ATTACHMENT MECHANISMS BETWEEN COTTON FIBERS AND FOREIGN-MATTER PARTICLES

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Abstract

In order to develop a fundamental understanding of the requirements for removing foreign matter from bulk cotton fiber, a video microscope was used to collect images of foreign-matter particles in lint from smooth-leaf and hairy-leaf cottons. A method is given for categorizing the particles according to color, shape, size, and texture, and then relating those characteristics to the type of attachment between the particle and the surrounding fiber. Images of several particles are included, and subsequent research is discussed.

Problem Definition

Background

Lint cleaning is required at the gin so that (1) excessive amounts of trash are not delivered to the textile mill and (2) producers avoid price discounts for poor leaf grade and poor preparation. However, lint cleaning has a detrimental effect on other fiber properties, primarily in increased short fiber content and neps. Recent reports that foreign mills have begun to consider leaf grade 3 as the "base" grade could lead to increased lint cleaning at gins. Thus, it is imperative that we improve our understanding of the "physics" of fiber and trash interactions so that innovative lint cleaning approaches can be developed.

Of recent interest has been determining the basic level of force required to remove extraneous material from a batt of cotton fiber. The key issues in determining that force are (1) what types and sizes/shapes of extraneous matter to remove, (2) how to mechanically grasp them, (3) how to hold the sample of bulk lint in such a way as to have a measurement with as much repeatability as possible. In attempting to answer these questions, it was concluded that development of a test procedure would be very difficult and was premature, because understanding how extraneous particles were attached to fiber should be answered first. It is therefore important to begin to classify how the various types and sizes of pre-lint-cleaning foreign-matter particles are attached to the fiber mass.

Literature Review

U.S. Cotton is mechanically harvested and contains about 25 to 60% foreign matter, depending on the harvesting practice used (Smith, 2001). The foreign matter includes plant leaves, bract, sticks, bark, grass, motes, etc. It is desirable for as much foreign matter as possible – within fiber-damage constraints – to be removed from cotton fiber at the gin. This process involves cylinder cleaners and stick machines before fiber-seed separation to remove large particles of leaf, bract, sticks, etc. from the seed-cotton, and lint cleaners after fiber-seed separation to remove smaller particles like leaf, motes, grass, bark, etc. that remain in cotton.

A typical machinery system at U.S. cotton gins includes one or more lint cleaners, two general types of which are currently on the market, the air-type and the predominant saw-type. In the saw-type lint cleaner, lint from the gin stand or a prior lint cleaner is formed into a batt on a condenser drum and fed onto a saw-cylinder through a set of feed rollers. While the fiber batt is on the saw cylinder, it is cleaned by a combination of centrifugal force, scrubbing action between saw cylinder and grid bars, and gravity assisted by an air current (Anthony and Mayfield, 1994).

It is generally agreed that saw-type lint cleaning at gins is able to improve the grade classification of the cotton fiber and increases the market value for the farmer in the current marketing system. However, it is also widely realized that during the cleaning process the saw-type lint cleaner damages fiber in creating short fibers and neps and reducing bale weights. One stage of saw-type lint cleaning removes about 20 lbs of material that includes at least 50% good fiber (Mangialardi and Anthony, 1998). As cotton fiber quality has become more and more important on the world market, researchers have been working to find the causes of the fiber damage and to develop new methodologies and mechanical systems to reduce the damage and loss of fiber while retaining the high efficiency of the saw-type lint cleaner (Hughs et al. 1990; Rutherford et al. 2004; Anthony and Griffin, 2001; Gordon and Bagshaw, 2007). Many improvements have been made in saw-type lint cleaner manufacturing over the years, but today we still use basically the same cleaning principles that were developed in the 1940s (Baker et al. 1992).

To explore the possibility of inventing a new fiber cleaning principle that is significantly different from “saw and bar” processing, it is critical to develop a fundamental understanding of the nature of cotton lint and foreign matter and their physical and chemical interactions before and during the cleaning process. One way to do this is through visualization of foreign matter and cotton fiber and their interactions. In a study related to the textile-mill occupational disease, byssinosis, Morey et al. (1976b) used stereomicroscopy and bright-field microscopy to examine botanical composition of Shirley Analyzer waste from machined-picked and machine-stripped seed cotton. Bract content ranged from 32 to 52% of the total waste amount, and cotton-leaf and weed particles were major components. It was observed that seed cotton contained a larger proportion of bract and leaf materials than did lint before lint cleaning. Using the same methods, Morey et al. (1976a) also determined the type of trash materials present in lint before and after saw-type cleaning, and whether lint cleaning selectively removed any of the botanical components. As the size of particles decreased, the proportion by weight of bract and leaf increased, and the content of seed-coat fragments decreased. About 25% of overall botanical wastes in lint were from weeds. They found lint cleaning to be ineffective at reducing the proportion by weight of leaf particles, but heavier materials like stem particles were reduced in proportion. While the work of Morey et al. was aimed at illuminating the botanical composition of trash particles in cotton and not at the way those particles are attached to the fiber, it does indicate that much can be learned through microscopy on foreign-matter particles in cotton fiber.

Objectives

The goal of this work is to develop a fundamental understanding of how foreign-matter particles are attached to cotton fiber so that new cleaning methods might be devised. Specific objectives involved using an imaging microscope to categorize (1) foreign matter particles in lint according to color, shape, texture, and size; and (2) relationships between foreign-matter particles and surrounding fibers according to cotton type and particle category.

Materials and Equipment

Two types of machine-picked cotton were used in this study: (1) a hairy-leaf variety, Stoneville 4892; and (2) a smooth-leaf variety, Deltapine 555. Both types were ginned on the same day and in the say way in the Microgin at the USDA-ARS Cotton Ginning Laboratory at Stoneville, Mississippi. The seed cotton cleaning sequence was as follows: cylinder cleaner, stick machine, cylinder cleaner. No drying and no lint cleaning were performed. After the gin stand the fiber was collected onto a battery condenser, and the batt coming off the condenser drum was manually rolled with a roll of brown paper so that the intact batt could be unrolled later for sample collection. The two cotton rolls were shipped to the BEST (Biological Engineering Sensor Technology) Laboratory of the Biological and Agricultural Engineering Department at Texas A&M University for microscopic analyses.

The BEST lab is equipped with a Caltex Scientific LX100 digital video microscope. This microscope along with its lens adapter is capable of magnifications from 15x to 200x. It has macro and micro focus adjustments, a built-in light ring, an 8-inch video screen, and can operate at a lens-to-sample distance of 4.7 inches and angles from 0 to 35º. Software provided by the manufacturer allows for instant still-image and video capture.

Methods

The two cotton batts were unrolled in the BEST lab, and three samples of roughly 500 g were collected at random locations along the length of each roll. Then two subsamples of roughly 10 g were collected from random locations within each sample. Thus, for each cotton type, we had three samples with two subsamples for a total of 6 subsamples per cotton type.

Within each subsample microscopic still images were collected with the video microscope on 10 to 12 of the particles adhering therein. Particles were selected so as to give a reasonable representation of the entire number within the subsample. When images were collected, care was taken to ensure that each particle was in the best possible focus. After each still images was collected, a video file was captured for each particle as follows: (1) the video was started with the particle in focus; (2) the video continued as the focal plane was drawn toward the microscope lens such that the fibers between the particle and the lens came into focus; and (3) the video continued as the focal plane was drawn away from the microscope lens such that the fibers behind the particle came into focus. This video technique was employed as an aid in determining how tightly the particle was bound up in the surrounding fiber.

A table is being created for visual data collection on each particle image. The table includes particle number, color, shape, texture, size, and relationship with the surrounding fiber (Table 1). Particle-fiber relationships are being defined in terms of proximity between the particle and surrounding fiber, the quantity of fibers surrounding the particle, and the conformity of surrounding fibers to the edge of the particle. So that particles can be categorized into a reasonable number of categories, all of the categorical variables are being limited according to definable ranges of what has been seen. Color is limited to tan, red, brown, and black. Shape is limited to round, rectangular short, rectangular long, and branched. Texture is limited to smooth and shiny, smooth and dull, and rough. Size is limited to small, medium, and large. Attachment type is limited to loose, moderate, and tight. Analyses are being conducted to determine the effect of the various particle categories on attachment type.

Table 1. Categorization of particles according to morphological parameters and mode of fiber attachment.

Particle					
Number	Color	Shape	Texture	Size	Attachment Type
H1B1	Brown	Round	Smooth and Shiny	Medium	Tight
H1B2	Brown	Rectangular Short	Rough	Medium	Moderate
S1A7	Red	Rectangular short	Rough	Medium	Loose
S2A6	Tan	Rectangular long	Rough	Medium	Loose

Results

Since the video microscope was purchased on November 19, 2007, there was only enough time to complete collection of microscopic images and video files prior to the Beltwide Cotton Conference in January 2008. At this point we are still in the process of reviewing all the images to classify particle types and the video files to help classify attachment type. A few images of particles are given as a representation of the roughly 150 images collected to date (figures 1 through 4). As soon as the particle classifications are complete, the analyses to relate particle type to attachment type will be conducted.

Figure 1. Microscopic image of foreign-matter particle 1 in hairy-leaf cotton, sample 1, subsample B.

Figure 2. Microscopic image of foreign-matter particle 2 in hairy-leaf cotton, sample 1, subsample B.

Figure 3. Microscopic image of foreign-matter particle 7 in smooth-leaf cotton, sample 1, subsample A.

Figure 4. Microscopic image of foreign-matter particle 6 in smooth-leaf cotton, sample 2, subsample A.

Future Research

The effect of various machines on particle-fiber attachment will be considered in subsequent work. Five samples of seed cotton have been hand-harvested at the Texas A&M research farm in Burleson County, TX. The locations of these samples were selected in an effort to account for field variability, and a soil-EC map was used as the principal source of predicted field variability. The hand-harvested samples are being hand-ginned. At these hand-sampling locations machine-harvested seed cotton samples were also collected as the seed cotton was being blown into the picker basket. The modules made from the cotton harvested in these hand-sampled areas were ginned at Scarmardo Gin nearby, and sampling was conducted in the gin at points after seed-cotton cleaning, fiber-seed separation, and one stage of lint cleaning. There are thus five treatments for each hand-harvest field location, for a total of 25 samples. Each sample will be subsampled to allow multiple photographs of particle-fiber attachment to be taken for each sample. In addition to the photographs, HVI and AFIS data will be collected on the samples in an effort to relate known measured quantities associated with fiber damage to the types and frequencies of particle-fiber attachment seen in the photographs.

References

Anthony, W. S., and W. D. Mayfield, eds. 1994. Cotton Ginners Handbook, rev. Agricultural Handbook 503, pp. 102-104. Washington, D.C.: U.S. Dept. of Agriculture.

Anthony, W. S., and A. C. Griffin. 2001. Fiber breakage at cotton gins: causes and solutions. In *Proc. Beltwide Cotton Conf.* 1347-1357. Memphis, Tenn.: Nat. Cotton Council Am.

Baker, R.V., S. E. Hughs, and G. J. Mangialardi. 1992. Lint cleaning: basic principles and new developments. In *Proc. Beltwide Cotton Conf.* 539-542. Memphis, Tenn.: Nat. Cotton Council Am.

Smith, D. T. 2001. Cotton gin by-product use in beef cattle and dairy cow diets. Soil & Crop Sci. Dept. Technical Report 01-08. College Station, Tex.: Texas A&M University.

Gordon, S. G., and K. M. Bagshaw. 2007. The effect of working elements in the fixed batt saw lint cleaner on ginned fiber properties. In *Proc. Beltwide Cotton Conf.* 1977-1982. Memphis, Tenn.: Nat. Cotton Council Am.

Hughs, S. E., M. N. Gillum, C. K. Bragg, and W. F. Lalor. 1990. Fiber and yarn quality from coupled lint cleaner. *Trans. ASAE* 33(6):1806-1810.

Mangialardi, G. J., and W. S. Anthony. 1998. Field evaluation of air and saw lint cleaning systems. *J. Cotton Sci.* 2(1):53-61.

Morey, P. R., R. M. Bethea, P. J. Wakelyn, I. W. Kirk, and M. T. Kopetzky. 1976a. Botanical trash present in cotton before and after saw-type lint cleaning. *Am. Ind. Hyg. Assoc. J.* 37(6):321-328.

Morey, P. R., P. E. Sasser, R. M. Bethea, and M. T. Kopetzky. 1976b. Variation in trash composition in raw cottons. *Am. Ind. Hyg. Assoc. J.* 37(7):407-412.

Rutherford, R. D., D. W. Van Doorn, and J. W. Thomas. 2004. Fiber quality characteristics of conventional controlled-batt versus non-conventional flow-through saw-type lint cleaners. In *Proc. Beltwide Cotton Conf.* 948-952. Memphis, Tenn.: Nat. Cotton Council Am.