COTTON FIBER PROPERTIES: RELATIVE HUMIDITY AND ITS EFFECT ON FLAT BUNDLE STRENGTH, ELONGATION, AND FRACTURE MORPHOLOGY

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Abstract

It is well known that cotton fibers readily exchange moisture content with their surrounding atmosphere. As moisture exchange progresses, several physical properties of the fiber are significantly affected. In this study, the effects of relative humidity (RH), a factor that affects the atmospheric moisture content, on cotton bundle strength and elongation measurements, and on fiber fracture morphology were investigated. Stelometer tests performed in conditions with higher RH generally resulted in higher strength and elongation values. The morphology of broken fibers was also affected by the testing conditions. Fibers broken at high RH (i.e., 71 ± 2°F and 80 ± 2% RH) showed a more frayed fracture where microfibrils were evident. In contrast, at standard conditions (i.e. 70 ± 2°F and 65 ± 2% RH) fiber fractures were more granular. These findings are of relevance to moisture control efforts currently employed in industry, and they may lead to a better understanding of the effects of fractures and damage on cotton fiber properties.

Introduction

Moisture content in cotton fibers affects a number of the fibers' properties. Weight, size, strength, and elongation are a few of key fiber properties that change with differing moisture content. (Backe, 2002) Gains in weight are of particular commercial importance since cotton bales are sold by weight. Moreover, changes in strength due to increased moisture content affect the ginning of seed cotton. (Byler, 2006) Ginning seed cotton below optimal moisture levels can result in shorter, damaged fibers, while ginning at high levels can result in more seed fractions in the processed fibers. Current understanding suggests that moisture incorporates into the amorphous regions of the cellulose polymers found in cotton. (Gordon et al., 2010) Cotton also contains crystalline, tightly packed cellulose polymers into where incorporation of water molecules is considered unlikely. Interactions between the water molecules and the cellulose polymers in the amorphous regions release internal polymer stresses by reorganizing the network of hydrogen bonds in cellulose. As a result, cellulose sheets in the cotton fibers can withstand applied loads independent of other sheets, and thus exhibit increased strength.

While the effect of varying moisture content on fiber fractures following tensile loads has been previously reported (Hearle et al, 1998), the testing conditions examined were very limited; the study compared fiber fractures for dry and wet cotton to fibers maintained at standard conditions. This current study aims to expand the reported characterization of cotton fiber fractures for conditions more commonly found in cotton processing facilities not maintained at standard conditions, since observations at these conditions would provide more practical insight. To obtain samples of cotton fiber fractures, cotton samples were subjected to stelometer testing at various environmental conditions. Stelometer testing provides the experimental advantage of providing measurements for flat bundle strength and elongation measurements. The variation of these measurements is also of commercial relevance and would follow early studies by Lawson et al. (1976)

Methods

Three cotton varieties were chosen for this study. Two of these were grown in 2005, while the remaining variety, an international cotton from Australia, was grown in 2006. An additional cotton variety, purchased from the Agricultural Marketing Service of the United States Department of Agriculture as an International Calibration Cotton Standard, was used for stelometer calibration.

All tests were performed at the SRRC-ARS-USDA. Subsamples from each cotton variety (5 g) were used to determine fiber strength and elongation, as measured with a stelometer, at three environmental conditions. Each sample was run on a stelometer following the ASTM D-1445-90 method. Five samples for each cotton variety were examined at each selected environment. Prior to measurements, cotton samples were equilibrated for at least 24 hours at the testing environmental conditions. Tests were performed at standard conditions (70 ± 2°F and 65 ± 2%

RH), at high RH (71 ± 2°F and 80 ± 2% RH), and low RH (67 ± 2°F and 50 ± 2% RH). Testing was conducted in a medium-sized atmosphere controlled glove-box (Coy laboratories; Grass Lake, Michigan, USA) that was altered to reach the desired environmental conditions and constantly monitored with calibrated devices.

Fiber fracture morphologies were determined by examining samples with a LEO Gemini scanning electron microscopy (FEI; Hillsboro, OR, USA). Broken fiber samples were mounted on a SEM stub and coated with a gold/palladium coat. Each sample was examined for changes in fracture morphology that resulted from the stelometer tensile test.

Results

Flat bundle strength measurements with a stelometer differed at the various atmospheric conditions tested (Figure 1). At a high RH (71 ± 2°F and 80 ± 2% RH) all cotton varieties exhibited increases in strength values when compared to measurements at standard conditions. Cotton I exhibited the highest strength, 28.0 g/tex; followed by cotton II and III (25.5 and 24.9 g/tex, respectively). The strength measurement for cotton II was higher at low RH (67 ± 2°F and 50 ± 2% RH) than at standard conditions (25.6 g/tex at 70 ± 2°F and 65 ± 2%RH). Strength measurements for cotton I and II at low RH were only slightly different from measurements at standard conditions. Still, measurements for these three varieties showed low reproducibility, possibly due to measurement variability due to operator error.

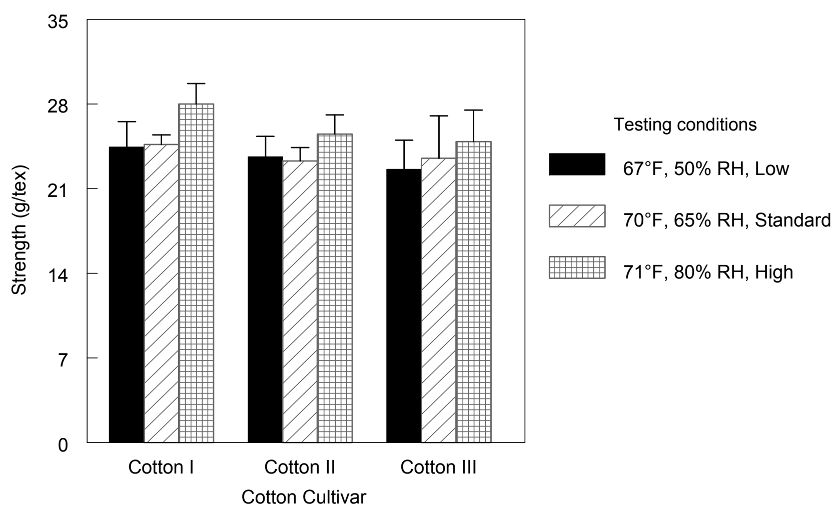

Figure 1. Strength measurements for three cotton varieties as measured with a stelometer at various atmospheric conditions.

Elongation measurements, similar to strength measurements, generally increase with greater RH levels (Figure 2). For example, cotton III, which showed the longest elongation at standard RH (5.78%), elongated 6.47% at high RH. In contrast, at low RH, cotton III elongated 5.51%. The observed trends in strength and elongation measurements might reflect variations in fiber properties produced by changes in atmospheric RH; however, further investigations that account for the moisture content of the bundles is required to develop a more complete understanding of these findings.

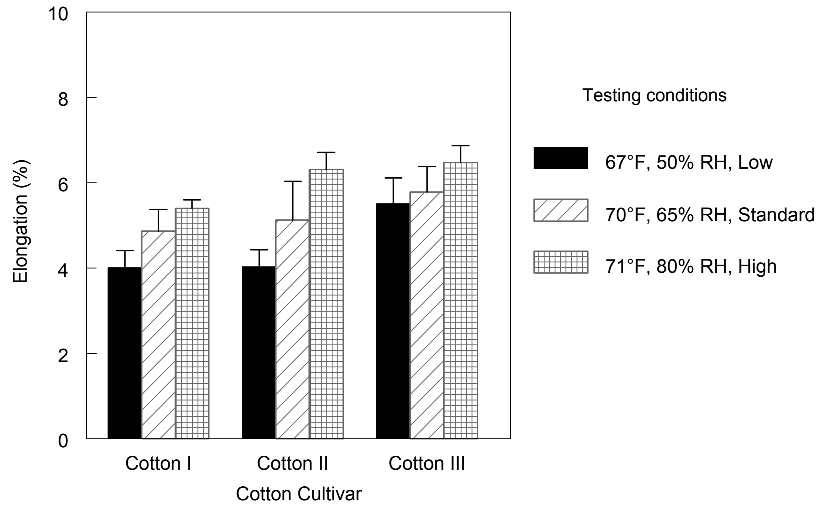

Figure 2. Stelometer elongation measurements at various atmospheric conditions.

The fracture morphology of the tested cotton fiber was affected by the testing conditions (Figure 3). Fibers broken at high RH showed a frayed morphology indicative of independent microfibril failure. At high RH, moisture in the cotton fiber disrupted microfiber interaction, which led to independent microfibril breaks for all the cotton varieties, and frayed broken fibers. In contrast, at standard conditions fiber fractures were cleaner, a reflection of a more unilateral breaking action. This simultaneous breakage of the microfibrils composing the cotton fiber suggests moderate microfibril interactions. At low RH, fiber fractures exhibited a distorted granular pattern. Notably, these fibers exhibited surface damage that extended well beyond the fracture location; an indication of the brittleness of the cotton fibers at low RH. Independent of testing conditions, differences were observed between the fractures of weak and strong fibers, with the weaker fibers often displaying thinner microfibrils.

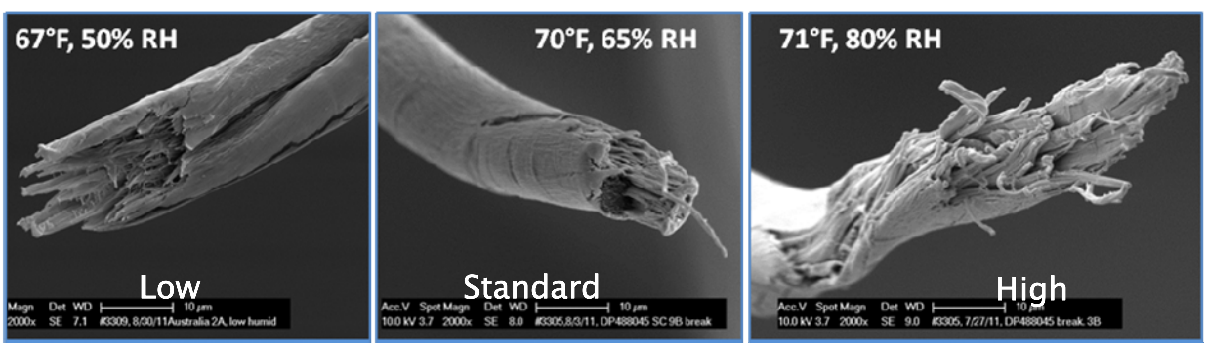

Figure 3. Fiber fracture morphology for cotton samples following stelometer tensile tests at the indicated environmental conditions.

Summary

This study sought to explore the effect of testing environment RH on cotton flat bundle strength and elongation measurements, and on fiber-fracture morphology. General trends were observed for strength and elongation measurements. Higher RH generally resulted in increased strength and elongation values. However, further investigations are required to develop a more complete understanding of the system. Electron micrographs of fiber fractures showed that fracture morphology is affected by the RH of the testing environment. In general, at higher RH, fractures of more independent microfibrils were observed. Fiber broken at 50% RH exhibited more extensive surface damage. The observed fiber fracture trends might affect the way seed cotton and cotton fibers are treated post-harvest.

Disclaimer

The use of a company or product name is solely for the purpose of providing specific information and does not imply approval or recommendation by the United States Department of Agriculture to the exclusion of others.

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