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TRASH IDENTIFICATION AT THE CARD

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Abstract

Trash removal is required during processing for improved textile-processing efficiency. Cotton trash has often been a leading cause of ends-down during spinning. Trash arises from various plant sources and field contamination. To combat trash and efficiency problems textile mills often specify cotton bales, which they acquire, should have a leaf classification no higher than 3 for processing on their Airjet or Vortex Spinning systems. In processing, the card is an excellent location to optimize cotton cleaning due to thin webs of cotton fibers. This study involved a mill running a 40 bale laydown from which samples were taken at 8 separate cleaning points on a card on the same cleaning line running a (50/50) cotton/polyester blend. This research evaluated several measurement techniques to characterize trash particles at numerous cleaning points on 5 different modern cards. This study compared the weight, size, and distribution of particles at 8 cleaning points. Further work is needed to determine the effect of cotton trash removal at these 8 cleaning points on high speed textile spinning.

Introduction

All cotton contains trash, dust, and other impurities. One cotton bale contains approximately 60 billion fibers (Steadman, 1997) and unidentified levels of trash and dust particles. Cotton contamination including large trash and small pepper trash is commonly referred to as visible foreign matter (VFM). Ultimately, textile processing is influenced by trash components found in all cotton bales. Cottons and their trash components are diverse in nature and respond differently to textile cleaning and further processing. The type and amount of trash, fiber-to-trash adhesion, and how well its behavior mimics a fiber determines the ease of trash removal and process spinning efficiency. It is common practice for textile mills to process cotton on several pieces of opening and cleaning equipment. Prior to spinning, the carding machine is the final opening and cleaning machine. At the card, trash extraction depends on the intensity of opening prior to carding (Szaloki, 1977). Cards have changed very little over the years with textile mill owners often stating that “the card is the heart of the spinning mill” (Szaloki, 1977).

The card is perhaps the single most important piece of textile processing equipment that influences spinning. Over the years, card productivity has improved with carding progressing from 4 lb/hr (Szaloki, 1977) to today’s cards, which operate at 200 lb/hr (Anonymous, 2004). The practical production rate for any card depends upon the material processed, sliver weight, and yarn quality (Szaloki, 1977). The purpose of carding is to 1.) separate fiber tufts into individual fibers, 2.) partly align the fibers in the longitudinal direction and uniformly distribute them over the cylinder’s surface, 3.) remove contamination from within the fiber tufts, 4.) intimately blend fibers, 5.) to open and remove neps, 6.) reassemble the fibers into a sliver, and 7.) coil the sliver into a can for spinning (Institute of Textile Technology, 2000).

Throughout carding, well opened fibers are presented to the “licker-in” of the card as a uniform mass. Fibers are passed over a series of grid bars to remove trash and deposit the fibers onto the main card cylinder. The main cylinder’s surface speed is higher so that the fibers are stripped off the “licker-in”. Longer fibers are attracted to the main cylinder covered with the fine wire. This wire individually separates the fibers forming a loose network of fibers. The main cylinder passes these fibers beneath another set of fine wire affixed to steel bars called “flats”. These “flats” have a much slower surface speed than the fast rotating cylinder. The wire on the flats along with the close settings to the card cylinder help open tufts, orient fibers, and remove short fibers, neps, dust, and trash (Institute of Textile Technology, 2000). The point where the “licker-in” meets the feed roll and where fibers are separated is where the majority of cleaning occurs through mechanical, gravitational, centrifugal, and pneumatic forces (Harrison, 1992). Cleaned fibers are removed from the main cylinder by a smaller slower surface speed wire covered cylinder called a “doffer”. The “doffer” cylinder condenses the fiber web and disorients fibers for web stability. These fibers are condensed and removed to form a “sliver” for drawing and spinning.

The card works independently of speed and trash extraction of the card depends upon the intensity of opening (Szaloki, 1977) but little is known about trash extracted by cleaning points on the card. Cotton contains trash with conflicting issues such as leaf vs. seed coat, size vs. type, and size vs. distribution. Standardized techniques exist to analyze trash in cotton lint because trash affects processing and utilization. Trash particles can be difficult to locate, measure, and describe since they arise from many components and can be irregularly sized, erratically positioned, partly covered by cotton fibers, or light colored in nature. ITMF has defined the following particle size ranges; respirable dust 0-15 µ (0-0.0006 in), micro-dust 15-50 µ (0-0.002 in), dust <500 µ (<0.02 in), and trash >500 µ (>0.02 in) (Farber et al., 1990). The objective and nondestructive High Volume Instrument (HVI™) provides a rapid trash measurement at a low cost using a scanning video camera at one set of conditions. Recent HVI™ software developments are able to rapidly quantify cotton trash and provide a particle frequency distribution (Ghorashi, 2000). Advanced fiber information system (AFIS™) (Uster Technologies Inc., Knoxville, TN) is a destructive method (Bragg and Shofner, 1993) that mechanically opens fibers and separates trash for electro-optical measurement thus producing a trash and dust particle size distribution. The micro-dust and trash monitor (MTM™) (Uster Technologies Inc., Knoxville, TN) provides destructive trash measurement using aeromechanical processes. The MTM™ classifies it as 1. trash, 2. micro-dust, or 3. fiber fragments, and reports its weights as percentages of lint, which can be collectively sieved through standard testing sieves thus obtaining particle size distributions.

As processing speeds increase, high-speed spinning machinery is less tolerant of short fiber, trash, and dust so continued improvements in the cotton card are desirable. New processing techniques and/or instruments are necessary to provide rapid, consistent, and quantitative cotton fiber and trash results. The goal is to understand the type of trash and fiber removed from diverse cleaning points on a card.

Materials and Methods

Cotton

Sample bales were all harvested, ginned, and baled by commercial methods and selected by Hamrick Mills because of their narrow range of leaf grade officially determined by USDA AMS. To combat trash and efficiency problems, Hamrick Mills specifies cotton bales that they purchase should be no higher than a 3 leaf for processing on their Murata Airjet Spinner (MJS) or Murata Vortex Spinner (MVS) (Murata Machinery USA, Inc., Charlotte, NC). This is based on their past efforts where they experience processing problems during weaving with excessive loom stops.

Textile Processing

A forty-bale laydown was analyzed from the Hamrick Mills Musgrove plant in Gaffney, South Carolina. This laydown contained twenty bales of cotton purchased according to their specifications (no greater than a 3 leaf grade). The remaining twenty bales of the laydown consisted of polyester fibers, which typically have high strength and are resistant to shrinking and stretching. Natural and synthetic fibers were processed to form a blend of 50/50 cotton/polyester yarn.

This cotton and polyester blend was removed from a 40-bale laydown for processing using a Truetzschler BDT 019 Top Feeder (American Truetzschler Inc., Charlotte, NC). All fiber was processed through the following sequence: Truetzschler LVSA condenser fan (American Truetzschler Inc., Charlotte, NC), Truetzschler MPM10 (ten cell mixer) (American Truetzschler Inc., Charlotte, NC), Truetzschler Maxi-Flo (American Truetzschler Inc., Charlotte, NC), Truetzschler CVT1 (American Truetzschler Inc., Charlotte, NC), Truetzschler Dustek (American Truetzschler Inc., Charlotte, NC), Truetzschler condenser fan (American Truetzschler Inc., Charlotte, NC), Truetzschler MPM4 mixer (4 cell mixer) (American Truetzschler Inc., Charlotte, NC), Truetzschler MS reserve (American Truetzschler Inc., Charlotte, NC), and Truetzschler 803 card (American Truetzschler Inc., Charlotte, NC). Fiber was processed through the card to produce a 60-grain sliver at 140 lbs/hour.

Five separate cards on the same cleaning line were used for card waste sample collection. Prior to testing, all Truetzschler 803 cards were positioned with the same settings to run the same sliver weight. Eight discharge points for waste samples were identified on the Truetzschler 803 card. During processing, waste samples were collected using a blow room waste collector (BR-WC) (American Truetzschler Inc., Charlotte, NC) at the following locations: 1.) licker-in 1, 2.) licker-in 2, 3.) licker-in 3, 4.) flats, 5.) back hood, 6.) top front hood, 7.) front bottom hood, and 8.) take-off roll . Waste samples removed at these 8 locations (figure 1) were stored for additional testing.

Cotton testing

To evaluate the new and improved High Volume Instrumentation (HVI™) (Uster Technologies Inc., Knoxville, TN) Trashmeter, cotton quality trash measurements were performed on a HVI™ 900A (Zellweger Uster, Knoxville, TN) by the Testing Laboratory at Cotton Quality Research Station (CQRS). The viewing area of the HVI™ in this study was 3.14 in^2 with one square inch approximately equal to 14,363 pixels. The HVI™ Trashmeter camera has a sensing array of 510 by 480 pixels with a resolution of 484 by 464 pixels with every other line used. The Trashmeter ignores trash particles less than 2 pixels in area for noise reduction with the software calculating the total trash, percent of viewed area, and trash particle distribution. The smallest viewable trash accepted by this software is 0.013 inch. The Trashmeter allows cotton to be evaluated for the number of trash particles per various classes of trash size, distribution of trash particles, average particle size, and sum of trash particles. Trash particle size distributions were obtained for all cotton samples.

Advanced fiber information system (AFIS™) (Uster Technologies Inc., Knoxville, TN) is a destructive method that aeromechanically opens fibers and separates trash and dust for electro-optical measurement thus producing a trash particle size distribution. In addition to dust and trash, the AFIS™ also analyzes neps, fiber length, and fiber maturity. These AFIS™ measurements were obtained for all cotton samples.

Aeromechanical processes were used by the micro-dust and trash monitor (MTM™) (Uster Technologies Inc., Knoxville, TN) to quantitatively determine foreign matter in fiber waste samples (Shofner and Williams, 1986). The Shirley analyzer deposits excessive lint in the trash (Montalvo and Mangialardi, 1983) and does not collect dust so the MTM was utilized to collect dust and remove as much trash from the lint with minimum lint in trash. The MTM separates foreign matter, classifies it as 1. trash, 2. micro-dust, or 3. fiber fragments, and reports its weights as percentages of lint. Quantitative trash, micro-dust, and fiber fragment categorizations were obtained for all cotton samples.

The cotton trash, micro-dust, and fiber fragments separated and collected on the MTM filters were collectively sieved through a series of stainless steel USA Standard Testing Sieves (2 in deep, 8 in diameter). These sieves contained wire mesh with a size of 18, 35, and 60 and respective mesh openings of 0.0394 in (1.0 mm), 0.0197 in (0.5 mm), and 0.0098 in (0.25 mm). The smallest cotton trash particles that passed through all mesh openings fell into a collection pan in series. MTM filter contents (fiber and trash) were emptied onto the sieves and manually opened for an additional 15 min due to fiber and trash adhesion. Sieves containing the fiber and trash were shaken for 5 min to produce the card waste particle size distributions.

The properties and mean data were statistically analyzed with the MEANS procedure in SAS to compute descriptive statistics for variables across all observations (SAS Institute Inc., 1985).

Results and Discussion

HVI™ 900A Trashmeter software is able to estimate the size of each particle counted consequently creating a trash frequency distribution (Foulk et al., 2003). Trashmeter software was used to analyze trash at 8 separate cleaning points on five identical cards. Trash classification was performed using the new HVI™ Trashmeter software and referred to as 1 (<5 pixels), 2 (>5<10 pixels), 3 (>10<15 pixels), in 5 pixel increments until category 21 (>100<200 pixels), 22 (>200<300 pixels), 23 (>300<400 pixels), 24 (>400<500 pixels), and 25 (>500 pixels). AFIS™ aeromechanically opens fibers and separates trash and dust for electro-optical measurement thus producing trash particle size distribution. Generated trash classification results were compiled for all cards at each sampling location. HVI™ Trashmeter and AFIS™ data results demonstrated an exponential decay of trash particles with many small particles decreasing to a few large particles (see Figures 2-3).

Aware that AFIS™ and HVI™ trash particle size distributions were exponential, LIFEREG a standard SAS procedure for parametric survival analysis was used for card cleaning point assessment (SAS Institute Inc., 1985). Raw trash particle sizes, rather than trash classification results, within each card cleaning point in the cards were compared using SAS LIFEREG. SAS LIFEREG is a procedure that fits parametric models to the trash particle size data and conducts a statistical test to determine whether the distributions are the same. Trash particle size distribution data were fitted to a Weibull model using Weibull regression. Individual cotton cleaning points in a card were the independent variable and trash particle size was the dependent variable. Analysis of raw trash histogram data (visibly the shape of survival data) involves two main functions that are inter-related: the hazard function and the survival function (Kleinbaum, 1997). The hazard function h(t) provides the instantaneous potential of an individual to undergo the event of interest given survival until time t (determines the shape of the distribution). The survival function S(t) gives the probability of survival for longer than time t (overall survival time). There exists a mathematical relationship between these two functions because a high probability of survival corresponds to a low probability of undergoing the event of interest (Kleinbaum, 1997).

HVI™ and AFIS™ results generated using LIFEREG were used to determine equation coefficients and p-values for each card cleaning point. The p-values indicate which card cleaning locations are different than the remainder of the card cleaning points that form the equation's baseline. Evaluation of the card cleaning locations with the new HVI™ Trashmeter software, demonstrates that card cleaning points in this study were all significantly different ($P<0.05$ level). These results appear to demonstrate that there is a significant difference in trash particle size distributions between the 8 card cleaning points. Evaluation of the card cleaning locations by AFIS™ , further demonstrates that card cleaning points in this study were all significantly different ($P<0.05$ level). Corresponding to the HVI™ results, AFIS™ demonstrated that trash particle size distributions statistically varied between the 8 card cleaning points. All cotton had an official leaf grade of 3 with different trash size distributions removed at each cleaning point in the card.

The HVI™ instrument is a non-destructive method that optically scans the surface of cotton samples to separate trash particles from the lint. Samples do not require mechanically opening that would likely break trash particles. HVI™ Trashmeter software (Table 1) demonstrated that the mean size of trash at each cleaning location varied from 415 µm at the front bottom hood to 763 µm at licker-in 3 while the total trash area respectively varied from 0.7 cm^2 to 12.7 cm^2. Top four mean trash sizes were as follows: licker-in 3 (763 µm), back hood (614 µm), licker-in 2 (590 µm), and licker-in 1 (542 µm). As expected for a consecutive card cleaning system, trash mean size and total trash area extracted at the 8 cleaning points generally decreased with continued cleaning. Licker-in 3 mean trash size and total trash area were statistically larger than all cleaning locations. Although not statistically different ($P<0.05$ level) than licker-in 2 the back hood removed trash with a larger mean size and total area than all cleaning points except the first cleaning point in the card. Total trash area for cleaning points demonstrated a sequential decrease in total trash area with the exception of the back hood. Top four total trash areas were as follows: licker-in 3 (12.7 cm^2), back hood (8.9 cm^2), licker-in 2 (7.8 cm^2), and licker-in 1 (5.6 cm^2).

Most trash particles are fragile and can be easily broken in processing. The AFIS™ instrument is a destructive process that aeromechanically opens fibers and separates trash and dust for electro-optical measurement. AFIS™ carding action may allow it to find trash particles that the HVI™ has difficulty locating and measuring. Smaller dust particles and larger trash particles were found in the first cleaning steps in the card (Table 2). AFIS™ software demonstrated that the mean size of total particles at each cleaning location varied from 300 µm at the take off roll to 457 µm at back hood. Top four mean trash sizes were as follows: back hood (457 µm), flats (424 µm), licker-in 3 (417 µm), and licker-in 2 (366 µm). Licker-in 3, back hood, and flats statistically all had the same mean trash size ($P<0.05$ level). Licker-in 2, licker-in 1, and front bottom hood statistically all had the same mean size ($P<0.05$ level). Regardless of method, the front bottom hood and take-off roll contained the significantly smallest particles ($P<0.05$ level). AFIS™ mean total particle size results did not demonstrate the same general trends by location as the HVI™. Trash count per gram ranged from 2063 for the back hood to 181 for the take off roll. Top four trash counts per gram were as follows: back hood (2063), front top hood (1409), licker-in 3 (964), and flats (836). The card appears to be removing different amounts of trash by carding location and with removal rates possibly related to opening efficiency of card cleaning points.

AFIS™ measures dust as well as trash and the highest level of dust per gram was collected by the front top hood (7476) with the lowest collected at the take off roll (902). Throughout carding the fibers are continually opened and further separated from the trash and dust hence increasing the surface area of the material and allowing additional dust (previously entrapped within fiber bundles) to be removed from the fine web. The top four dust count per gram locations were as follows: front top hood (7476), back hood (3995), front bottom hood (3701), and licker-in 2 (3294). Statistically ($P<0.05$ level) the back hood produced higher levels of trash at the back hood while statistically higher levels of dust were found at the front top hood. Twenty-eight percent of all trash particles were removed by the back hood while 19 % of trash particles were removed by the front top hood. Twenty-eight percent of all dust particles were removed by the front top hood while 15 % of dust particles was removed by the back hood. Combining trash and dust results allows the AFIS™ to provide a total count per gram with the top four as follows: front top hood (8886), back hood (6057), licker-in 2 (4128), and front bottom hood (4119). AFIS™ also provides a prediction for the trash and dust gravimetric weight percentage (VFM %) based on number and size of trash and dust particles ranging from back hood (30.22%) to take off roll (2.66%). Top four VFM were as follows: back hood (30.2%), licker-in 3 (23.2%), front top hood (21.1%), and licker-in 2 (15.0%). The back hood contains the majority of larger particles and dust since it trails the transfer of fibers from the licker-in 1 to the cylinder, which is where the majority of cleaning occurs (Harrison, 1992).

AFIS™ was originally developed for fiber length measurements such as length and fineness. AFIS™ (Table 3) demonstrated that the mean fiber length (weight basis) at each cleaning location varied from the flats (1.02 in) to front bottom hood (0.67 in). Flats and licker-in 1 removed fibers with the longest mean length (weight basis), which were significantly longer than fiber removed by licker-in 2. Top four mean fiber lengths collected at cleaning points during processing were as follows: flats (1.02 in), licker-in 1 (1.00 in), licker-in 2 (0.93 in), and licker-in 3 (0.88 in). Licker-in 1, licker-in 2, flats, and licker-in 3 removed fibers with the longest upper quartile length (weight basis). These cleaning locations are excellent at separating trash particles from the lint however they are removing long fibers. Top four fiber upper quartile lengths collected at cleaning points during processing were as follows: licker-in 1 (1.35 in), licker-in 2 (1.34 in), flats (1.34 in), and licker-in 3 (1.25 in). Mean fiber length and upper quartile length varied with fibers removed later generally having reduced lengths perhaps due to fiber individualization via carding and increased processing. Related to mean fiber length and upper quartile length top four short fiber contents (weight basis) were as follows: front bottom hood (41.8%), front top hood (38.3%), take off roll (35.3%), and licker-in 3 (25.7%). Through processing, a higher percentage of short fibers exist in the later stages of processing (examples include: front top hood, front bottom hood, and take-off roll). Fibers removed by these cleaning points have been passed through multi-step mechanical opening and carding action, which decreases fiber length. Fiber removed later in processing typically contained higher amounts of short fibers with a lower maturity index.

MTM determines the total foreign matter in lint and divides this foreign matter into trash, microdust, and fiber fragments (Table 4). Total foreign matter and trash in foreign matter produced results similar to AFIS™ and HVI™ with back hood and licker-in 3 significantly larger (P<0.05 level) than other cleaning locations. Total foreign matter ranged from 52.6% at the back hood to 8.2% at the front bottom hood. The top four total foreign matter locations were as follows: back hood (52.6%), licker-in 3 (46.2%), front top hood (23.4%), and licker-in 2 (22.4%). Trash in the visible foreign matter ranged from 45.5% at the back hood to 2.7% at the take-off roll. Top four trash locations were the back hood (45.4%), licker-in 3 (42.7%), licker-in 2 (17.3%), and front top hood (15.6%). The highest intensity of microdust was collected by the licker-in 2 (0.55%) with the lowest collected at the licker-in 3 (0.10%). Top four microdust locations were as follows: licker-in 2 (0.55%), front top hood (0.46%), takeoff roll (0.40%), and front bottom hood (0.34%). The significantly lowest levels (P<0.05 level) of microdust were located at the licker-in 3 the card's first cleaning stage while the significantly highest levels of fiber fragments (P<0.05 level) were located at the take-off roll the final cleaning stage in the card.

Trash collected via MTM filters were sieved through a series of stainless steel USA Standard Testing Sieves (Table 5). Rather than an actual number of trash particles, these results were based on the weight of the total number of trash particles sieved. These results demonstrated an exponential decay of trash particle categories with the weight percentage of large particles decreasing to a lesser weight percentage of smaller particles (Figure 4). As with textile processing, fiber-to-trash adhesion affected the ease of trash removal with some lint (1/8 in and shorter) remaining attached to trash and collected in the largest sieve. Percent trash in sieve 18 ranged from 31.5% collected from licker-in 3 to 5.2% collected from the front bottom hood. Licker-in 3 significantly (P<0.05 level) contained the largest amount of trash and attached lint followed by the back hood, which agrees with the HVI™ and AFIS™ results. The largest weight percent trash in sieve 35 ranged from 16.8% collected from back hood to 0.77% collected from the front bottom hood. Sieve 35 significantly (P<0.05 level) contained the largest trash weight percentage for waste collected by the back hood followed by the licker-in 3 and licker-in 2. Percent trash in sieve 60 ranged from 6.2% collected from back hood to 1.1% collected from the flats. Thru processing the trash particles have gradually been reduced in size demonstrated by the larger amount of finer trash particles found in front top hood. Percent trash in fines ranged from 1.6% collected from front top hood to 0.26% collected from the flats. The back hood and front top hood contained the highest weight percentage of trash particles collected in sieve 60 and fines. These results identify that while the particle count histogram decreases from many small particles to a few large particles the weight percentage of these few larger particles outweigh the many small particles.

Recognizing that the eight cleaning points on the card have assorted trash removal techniques intuitively indicates that the trash sizes and distributions will vary by location. HVI™ and AFIS™ results generated using LIFEREG demonstrates that card cleaning points in this study were all significantly different (P<0.05 level). The eight cleaning points on these cards appear to have different trash particle size distributions indicating that particle size distributions vary by cleaning location. Cotton fibers and trash are concurrently processed and instinctively one speculates that the fibers and trash to be involuntarily broken down into smaller fractions. This study indicates that the HVI™ mean size of trash particles and total trash area are statistically largest for licker-in 3 and significantly different than licker-in 2 and the back hood. AFIS™ results are on a lower level due to the additional carding action of the instrument but nonetheless indicate that the back hood, flats, and licker-in 3 statistically contain the largest sized particles followed by licker-in 2, licker-in 1, and front top hood, with no differences in the means. HVI™ and AFIS™ confirm that trash sizes vary by location within a card.

Coupled with these size results AFIS™ indicates the largest count of trash particles was collected from the back hood followed by the front top hood. AFIS™ indicates the largest count of dust was collected from the front top hood and significantly different than the back hood, front bottom hood, and licker-in 2. Visible foreign matter results from the AFIS™ indicate that the back hood contains the highest level of foreign matter and significantly different than the licker-in 3 and front top hood. Optoelectronic results from AFIS™ and HVI™ were confirmed using MTM quantitative categorization indicating that total foreign matter collected from the back hood and licker-in 3 were significantly heavier than front top hood, licker-in 2, licker-in 1, take-off roll, and flats. These results were further confirmed from sieve results where more particles (weight basis) were removed by the licker-in 3 and significantly heavier than the back hood. MTM, HVI™, and AFIS™ indicate that trash particles are reduced in size through processing.

Textile equipment has become less tolerant of short fibers, trash, and dust with increases in processing speed. Results indicate that card cleaning locations within the card remove trash particles of different sizes and different size distributions and in addition varying levels of dust and short fiber. These different trash particle sizes and distributions may be able to provide additional information to improve card cleaning. These preliminary results may allow textile mills to better understand the type of trash distributions causing processing problems. In other words, more trash particle distribution information may help explain the impact of trash on high speed processing.

Disclaimer

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Table 1. Summary of HVI™ Trashmeter results from eight cleaning points on five separate cards*

	Mean trash size (µm)	Total trash area (cm^2)
licker-in 3	763 a	12.7 a
licker-in 2	590 b	7.8 b
licker-in 1	542 c	5.6 c
back hood	614 b	8.9 b
flats	519 c	4.4 c
front top hood	454 d	5.0 c
front bottom hood	415 e	2.1 d
take-off roll	444 d,e	0.7 d

* HVI™ Trashmeter cotton quality trash measurements were performed using new HVI™ Trashmeter software on a HVI™ 900A (Uster Technologies Inc., Knoxville, TN) by the Testing Laboratory at USDA, ARS, CQRS, Clemson, SC.

Table 2. Summary of AFIS™ trash measurements by card cleaning location *

	VFM (%)	Total count/gram	Trash count/gram	Dust count/gram	Nep count/gram	Trash mean size (µm)	Dust mean size (µm)	Total particle mean size (µm)
licker-in 3	23.1 b	3877 c,d	964 c	2913 c,d,e	440 c	746 a,b	193 e	417 a
licker-in 2	15.0 c	4128 c	834 c,d	3294 b,c,d	1042 a	757 a,b	210 d,e	366 b
licker-in 1	12.7 c	3025 c,d	641 d,e	2384 d,e	761 b	755 a,b	207 d,e	354 b
back hood	30.2 a	6057 b	2063 a	3995 b	533 c	786 a	242 a,b	457 a
flats	12.5 c	2756 d	836 c,d	1920 e	664 b	791 a	219 c,d	424 a
front top hood	21.1 b	8886 a	1409 b	7476 a	935 a	665 c	250 a	344 b
front bottom hood	7.3 d	4119 c	418 e,f	3701 b,c	661 b	626 c	235 a,b,c	300 c
take-off roll	2.7 e	1083 e	181 f	902 f	701 b	730 b	225 b,c,d	300 c

* AFIS™ (Uster Technologies Inc., Knoxville, TN) cotton quality results were obtained at USDA, ARS, CQRS, Clemson, SC.

Table 3. Summary of AFIS™ length measurements by card cleaning location *

	UQL (w) (in)	Fiber mean length L(w) (in)	Fiber L(w) CV	SFC (w) (%)	Fiber mean length L(n) (in)	Fiber L(n) CV	SFC (n) (%)	Maturity ratio (IFC) (%)	Fineness (mtex)
licker-in 3	1.25 a,b	0.88 c,d	50.8 c,d	25.7 b	0.55 c	76.8 b,c	57.5 c,d	4.2 c	169 a,b
licker-in 2	1.34 a	0.93 b,c	49.2 d	22.5 b,c	0.58 c	78.3 b	54.9 d	4.2 c	168 a,b,c
licker-in 1	1.35 a	1.00 a,b	42.8 e	15.9 c,d	0.68 b	68.2 d	43.8 e	4.9 a	167 b,c
back hood	1.21 b	0.85 d	50.8 c,d	25.6 b	0.56 c	72.7 c	55.0 d	4.5 a,b,c	165 c
flats	1.34 a	1.02 a	33.9 e	12.1 d	0.75 a	60.8 e	35.5 f	4.8 a,b	169 a,b
front top hood	1.03 c,d	0.72 e	60.6 a,b	38.3 a	0.42 d	83.9 a	70 a,b	4.2 b,c	167 b,c
front bottom hood	0.96 d	0.67 e	61.8 a	41.8 a	0.40 d	83.1 a	72.4 a	3.9 c	165 c
take-off roll	1.09 c	0.80 d	55.7 b,c	35.3 a	0.51 c	77.7 b	63.2 b,c	3.9 c	170 a

* AFIS™ (Uster Technologies Inc., Knoxville, TN) cotton quality results were obtained at USDA, ARS, CQRS, Clemson, SC.

Table 4. Summary of MTM trash measurements by card cleaning location *

	Total foreign matter (%)	Visible foreign matter trash (%)	Microdust (%)	Fiber Fragments (%)
licker-in 3	46.2 a	42.7 a	0.10 b	1.4 b
licker-in 2	22.4 b	17.6 b	0.55 a	1.4 b
licker-in 1	14.5 b,c	12.0 b,c	0.26 a,b	0.78 b
back hood	52.6 a	45.4 a	0.21 a,b	1.7 b
flats	14.4 b,c	11.6 b,c	0.22 a,b	0.24 b
front top hood	23.4 b	15.6 b	0.46 a,b	2.8 b
front bottom hood	8.2 c	3.9 c	0.34 a,b	1.7 b
take-off roll	14.5 b,c	2.7 c	0.40 a,b	14.5 a

* MTM (Uster Technologies Inc., Knoxville, TN) cotton quality results were obtained at USDA, ARS, CQRS, Clemson, SC.

Table 5. Summary of sieve trash measurements by card cleaning location *

	Percent trash in lint Sieve 18 1000 µm (%)	Percent trash in lint Sieve 35 500 µm (%)	Percent trash in lint Sieve 60 250 µm (%)	Percent trash in lint Fines <250µm (%)	Percent trash in trash Sieve 18 1000 µm (%)	Percent trash in trash Sieve 35 500 µm (%)	Percent trash in trash Sieve 60 250 µm (%)	Percent trash in trash Fines <250µm (%)
licker-in 3	31.5 a	9.0 b	3.0 b	0.67 b,c	71.6 a	20.3 c,d	6.7 e	1.49 c
licker-in 2	10.2 c	5.3 b,c	2.6 b,c	0.64 b,c	54.7 c,d	28.1 b	13.8 c,d	3.4 b,c
licker-in 1	8.9 c	2.1 c	1.2 b,c	0.36 c	70.9 a	16.7 c,d	9.5 d,e	2.9 c
back hood	22.6 b	16.8 a	6.2 a	1.1 a,b	48.8 d	34.9 a	13.7 c,d	2.6 c
flats	7.9 c	2.5 c	1.1 c	0.26 c	66.2 a,b	21.3 c	10.2 d,e	2.3 c
front top hood	6.2 c	2.5 c	5.9 a	1.6 a	37.5 e	15.6 d,e	37.0 a	9.9 a
front bottom hood	5.2 c	0.77 c	1.9 b,c	0.63 b,c	59.2 b,c	8.3 f	22.6 b	9.8 a
take-off roll	10.1 c	1.7 c	2.5 b,c	0.84 b,c	66.3 a,b	11.8 e,f	15.6 c	6.3 b

* Trash sieved through a series of stainless steel USA Standard Testing Sieves containing wire mesh with a size of 18, 35, and 60 with respective mesh openings of 0.0394 in (1.0 mm), 0.0197 in (0.5 mm), and 0.0098 in (0.25 mm) at USDA, ARS, CQRS, Clemson, SC.

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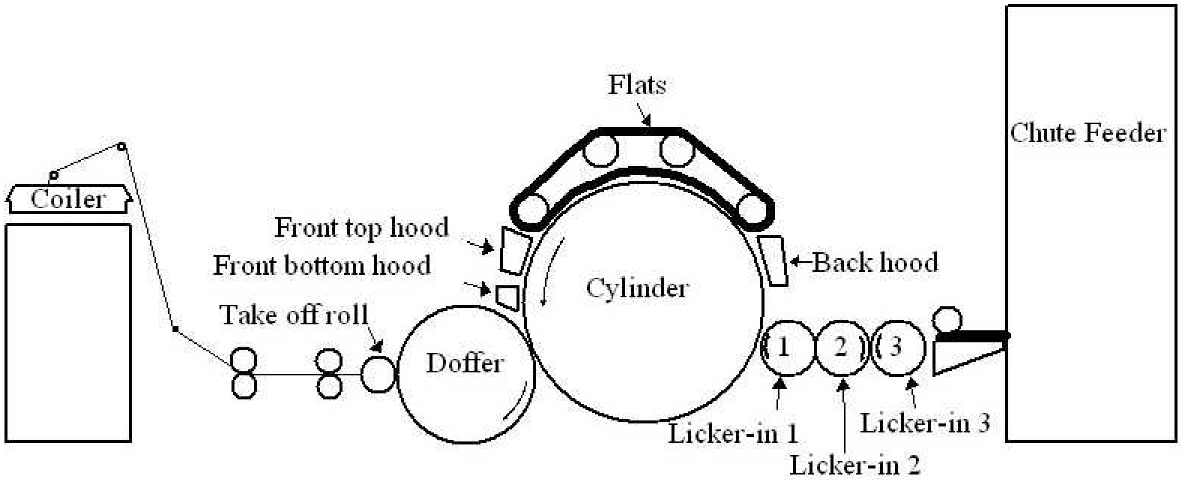

Figure 1. Schematic diagram of Truetzschler 803 card.

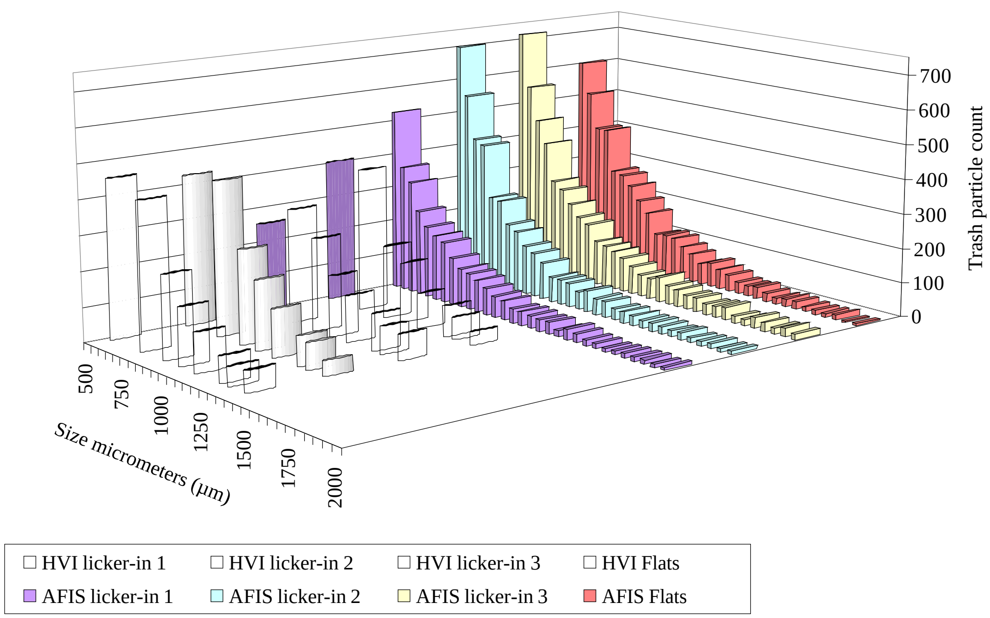

Figure 2. HVI™ and AFIS™ exponential decay for trash size distribution at licker-in 1, licker-in 2, licker-in 3, and flats cleaning locations.

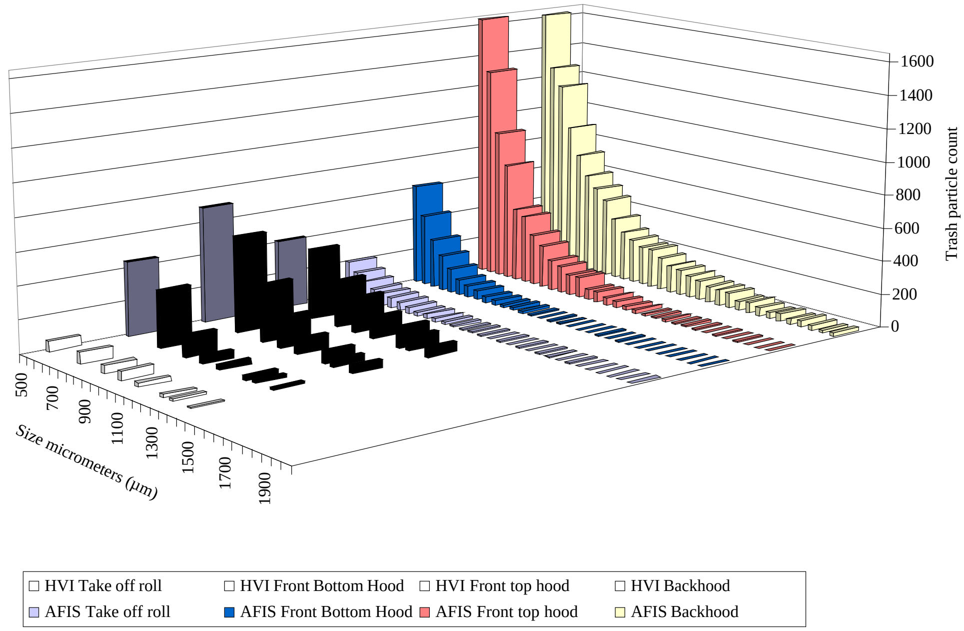

Figure 3. HVI™ and AFIS™ exponential decay for trash size distribution at take-off roll, front bottom hood, front top hood, and back hood cleaning locations.

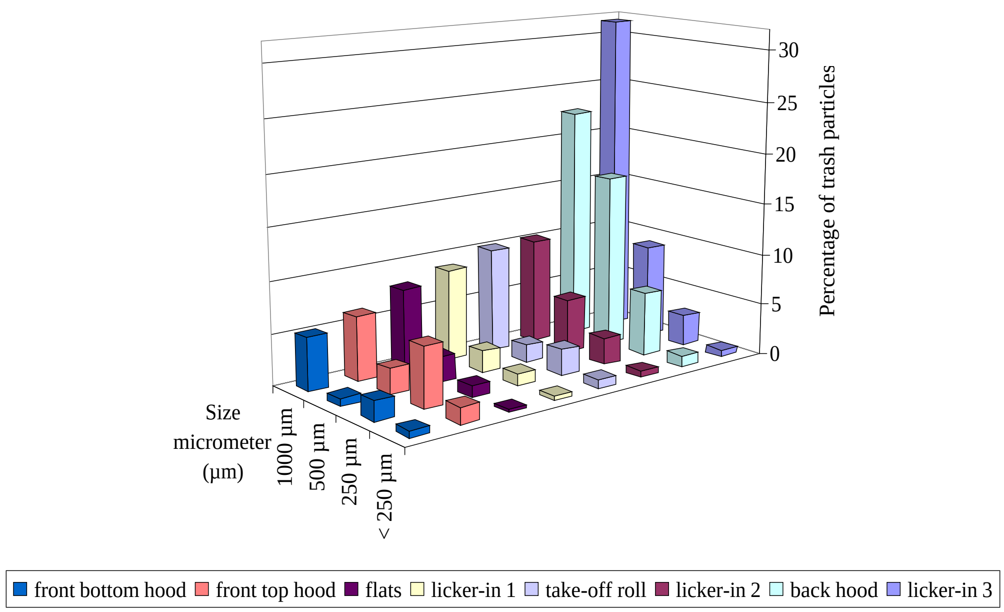

Figure 4. MTM exponential decay for trash size distribution at take-off roll, front bottom hood, front top hood, back hood, licker-in 1, licker-in 2, licker-in 3, and flats cleaning locations.