APPROACHES TO CHARACTERIZE LINT REMOVED DURING LINT CLEANING

C.D. Delhom
USDA-ARS-Cotton Structure and Quality Research Unit
New Orleans, LA
J.C. Boykin
USDA-ARS-Cotton Ginning Research Unit
Stoneville, MS
V. Martin
E. Barnes
Cotton Incorporated
Cary, NC

Abstract

Cotton lint contains foreign matter and less desirable short fiber after ginning. Lint cleaners are commonly employed to improve the overall quality of ginned lint by removing this material. In order to improve the efficiency and performance of lint cleaners, the entire material flow must be analyzed including both the quantity and quality of the material removed by the lint cleaner. Typical analysis of material removed during lint cleaning is a mass-balance calculation to determine the percentage of material removed, while fiber quality testing is performed on the cleaned lint collected from the lint cleaner. Several approaches were examined to characterize the waste flow in greater detail, including the percentage of lint and non-lint content in the waste stream and the quality of the lint in the waste stream to better understand fiber quality changes during lint cleaning. A variety of methods were explored utilizing hand-sorting of the waste material as well as mechanical sorting of the waste material. Lint quality in the waste material was examined using AFIS both with and without removal of the non-lint material.

Introduction

Saw-type lint cleaners are commonly used to improve the overall quality of ginned lint through the removal of foreign matter and short fiber. The removal of undesired material improves the leaf grade, mean length, and overall fiber length distributions of the lint entering the bale, which increases the value and improves textile processing of the lint (Anthony, 1999). Trials were run at the Cotton Ginning Research Unit in Stoneville, Mississippi to examine the influence of saw-type lint cleaners on fiber quality. Typical analyses of the effect of cleaning equipment on fiber quality involve examining the quality of the lint before and after cleaning and performing a mass-balance calculation to determine the amount of material removed during cleaning. It is generally accepted that some good quality lint is loss during cleaning, but it is the price that must be paid for the increase in overall quality. Gin managers are often judged by their customers on how “white” the trash pile is. The general perception is that if there is too much white in the pile, then the gin is probably over cleaning. This is purely subjective and without basis of fact.

The data presented is from two studies in which the material removed by the saw-type lint cleaner was collected. A mass-balance was performed to determine the amount of material removed with various settings on the lint cleaner in place and then fiber quality analyses were performed. One set of samples was hand-sorted for determination of the make-up of the lint cleaner waste. This same set of samples was subjected to AFIS testing without cleaning as well as AFIS testing of the clean lint that was hand sorted from the waste. A second set of samples was subjected to testing via the Uster MTM (Trash and Dust analysis), SDL Atlas Shirley Analyzer (lint and non-lint content analysis) (ASTM D2812) and Uster AFIS testing.

Materials and Methods

Three Deltapine (Memphis, TN) cotton varieties were used in this work. Both studies consisted of the same varieties of cotton, DPL 117, 164, and 444. The cottons were grown and spindle harvested in Stoneville, MS, during the 2007 crop year. The cottons were saw ginned in the micro-gin facilities at the Cotton Ginning Research Unit in Stoneville, MS. The ginning sequence consisted of a shelf dryer, cylinder cleaner, stick machine, shelf dryer, cylinder cleaner, extractor-feeder, and a 20-saw (16 in diameter) gin stand. The lint cleaner employed in the study was a Continental (Prattville, AL) model 16D operated with a brush speed of 1535 rpm. Dryer settings, lint cleaner saw speed and louver settings varied by study. The HVI results for the cottons, with one lint cleaner at 870 rpm, are shown in Table 1. Each lot ginned consisted of between 60 and 150 lb of seed cotton.

Table 1. HVI results for all cottons with one lint cleaner at 870 rpm.

Variety	Leaf Type	Length (in)	Mic	Strength (cN/tex)	Rd	+b	Uniformity	Trash Area (%)	Trash Count
117	Hairy	1.13	4.34	30.4	73.0	8.4	81.8	0.69	48.6
164	Smooth	1.13	4.43	28.1	75.6	8.7	81.4	0.48	30.0
444	Semi	1.12	4.26	29.5	72.7	8.3	82.1	0.51	36.2

All studies were run with three replications of the three varieties and all treatment factors. The experimental design for the first study was a split-plot design and a complete random block design was used for the second study. Data were analyzed using Minitab Ver. 15.1 (State College, PA) and SAS Ver. 9.2 (Cary, NC). Least square means of properties were analyzed by the Waller-Duncan procedure with a significance level of $P \leq 0.05$.

Study #1

In the first study the effects of the various components of saw-type lint cleaners were being studied. This study utilized a louver equipped lint cleaner which was operated with 0, 1, 2 and 5 grid bars active. The 0 grid bar state was achieve utilizing a sheet metal shroud to deactivate the first grid bar and all of the louvers were in the closed position. The results of this study were previously discussed (Delhom et al., 2008); however the examination of the material ejected by the lint cleaner is presented in this report.

In this study the waste material was collected and examined using hand sorting to determine the amount of lint and non-lint material in the waste stream. The hand sorting was compared to machine sorting performed by the SDL Atlas (Stockport, England) Shirley Analyzer. Quality of the lint in the waste stream was determined by the Uster (Charlotte, NC) AFIS. Raw waste samples were run on the AFIS as were clean lint samples from the hand sorting process. Raw waste samples were tested with 5 repetitions while hand cleaned lint samples were tested with 3 repetitions per sample; each repetition measured 5000 fibers.

Hand sorting was performed using a single operator working in an environmentally controlled laboratory. The technician sorted the waste material into three categories: 1) clean free lint, 2) clean free non-lint content, and 3) lint with attached non-lint content. Samples were hand-sorted until either ~2 grams of clean free lint was obtained or the sample was exhausted. This amount of clean free lint allows for AFIS testing which requires 0.5 grams per repetition. Total weights of sorted material were recorded to allow for the percent lint and non-lint content to be established.

AFIS testing was also used to characterize the waste material. Technicians prepared sliver from the waste material collected from the lint cleaner with no removal of material. Slivers were also prepared from the clean free lint gathered in the hand-sorting stage for a comparison of results and determination of bias from the instrument due to the excessive non-lint content.

Study #2

In the second study the effects of a wire brush replacement for grid bars was studied. In this study, the standard lint cleaner, contained five active grid bars and a saw speed of 870 rpm. The modified lint cleaner contained wire brush replacements for the grid bars and the saw speed was increased to 1400 rpm. Modifying the lint cleaner was expected to have an effect on both the fiber quality and the amount of material removed by the lint cleaner. The main results of this study were previously reported (Delhom and Byler, 2009) however; the examination of the waste stream is reported here.

In this study the waste material was collected and examined using machine sorting by the AFIS, Microdust and Trash Monitor (MTM) and Microdust and Trash Analyzer (MDTA3). Samples were processed on the AFIS with no prior cleaning, as well as after MTM and MTM, followed by MDTA3 processing.

Results and Discussion

Study #1

Means for ginning data from the first study are shown in Table 2. Lint cleaner waste increased significantly as additional grid bars were activated, as expected. Lint cleaner waste, scaled up to a 500lb bale ranged from a mean of 4.1 lb of waste with no grid bars active to 9.8 lb with all five grid bars active. Non-lint content in the ginned lint, as determined by Shirley Analyzer, decreased significantly as grid bars were activated, as expected.

Table 2. Least squares means for ginning data by configuration, separated by Waller-Duncan[1] (Study #1)

Least Square Means for Variable	No Lint Cleaner	0 Grid Bars	1 Grid Bar	2 Grid Bars	5 Grid Bars	MSD[2]
Turnout (%)	36.22a	36.06a	35.77a	35.41a	37.26a	3.76
Lint Cleaner Waste (lb)	N/A	4.12d	6.06c	7.45b	9.81a	0.42
Shirley Analyzer Waste (%)	6.37a	5.69b	5.35c	4.79d	4.60d	0.32

[1]Means with the same letter in each row are not significantly different
[2]Minimum significant difference

Hand-sorting of the lint cleaner waste material is shown in Table 3. The recovered material indicates a small percentage, up to 2%, of the material weighed for sorting was not recovered after sorting. This is equivalent to the so-called "invisible waste" of machine sorting methods and is most likely dust and other extremely small particles. The "invisible waste" increased as more grid bars were activated. The amount of clean-free lint in the waste material increased as the number of grid bars was increased. The Shirley Analyzer data (Table 4) has general agreement with the hand-sorting results. More lint was present in the waste as the number of grid bars was increased. The lint measurements for the Shirley Analyzer make distinction between clean-free lint and lint with attached non-lint content. The saw-tooth cylinder of the Shirley Analyzer is capable of separating some of the entrained non-lint content from the lint in the waste material.

Table 3. Least squares means for Hand-Sorted LC Waste, separated by Waller-Duncan[1] (Study #1)

Least Square Means for Variable	0 Grid Bars	1 Grid Bar	2 Grid Bars	5 Grid Bars	MSD[2]
Recovered Material (%)	99.28a	98.56ab	98.41b	97.90b	0.856
Clean Free Lint (%)	4.76c	8.48bc	9.73ab	13.18a	3.805
Free Non-Lint (%)	37.72a	35.61ab	28.17bc	25.98c	9.527
Lint attached to non-lint (%)	56.79a	54.48a	60.51a	58.74a	13.928

[1]Means with the same letter in each row are not significantly different
[2]Minimum significant difference

Table 4. Least squares means for Shirley Analysis of Lint Cleaner Waste, separated by Waller-Duncan[1] (Study #1)

Least Square Means for Variable	0 Grid Bars	1 Grid Bar	2 Grid Bars	5 Grid Bars	MSD[2]
Total Lint Cleaner Waste (%)	0.082d	1.21c	1.49b	1.96a	0.08
Lint (%)	9.44b	9.79b	12.77ab	15.33a	4.35
Non-Lint (%)	85.49a	86.26a	84.18a	82.45a	5.10

[1]Means with the same letter in each row are not significantly different
[2]Minimum significant difference

The hand and machine based sorting only provides a quantitative analysis of lint content in the waste stream. Neither method provides any indication of the quality of the lint. If the lint in the waste stream consists of mainly short and/or immature fibers, it is in the ginner and textile mill's interest to remove the material before it enters the bale. AFIS testing was used to provide qualitative testing of the lint in the waste material.

Initially, 0.5 gram slivers were prepared by technicians directly from the raw waste material to be run on the AFIS instrument. The technicians removed any large pieces of non-lint content which may cause a malfunction of the AFIS, otherwise the raw waste material was processed with no cleaning or further preparation. Shirley Analyzer testing had shown that approximately 85% of the material in the waste stream was non-lint content. The AFIS is designed to separate lint and non-lint content using a fiber individualizer based on air flow and centrifugal force (Figure 1). The AFIS is not designed to handle samples which are more non-lint than lint and the results from the instrument for the non-sorted samples cannot be readily validated. It is possible that the fiber individualizer will provide some mechanical cleaning akin to the Shirley Analyzer, separating some of the lint from the "lint attached to non-lint" category.

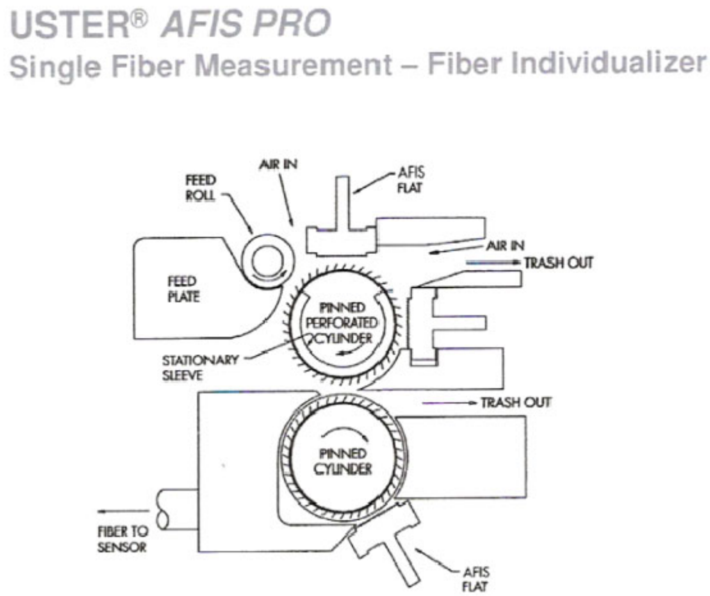

Figure 1. AFIS Fiber Individualizer (courtesy of Uster, 2008)

Tables 5 and 6 contain the AFIS data for lint cleaner waste with no preparation and with hand sorting, respectively. Although no statistical differences were found for short fiber content (SFC) without any preparation, some differences were found with hand sorting. The non-prep samples followed a trend of less SFC as grid bars were increased. This measurement is weight-based and it is logical that as more material is removed, the amount of short fibers, by weight, would be less. No clear pattern exists for SFC with the hand-sorted samples, although the minimum significant difference (MSD) is greatly reduced, indicating less variability in the measurements. The Upper Quartile Length (UQL) measurement shows an increase in the UQL of the waste stream as more material is removed via an increased number of grid bars. Unlike SFC, the MSD of the UQL is similar for both preparation methods.

The maturity ratio of the waste material increases for both methods as grid bars are increased. This indicates more mature fibers are being removed as more material is being removed. The hand-sorted samples generally indicate less mature fiber content than the samples with no preparation. The MSD for both test methods is similar. The fineness measurements follow the same general trend. No statistical differences were found between treatments for either maturity ratio or fiber fineness.

Table 5. Least squares means for AFIS LC Waste with no prep, separated by Waller-Duncan[1] (Study #1)

Least Square Means for Variable	0 Grid Bars	1 Grid Bar	2 Grid Bars	5 Grid Bars	MSD[2]
Short Fiber Content (w) (%)	15.85a	14.05a	12.1a	11.3a	6.19
Upper Quartile Length (in)	1.148a	1.145a	1.160a	1.170a	0.069
Fineness (mtex)	165.8a	163.5a	167.0a	168.6a	8.83
Maturity Ratio	0.882a	0.883a	0.902a	0.912a	0.057
Nep Count (#/g)	566.0a	368.2b	330.5b	333.5b	138.3
Seed Coat Nep Count (#/g)	103.8a	70.0ab	66.7ab	61.8b	40.6
Trash Count (#/g)	510.5a	637.2a	570.5a	609.0a	491.8
Dust (#/g)	1851.2a	2435.7a	2086.7a	2462.0a	1925.4
Visible Foreign Matter (%)	10.88a	13.05a	11.84a	12.15a	10.913

[1]Means with the same letter in each row are not significantly different
[2]Minimum significant difference

Table 6. Least squares means for AFIS Hand-Sorted LC Waste, separated by Waller-Duncan[1] (Study #1)

Least Square Means for Variable	0 Grid Bars	1 Grid Bar	2 Grid Bars	5 Grid Bars	MSD[2]
Short Fiber Content (w) (%)	15.06a	10.96c	12.48bc	14.06ab	1.93
Upper Quartile Length (in)	1.121a	1.125a	1.142a	1.137a	0.074
Fineness (mtex)	157.2a	154.7a	160.3a	159.7a	9.35
Maturity Ratio	0.849a	0.852a	0.879a	0.873a	0.050
Nep Count (#/g)	1083.5a	422.1c	596.3b	535.1bc	172.9
Seed Coat Nep Count (#/g)	72.3a	36.3c	51.0bc	52.3b	14.8
Trash Count (#/g)	307.6ab	241.1b	353.9ab	389.5a	134.9
Dust (#/g)	1289.6a	1026.5a	1328.7a	1460.0a	564.7
Visible Foreign Matter (%)	5.16a	4.04a	5.73a	6.10a	2.13

[1]Means with the same letter in each row are not significantly different
[2]Minimum significant difference

Study #2

Means for ginning data from the second study are shown in Table 7. Lint cleaner waste, scaled to a 500 lb bale, was reduced for the modified lint cleaner. For this trial, all 5 grid bars remained active, only the grid bar modification and saw-speed was changed for the modified lint cleaner compared to the standard lint cleaner.

Table 7. Least squares means for ginning data by saw speed, (Study #2)

Least Square Means for Variable	Standard	Modified
Turnout (%)	35.22	35.93
Lint Cleaner Waste (lb)	17.21	7.64

The Shirley Analyzer method is an aggressive operation which results in a measurement for Lint and Non-Lint content with a quantification of "invisible waste" being the difference between the sum of lint and non-lint with the original mass processed by the instrument. The Uster MTM instrument is designed to use similar aeromechanical properties as the AFIS fiber individualizer and the Shirley Analyzer, while providing more specific information on the foreign matter in lint (Figure 2). The MTM was used prior to AFIS testing to determine non-lint content and provide a means of gently cleaning the lint cleaner waste material in preparation for AFIS. The Uster MDTA3 is another instrument intended to separate lint from non-lint content and provide detailed information on the non-lint content. MDTA3 was performed on the lint cleaner waste samples after MTM, prior to being run on AFIS for further cleaning and preparation for testing.

The MTM results provide a more detailed analysis of non-lint content than the Shirley Analyzer (Table 8). Approximately 56% of the material in the waste stream of the standard lint cleaner was non-lint content, while more than 74% of the waste stream of the modified lint cleaner was non-lint content. MDTA3 was performed on the lint cleaned by the MTM (Table 9). The MDTA3 shows that after MTM, the lint sample is more than 95% lint, which is more typical of a sample to be measured by the AFIS.

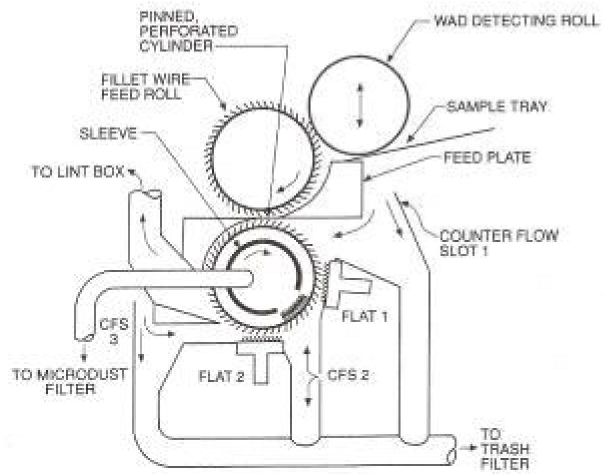

Figure 2. Schematic diagram of the MTM separation mechanism (courtesy of Uster, 1990)

Table 8. Least squares means for MTM data on Lint Cleaner Waste (Study #2)

Least Square Means for Variable	Standard	Modified
Total Foreign Matter (%)	56.05	74.22
Visible Foreign Matter (%)	50.90	68.07
Fiber Fragments (%)	1.53	1.69
Microdust (%)	0.19	0.17
Invisible Foreign Matter (%)	3.43	4.28

Table 9. Least squares means for MDTA3 data of Lint Cleaner Waste after MTM (Study #2)

Least Square Means for Variable	Standard	Modified
Lint (%)	96.17	95.98
Trash (%)	3.15	3.39
Fiber Fragments (%)	0.44	0.50
Dust (%)	0.13	0.13

Partial results of AFIS testing of lint cleaner waste with no prior preparation is shown in Table 10, while results after MTM are in Table 11 and after MTM and MDTA3 are in Table 12. AFIS testing with no preparation does not show many differences between the two lint cleaner treatments. Prior processing of the samples does not show differences between the lint cleaner treatments, but SFC increases for both treatments after MTM processing. SFC shows a slight decrease after MDTA3, which is likely due to short fibers being removed from the lint stream and captured as fiber fragments by the MDTA3.

Table 10. Least squares means for AFIS of Lint Cleaner Waste (Study #2)

Least Square Means for Variable	Standard	Modified
Short Fiber Content (w) (%)	14.83	14.47
Upper Quartile Length (in)	1.132	1.136
Fineness (mtex)	164.3	168.7
Maturity Ratio	0.87	0.88

Table 11. Least squares means for AFIS of Lint Cleaner Waste after MTM (Study #2)

Least Square Means for Variable	Standard	Modified
Short Fiber Content (w) (%)	29.23	28.70
Upper Quartile Length (in)	1.01	1.00
Fineness (mtex)	160.7	164.3
Maturity Ratio	0.81	0.82

Table 12. Least squares means for AFIS of Lint Cleaner Waste after MTM and MDTA3 (Study #2)

Least Square Means for Variable	Standard	Modified
Short Fiber Content (w) (%)	24.99	24.38
Upper Quartile Length (in)	1.033	1.033
Fineness (mtex)	167.0	169.8
Maturity Ratio	0.85	0.86

Summary

Knowledge of the fiber quality of lint contained in lint cleaner waste is important in order to understand what material is being removed during lint cleaning. Lint cleaning is a balance between improving the quality and value of the baled material and removing excessive valuable material which negatively impacts the producer. A simple mass-balance tells a portion of the story, but the quality of the lint must be ascertained. Simple analyses, such as Shirley Analyzer, are important to determine the percentage of lint in the waste stream; however, it is equally important to assess the quality of the lint in the waste stream.

The waste stream, by design, contains more non-lint material than lint and this confounds the problem. Although the AFIS is not designed to examine lint quality in such a heavily contaminated sample, it appears adequate for the task at hand. Sorting the lint cleaner waste, either mechanically or by hand, did not readily improve the ability of the AFIS to detect differences between lint cleaner treatments, or in some cases may mask differences. Mechanical sorting of the lint from the waste stream was shown to have some impact on the measured values due to unintentional damage of the lint. Hand-sorting of lint cleaner waste did reveal that only a limited portion of the lint content in the waste stream is indeed free-clean lint. Most of the lint in the waste stream was physically entrained with non-lint content.

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.

Acknowledgements

The authors would like to acknowledge Cotton Incorporated for the funding of this research. The authors are grateful for the work of many technicians in preparing the samples used in this report. Notable amongst the many technicians are Eddie Horton at the Cotton Ginning Research Unit for hand-sorting waste samples and Regina Horton at Cotton Incorporated for performing MTM and MDTA3 analyses. A variety of technicians and staff at the Cotton Ginning Research Unit, Cotton Structure and Quality Research Unit, and Cotton Incorporated were invaluable for all of the testing.

References

Anthony, W.S. 1999. Methods to reduce lint cleaner waste and damage. ASAE Paper No. 991124. St. Joseph, MI: ASAE.

ASTM Standards. 2007. D2812-07: Test for non-lint content of cotton. West Conshocken, PA: ASTM.

Delhom, C.D. and R.K. Byler, 2009. Study of a wire brush grid bar replacement for saw-type lint cleaners. *In* Proc. of Beltwide Cotton Conference, 487-491.

Delhom, C.D., R.K. Byler, X. Cui, and D.P. Thibodeaux. 2008. Saw-type lint cleaner damage by machinery components. ASABE Paper No. 084094, St. Joseph, MI: ASABE.

Uster. 2008. Uster AFIS Pro data interpretation and application guide. Charlotte, NC.

Zellweger Uster. 1990. Uster MTM instruction manual. Charlotte, NC.