TRASH PARTICLE ATTACHMENT TO FIBER AND THE EFFECTS OF VARIOUS MACHINE-FIBER INTERACTIONS

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Abstract

U.S. cotton is at a competitive disadvantage from a fiber-quality standpoint, because lint cleaning is required for mechanically harvested cotton, and lint cleaning causes fiber damage. Lint-cleaning research has focused mainly on modifying saw-type lint cleaners, but the work reported here focuses on the physics of cleaning foreign matter from cotton. Individual particles were examined under a microscope, and the observations made and data collected indicate that (1) cotton fibers adhere to foreign-matter particles by becoming restricted in cracks at fractured particle edges, and (2) all instances of machine processing of cotton from harvesting through ginning tend to increase the tightness of fiber-particle attachment.

Introduction

U.S. cotton is mechanically harvested – unlike cotton produced in many other parts of the world – so it must be subjected to at least one stage of lint cleaning to reduce its foreign-matter content to a marketable level. Since lint cleaning is damaging to fibers – in terms of increasing the numbers of both short fibers and neps – U.S. cotton is at a disadvantage on the world market because of quality issues.

A common view among experts is that every instance of machine interaction with cotton fiber increases short-fiber content or nep content or both. Since lint cleaners (1) have several aggressive interaction points and (2) are known to cause more fiber damage than any other gin machine besides the gin stand, mechanical improvements to the traditional saw-cylinder type lint cleaner have been researched. Even though many improvements have been made in saw-type lint cleaners over the years, today we still use basically the same cleaning principles that were developed in the 1940s (Baker et al., 1992). Some recent research has focused on developing completely new methods for cleaning lint cotton. One of these efforts has approached the problem from two angles: (1) modeling the physics to determine the effects that current saw-type lint cleaners have on cotton fiber (Thomasson et al., 2006, 2007), and (2) determining the fundamental requirements for removing foreign-matter particles from cotton fiber (Thomasson et al., 2008). Since the literature does not speak to how cotton fibers are attached to particles of extraneous matter, this report expands on that of Thomasson et al. (2008) and considers how each stage of machine processing – from harvesting through ginning – affects fiber-particle attachment.

The objectives of this work were four-fold: (1) to determine fundamental characteristics of fiber-particle attachment; (2) to consider effects of various machine interactions on particle type and size, on fiber-particle attachment, and on fiber damage; (3) to consider effects of various particle types on fiber-particle attachment; and (4) to propose new methods to clean cotton that reduce fiber damage.

Materials and Methods

In 2007 a crop of cotton was grown in a field at Texas A&M University's IMPACT Center research farm near College Station, TX. Samples of seed cotton were hand-harvested at five locations expected to account for field variability, with a soil-EC map being used as the principal source of predicted field variability. The hand-harvested samples were hand-ginned, representing fiber prior to machine interaction. At the hand-sampling locations, machine-harvested seed cotton was also collected by hand as it was being blown into the picker basket. These samples were also hand-ginned, and they represent fiber that has undergone interaction with the harvester only. The modules made from the cotton harvested in the same field locations were ginned at a nearby commercial gin. Samples that were collected at the feeder apron were also hand-ginned, and they represent fiber that has undergone interaction with the harvester and seed-cotton-cleaning equipment in the gin. Samples were also collected immediately after fiber-seed separation, and they represent fiber that has undergone interaction with the harvester, the seed-cotton-cleaning equipment in the gin, and the gin stand. Samples were also collected after one stage of lint cleaning, and they represent fiber that has undergone interaction with the harvester, the seed-cotton-cleaning equipment in the gin, the gin stand, and one lint cleaner. There were thus five treatments for each of the five hand-harvest field locations, and three replicate samples were collected, for a total of 75 samples.

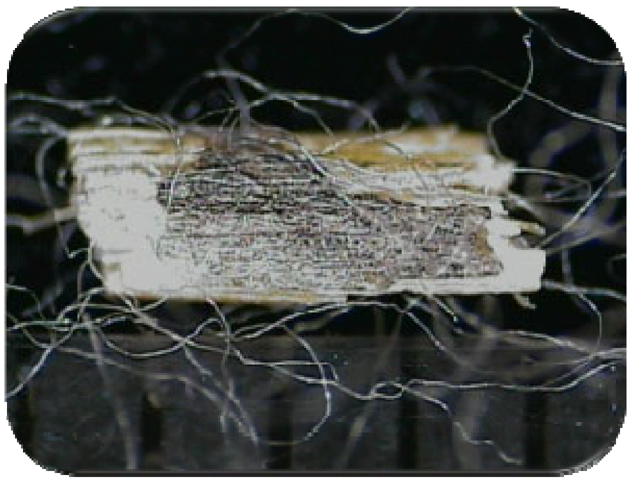
For each sample, the subsampling procedure involved removing a randomly selected portion of lint weighing 1.0 to 2.5 g. The subsamples were placed under a Caltex Scientific LX100 digital video microscope. Forty-five randomly selected foreign-matter particles were manually removed with delicate tweezers from each lint subsample, and particular attention was paid to minimizing the number of fibers removed with the particle. Observations were also made about how foreign-matter particles were attached to the fibers. Each particle was identified as belonging to one of 7 categories: leaf, bark, stick, shale, funiculi, seed-coat fragment, or other. Each particle was assigned a two-dimensional shape that best described it: rectangular, triangular, or round. Each particle was also measured for length in two dimensions. While being removed, each particle was subjectively assigned to a category in strength of attachment (low to high, 1 through five, respectively) and number of fibers attached (low to high, 1 through 3, respectively). After the 45 particles were removed, all remaining visible particles were carefully removed, and then the mass of all foreign-matter particles was measured. To date, sampling has been completed for 1 subsample from each treatment. Statistical analysis involved calculating averages of particle measurements for each treatment.

Results and Discussion

Results are discussed in terms of the four objectives. First, in terms of determining fundamental characteristics of fiber-particle attachment, one key observation was made: as a general rule, cotton fibers were attached to foreign-matter particles by being stuck in cracks at fractured edges of the particles. Thus, the primary mode of attachment is mechanical, fibers constricted in cracks or appendages protruding from fractured particle edges. This fact was largely true across the breadth of particle types, sizes, and shapes. Figure 1 gives a fairly clear indication of fiber attachment at particle edges. Figure 2 clearly shows fibers' having been pulled into a crack along the spine of a leaf. These figures typify observations across 225 particles of various types.

(a)

(b)



(c)

Figure 1. Microscopic photos of cotton fibers attached at fractured edges of particles of (a) leaf, (b) bark, and (c) stick. The scale in each photo has 1-mm increments.

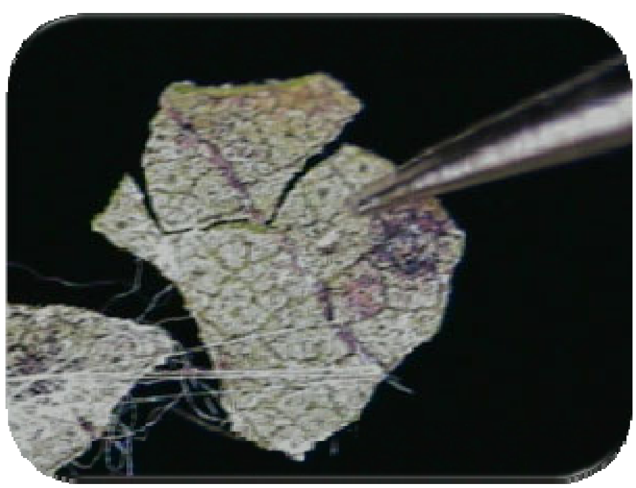


Figure 2. Microscopic photo of leaf particle with cotton fibers attached by being stuck in crack along spine of leaf.

Second, in terms of considering the effects of various machine interactions on particle type and size, fiber-particle attachment, and fiber damage, efforts to date have focused on the effects of machine interactions on fiber-particle attachment. Table 1 indicates that particle tightness of attachment tends to increase with an increasing number of machine interactions, except with respect to the gin stand. Confounded in the data is the fact that particles are removed at each stage, so it is unknown how much of the effect is due to tightening and how much is due to the removal of loosely attached particles. It can also be seen in Table 1 that the number of fibers attached to each particle was predominantly low before machine interactions took place and became increasingly higher as the number of machine interactions increased. Again, it is not known what contribution is attributable to the removal of particles with low numbers of fibers attached.

Table 1. Data on trash content, particle tightness, and number of fibers attached to particles by treatment (HH = hand-harvested; MH = machine-harvested and hand ginned; MSH = machine-harvested, seed-cotton-cleaned, and hand-ginned; MSM = machine-harvested, seed-cotton-cleaned, and machine-ginned; and MSML = machine-harvested, seed-cotton-cleaned, machine-ginned, and lint-cleaned).

Treatment	Trash	Tightness	# Attached Fibers		
	by mass	(1 to 5)	Low	Med	High
HH	1.50%	2.36	49%	29%	22%
MH	10.80%	2.84	20%	44%	36%
MSH	6.00%	3.58	9%	27%	64%
MSM	3.00%	2.62	7%	38%	56%
MSML	1.10%	3.84	7%	20%	73%

Third, consideration of the effects of various particle types on fiber-particle attachment remains to be done. Fourth and finally, the results from this portion of the study do not yet lend themselves to proposal of new methods to clean cotton that reduce fiber damage. However, the earlier modeling work has suggested that minimization of friction is a potentially practical method that might be applied in lint cleaning to reduce damage. This idea relates to the fact that the physical action that removes foreign matter in a lint cleaner is a force of momentum that exceeds the fiber-particle attachment force. If this force of momentum is maintained by keeping rotational velocities consistent with current machines, the cleaning force can be maintained and the stress imparted to fibers by stretching due to this force will be maintained. However, the shear stress imparted to the fiber as it contacts machine surfaces (e.g., grid bars) may be reduced by various means such as lubrication, low-friction materials on machine surfaces, and modification of machine-surface shapes.

Summary

Two primary conclusions were reached from the observations made and data collected and analyzed in this work: (1) the primary means of fiber-particle attachment is mechanical restriction of the fiber in cracks at fractured particle edges; and (2) the foreign-matter particles remaining in the lint after each stage of machine interaction are more tightly attached, both in terms of the force required to remove them and in terms of the number of fibers attached to them.

References

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.

Thomasson, J. A., J. D. Wanjura, R. Sui, and W. B. Faulkner. 2006. Lint cleaning improvement through first principles. ASABE Paper No. 061022. St. Joseph, Mich.: ASABE.

Thomasson, J. A., R. Sui, and P. Popov. 2007. Modeling cotton fiber dynamics in a lint cleaner. In Proc. Beltwide Cotton Conf. Memphis, Tenn.: Nat. Cotton Council Am.

Thomasson, J. A., R. Sui, R. K. Byler, and E. M. Barnes. 2008. Attachment mechanisms between cotton fibers and foreign-matter particles. Beltwide Cotton Conf. Memphis, Tenn.: Nat. Cotton Council Am.