, July (1947) 105.
[2.] D. P. Thibodeaux and K. Rajasekaran, Journal of Cotton Science, 3 (1999) 188.

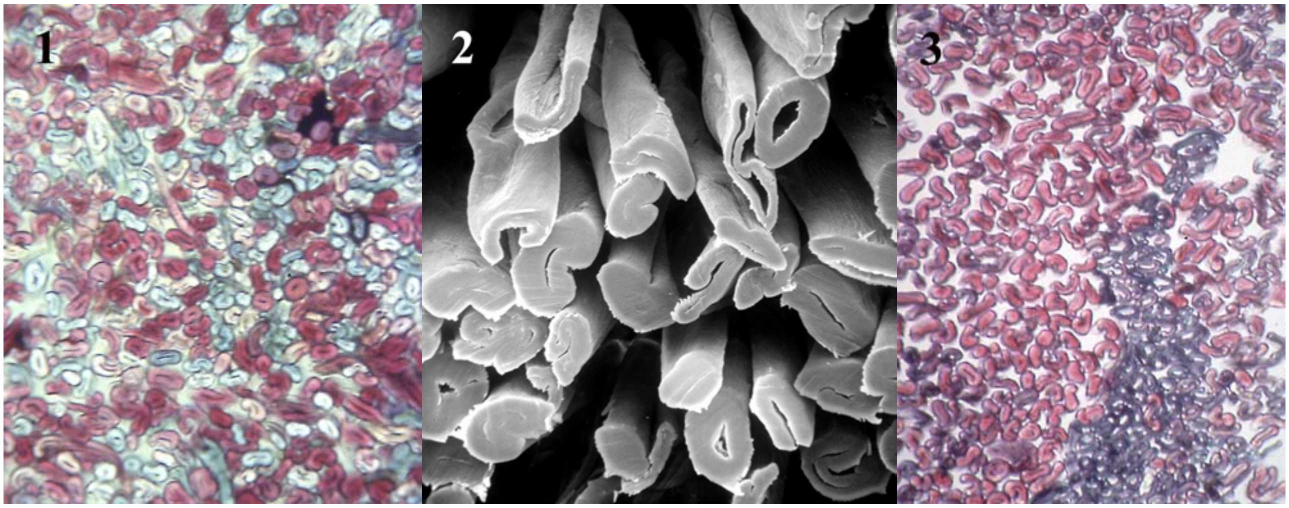

Fig 1. Cross sections of blended cotton fibers dyed with Goldthwait mixed dye showing red (mature) and green (immature) fibers (LM)
Fig 2. Ends of bundle of cotton fibers (SEM)
Fig 3. Cross sections of cotton fibers showing band of very thin-walled fibers (green) (LM)

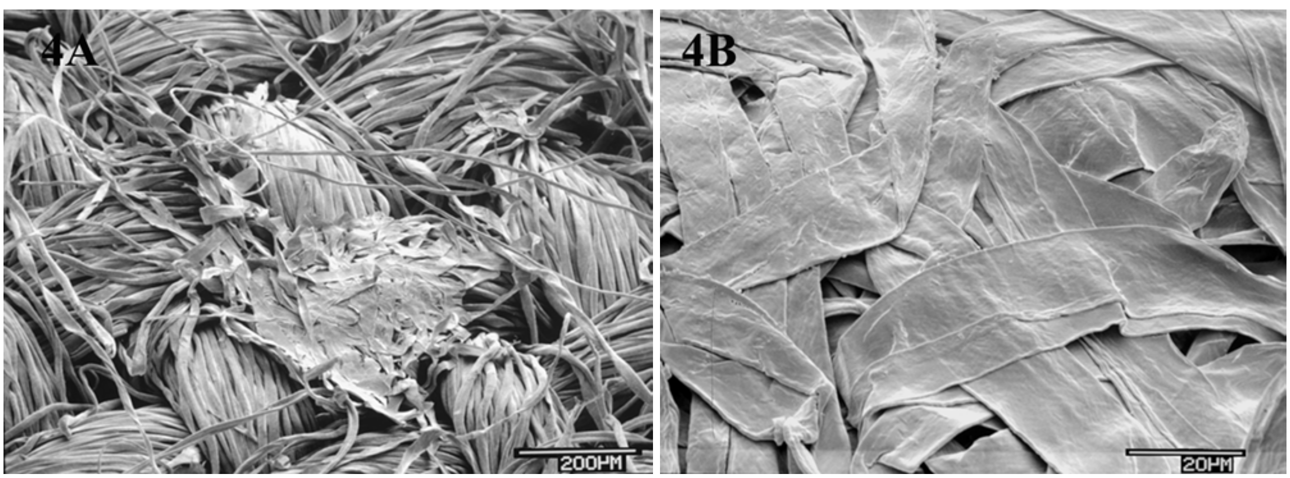

Fig 4A. Surface of cotton fabric with a very thin-walled fiber bundle defect (SEM)
Fig 4B. Higher magnification of 4a showing flat, ribbon-like fibers making up defect (SEM)

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