

THE MULTIBAR SAWLESS LINT CLEANER: A NEW APPROACH FOR CLEANING UPLAND COTTON LINT**Greg Holt****USDA-ARS****Lubbock, TX****Roy V. Baker****Retired USDA-ARS****Lubbock, TX****Edward M. Barnes****Cotton Incorporated****Cary, NC****Carlos Armijo****Southwestern Cotton Ginning Research Laboratory****Mesilla Park, NM****Abstract**

Experiments were conducted to evaluate the performance of a prototype lint cleaner named the Multibar Sawless Lint Cleaner (MBSLC). The MBSLC was conceived as a possible replacement for the first stage of lint cleaning in a cotton gin. The MBSLC has similarities to a saw-type lint cleaner, but the saws have been replaced with a spiked-tooth cylinder and a much denser series of grid bars are used. The theory of replacing the first stage was based on inefficiencies seen in a conventional two saw-type lint cleaner operation where the first stage of lint cleaning experiences the heaviest loading of trash and does a majority of the cleaning. The second stage is less efficient since it is both operationally and mechanically redundant to the first stage of lint cleaning. The MBSLC was designed under the premise that more effective and efficient cleaning of the lint would occur if different mechanical principles of operation were used in series rather than the traditional saw-type lint cleaner followed by a saw-type lint cleaner. This initial study was performed on a single variety of upland cotton that was stripper harvested with a field cleaner. The MBSLC was compared to a conventional saw-type lint cleaner by evaluating the fiber quality and lint waste produced by each machine. Results showed the MBSLC produced 73% less lint cleaner waste than the conventional saw-type lint cleaner. The MBSLC had improved fiber properties of length, short fiber content, and trash size. Fiber properties of Rd and leaf grade were better from the saw-type lint cleaner. All other measured fiber properties were the same for both lint cleaners. The results emphasized the potential application of this technology to improve lint cleaning, possibly by use as a stage of “pre-cleaning” before a saw-type lint cleaner, or even as a sole stage of cleaning for lint with low leaf levels.

Introduction

Controlled-batt saw-type lint cleaners are the most common means of cleaning lint for cotton gins processing mechanically harvested upland cotton (Columbus, 1985; Mangialardi, 1995). The use of lint cleaners has a significant impact on the value and quality of ginned lint (Baker, 1978). However, a balance exists between too much cleaning and not enough. Too little or too much cleaning of cotton can lower the value of the lint in the marketplace and create processing problems at the textile mill (Lalor and Baker, 1985; Bel et al., 1991; Mangialardi, 1996; Baker and Brashears, 1999). Finding the correct balance between over or under cleaning the lint is both an art and skill developed by an experienced ginner based on the condition of the incoming seed cotton. In past studies, one of the main issues evaluated was the number of stages of lint cleaning. Griffin et al. (1982) evaluated the effects of fiber damage and spinning qualities with up to six-stages of lint cleaning. Mangialardi (1993) conducted a four-year study of spindle-harvested cotton to determine the effect that various stages of lint cleaning had on fiber quality and market value. Baker and Brashears (1999) compared bale values of stripper harvested cotton based on zero to three stages of lint cleaning over a 5-year period. A commonality seen in those three studies was that increasing the number of stages of lint cleaning resulted in increased fiber damage, lint waste, and neps. The benefits gained by increasing the stages of lint cleaning (i.e. reducing the trash content) did not necessarily result in greater bale values (\$). Even though one stage of lint cleaning may be sufficient for some cotton, two stages of lint cleaning are still needed for other types of cotton which have higher trash levels.

When multiple stages of saw-type lint cleaners are operated in series, Mangialardi (1993) showed that the cleaning efficiency of each lint cleaner decreased significantly as the number of stages increased. Thus, this research was initiated to develop and evaluate an alternative lint cleaner. This lint cleaner could act as a first stage of cleaning by removing some of the foreign matter from the lint without adversely effecting fiber quality while producing less lint waste than the traditional saw-type lint cleaner. The prototype alternative lint cleaner was named the Multibar Sawless Lint Cleaner (MBSLC). For the initial evaluation, the objectives were to: 1) compare fiber quality, lint waste, and production data of the MBSLC to a conventional saw-type lint cleaner and 2) if the results showed a promising potential for the MBSLC, initiate plans for future studies evaluating other settings and configurations involving multiple varieties.

Materials and Methods

Equipment

The MBSLC (Fig 1) was constructed and installed behind the number one gin stand at the USDA-ARS, Cotton Production and Processing Research Unit in Lubbock, Texas. The MBSLC was constructed using a standard Hardwick-Etter lint condenser, feed works from a Continental 16D lint cleaner, a specially manufactured spiked cleaning cylinder (Fig 2), and twenty-two adjustable grid bars. The inside width of the lint condenser and MBSLC is 154.9-cm (61-in) and 167.6-cm (66-in), respectively. The MBSLC cleaning cylinder consisted of pins that were 3.2 mm (0.125 in) in diameter and 4.1 cm (1.625 in) long. The cylinder contained 0.2 pins/cm² (1.3 pins/in²).

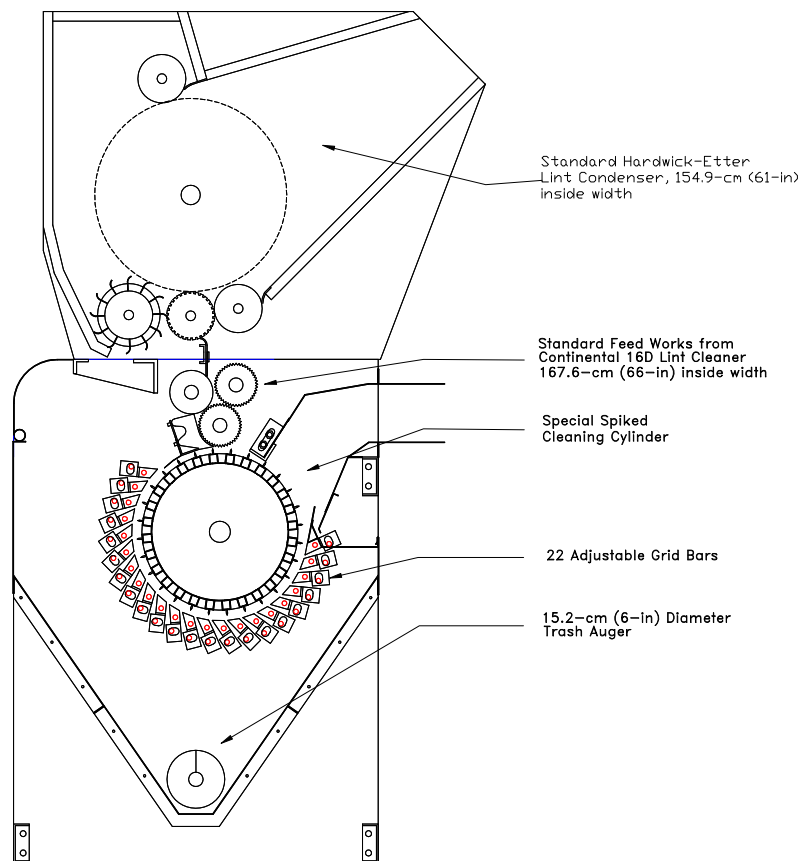


Figure 1. Schematic side-view of the multibar sawless lint cleaner evaluated in this study.

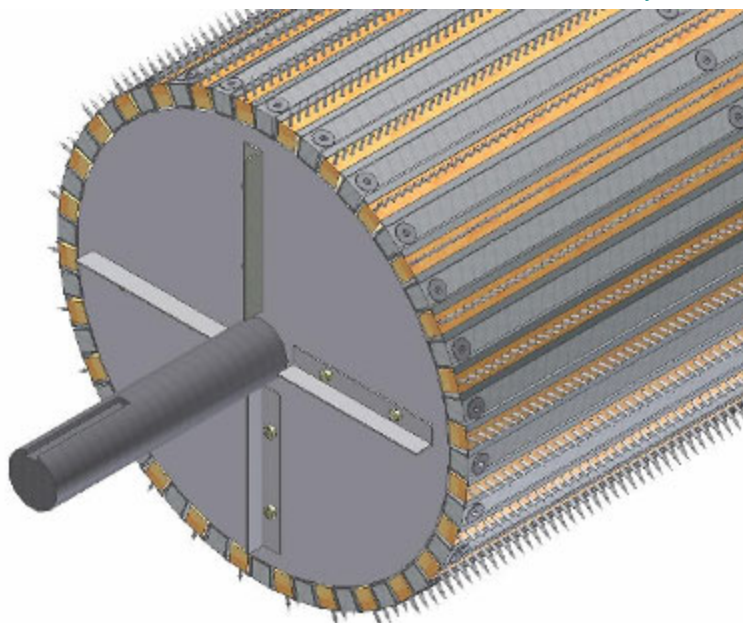


Figure 2. Close-up three-dimensional view of the spiked cylinder used in this study.

Setup, Testing, and Data Collection

The cotton variety used in this study was FiberMax 960BR. The seed cotton was stripper harvested with a field cleaner and moduled and stored in a dry area. Moisture content of the seed cotton was determined by Shepard (1972). The average moisture content, at the feeder apron, was 5.9% wet basis with a standard deviation of 0.15%, thus the seed cotton did not require the use of heat/drying during ginning.

The machinery sequence for all pre-cleaning and ginning of the seed cotton was the same; steady flow, cylinder cleaner, extractor, cylinder cleaner, extractor, feeder, and Continental Double Eagle 93-saw gin stand. The lint from the gin stand passed through either the standard Horn and Gladdin 66 (HG-66) saw-type lint cleaner or the MBSLC and then to the press. The ginning rate and combing ratio for the HG-66 test runs was 7.3 bales/h and 27:1, respectively. For the MBSLC test runs, the ginning rate was 7.4 bales/h and the combing ratio of the lint cleaner was 30:1. Each test run consisted of approximately 454 kg (1000 lb) of seed cotton.

The data recorded for each run consisted of: 1) time, 2) ambient temperature, 3) relative humidity, 4) weight of seed cotton used, 5) cleaning time, 6) gin time, 7) lint weight, 8) seed weight, and 9) mote weight. During each run, one seed cotton and three lint samples were collected. Lint samples were obtained before and after the lint cleaner for fiber quality analysis with the Advanced Fiber Information System (AFIS) and High Volume Instrument (HVI) fiber measurement systems (Uster Technologies, Knoxville, TN). The HVI analyses took place at the USDA-AMS Classing Office in Lubbock, TX and at Cotton Incorporated's facility in Cary, North Carolina. The AFIS analyses were done at Cotton Incorporated's facility. Seed cotton samples were collected for moisture analysis (Shepard, 1972) from the feeder apron. Lint cleaner waste was collected for fractionation and usable fiber content by the Shirley Analyzer (ASTM, 1996).

Experimental Design and Data Analysis

This study was a completely randomized design with two treatments, standard saw-type lint cleaner and MBSLC. Each treatment was replicated six times. Standard analysis of variance techniques were used to determine the statistical significance among the two treatments using Tukey's Honestly Significant Difference (HSD) test (release 9.1.3; SAS Institute Inc.; Cary, NC). The response variables evaluated from the data included: 1) Turnout, 2) Lint Cleaner Waste, 3) Loan Value, 4) AFIS data, and 5) HVI data.

Results and Discussion

Table 1 shows the observed significance level for comparisons of the standard lint cleaner to the MBSLC for the process response variables evaluated. The data shows the MBSLC to have higher turnout ($P = 0.035$) and less lint cleaner waste ($P < 0.001$) than the standard lint cleaner. The waste from the standard lint cleaner contained 26.9% fiber equating to 0.626 kg/bale (1.38 lb/bale). Lint cleaner waste from the MBSLC contained 25.3% fiber equating to 0.161 kg/bale (0.354 lb/bale). Even though more usable lint was removed from the standard lint cleaner, the improvement in grade by the removal of foreign matter resulted in a higher loan value [\$1.247/kg (\$0.5662/lb)] than the lint from the MBSLC [\$1.214/kg (\$0.5515/lb)]. Table 1 shows the bale weight to be higher ($P = 0.035$) for the MBSLC, which corresponds to the higher turnout obtained. The loan bale value shown in Table 1 was calculated by multiplying the loan value by the bale weight and was shown to be relatively the same for both lint cleaners. The similarity in bale loan value may seem surprising considering the lint from the saw-type lint cleaner had a higher loan value. However, the MBSLC had a higher bale weight which offset the higher loan value of the saw-type lint. Ginning rate for both treatments was shown to be the same ($P = 0.855$).

Table 1. Process data comparisons between a standard saw-type lint cleaner and the multibar sawless lint cleaner.

Response Variable	Unit	Standard Lint Cleaner	Multibar Sawless Lint Cleaner	Observed Significance Level
Turnout	%	28.4	29.2	0.035
Lint Cleaner Waste	%	1.03	0.28	<0.001
Gin Rate	bales/h	7.29	7.38	0.855
Loan Value ^z	\$/kg (\$/lb)	1.247 (0.5662)	1.214 (0.5515)	0.006
Bale Weight	kg (lb)	219.11 (483.05)	225.45 (497.04)	0.035
Loan Bale Value ^y	\$/bale	273.50	274.12	--

(z) 2007-08 CCC loan rates for Lubbock, TX.

(y) Loan Bale Value = Loan Value * Bale Weight. The value shown in the table is based on the English units. Differences between the reported units and those obtained with the metric units are due to rounding errors associated with conversion from English units.

Table 2 shows the observed significance level for the AFIS and HVI fiber quality data used as response variables. The AFIS fiber quality data shows the MBSLC to have longer length ($P = 0.019$ by weight and $P = 0.014$ by number), less short fiber ($P = 0.014$ by weight and $P = 0.026$ by number), fewer neps ($P = 0.004$), and smaller size trash ($P = 0.002$). The data also shows trash ($P = 0.002$), Dust ($P < 0.001$), and Visible Foreign Matter ($P < 0.001$) for the MBSLC to be higher than for the standard saw-type lint cleaner. The HVI data showed Upper Half Mean length ($P = 0.001$) to be longer for the MBSLC. The standard lint cleaner had higher Rd ($P = 0.009$) and +b ($P = 0.005$) values than the MBSLC. The standard lint cleaner had lower leaf grade ($P < 0.001$) than the MBSLC. The leaf grade in Table 2 has decimals because the reported values are the average of six runs. It should be noted that the seed cotton used in this study was field cleaned cotton that graded Strict Low Middling on color from samples collected prior to lint cleaning. Differences in fiber quality may be more/less evident when other varieties are evaluated with differing trash levels.

Table 2. Fiber quality data comparisons between a standard saw-type lint cleaner and the multibar sawless lint cleaner.

Response Variable ^z	Unit	Standard Lint Cleaner	Multibar Sawless Lint Cleaner	Observed Significance Level
Advanced Fiber Information System				
Length (w)	cm (in)	2.240 (0.882)	2.278 (0.897)	0.019
UQL	cm (in)	2.885 (1.136)	2.911 (1.146)	0.113
SFC (w)	%	16.88	15.73	0.014
Length (n)	cm (in)	1.589 (0.626)	1.635 (0.644)	0.014
SFC (n)	%	42.69	40.89	0.026
Trash Size	um	335.7	316.1	0.002
Dust	cnt/g	290.1	434.2	<0.001
Trash	cnt/g	62.5	80.4	0.002
VFM	%	1.18	1.62	<0.001
SCN Size	um	1123	1124	0.956
SCN	cnt/g	20.5	20.3	0.918
Neps	cnt/g	401	352	0.004
High Volume Instrument				
UHM	cm (in)	2.822 (1.111)	2.855 (1.124)	0.001
UI	%	80.33	80.64	0.057
Rd		78.56	77.57	0.009
+b		8.58	8.26	0.005
Leaf Grade		2.9	3.7	<0.001

(z) Length = length by weight (w) and by number (n), UQL = Upper Quartile Length, SFC = Short Fiber Content by weight (w) and by number (n), VFM = Visible Foreign Matter, SCN = Seed Coat Neps, UHM = Upper Half Mean, UI = Uniformity Index, Rd = reflectance, +b = yellowness. The value reported for Leaf Grade is the average of six runs which is why the value has a decimal.

The fiber quality and production results from the spiked cylinder of the MBSLC were different than those reported by Columbus (1989) and Le (2006). Both Columbus and Le reported shorter fiber length, higher short fiber content, and more neps from the spiked/pinned cylinders evaluated in their studies. Also, in Le's study he found the pinned cylinder to have lower turnout and produced more waste than the saw-type lint cleaner. The MBSLC performed almost exactly the opposite than the spiked/pinned cylinder in Columbus and Le. The pinned cylinder used in Le's study was one of the two evaluated in Columbus' study with the inclusion of additional speeds, varieties, and combing ratios. Possible explanations as to the differences seen in the two previous spiked/pinned cylinder studies and this one may be attributed to the differences in the spiked cylinders, the number of grid bars, and/or the scale of lint cleaner. The two cylinders evaluated by Columbus' study had 6.5 pins/cm² (42 pins/in²) and 0.77 pins/cm² (5 pins/in²) compared to the 0.2 pins/cm² (1.3 pins/in²) of the MBSLC. In addition to differences in spike/pin density, Columbus' cylinders had a maximum length of 1.9-cm (0.75-in) compared to 4.1 cm (1.625 in) of the MBSLC. The lint cleaner used in the previous studies contained five grid bars compared to the twenty-two adjustable grid bars of the MBSLC. The scale of the lint cleaners (i.e. 38.1-cm [15-in] width versus 167.6-cm (66-in) width) are more than likely the reason for differences in throughput (4.8 bales/h versus 7.4 bales/h for the MBSLC).

Recent Studies

Based on the results from the initial study, a study was just completed evaluating nine pin pattern configurations compared to a conventional saw-type lint cleaner. The pin pattern configurations recently evaluated included the original (Fig. 2) plus eight others shown in Fig. 3. The lags (i.e. metal slats that contain the pins) were bolted in place around the cylinder as shown in Fig 4. Fig 4 shows the cylinder with Lag Set 3. The lag sets shown in Fig 3 varied in pin density, angle of the pin extending from the lag, and pattern around the cylinder. Pin densities (pins/in²), over the surface area of the cylinder, of the new lag sets were: 1) Lag Set 1 = 4.16, 2) Lag Set 2 = 1.32, 3) Lag Set 3 = 2.19, 4) Lag Set 4 = 2.19, 5) Lag Set 5 = 4.41, 6) Lag Set 6 = 4.41, 7) Lag Set 7 = 4.16, 8) Lag Set 8 = 4.16. The original cylinder evaluated in this study was also used (pin density = 1.29). The latest study used three cotton varieties with different trash levels. The samples have been sent for analysis. The results should hopefully narrow the top choices for a more in-depth

experimental analysis.

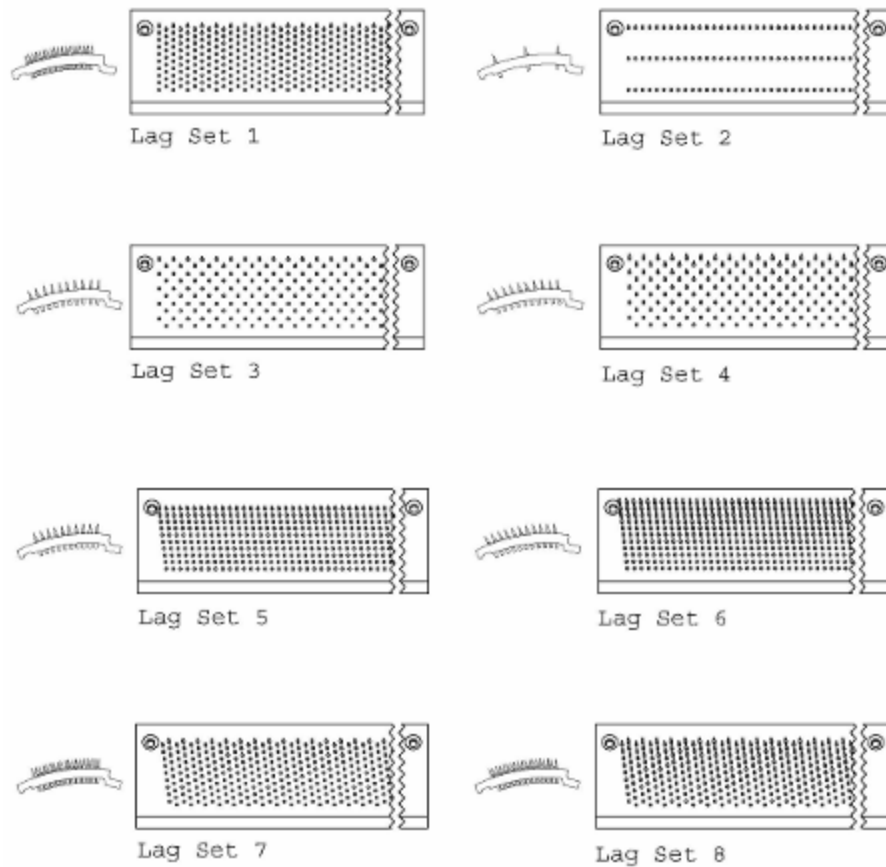


Figure 3. Side-view and top-view of an additional eight lag sets recently evaluated in the multibar sawless lint cleaner.

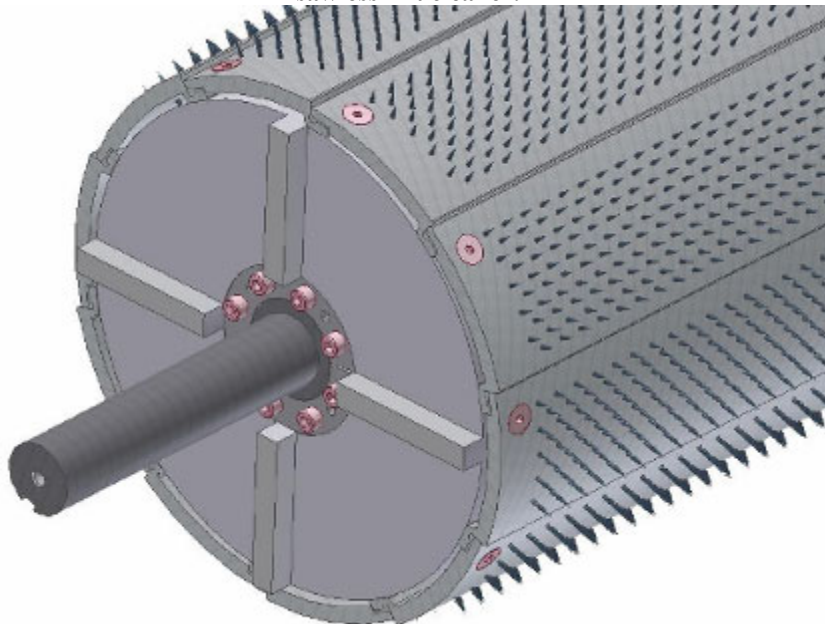


Figure 4. Close-up three dimensional view of lag set 3 on the cylinder recently evaluated in the multibar sawless lint cleaner.

Summary and Conclusions

A prototype sawless lint cleaner named the Multibar Sawless Lint Cleaner (MBSLC) was developed and tested at the USDA-ARS, Cotton Production and Processing Research Unit's gin lab in Lubbock, Texas. The initial evaluation consisted of ginning one variety of cotton and comparing turnout, fiber properties, and lint cleaner waste to a conventional saw-type lint cleaner. The results indicate the MBSLC to have longer length, less short fiber content, fewer neps and a higher turnout than the saw-type lint cleaner. However, the MBSLC had higher foreign matter, more leaf, and lower Rd than the conventional lint cleaner. The less aggressive nature of the MBSLC appears to be beneficial for retaining length and reducing neps but results in more foreign matter being left in the lint. Overall, the MBSLC has promise as a first stage of lint cleaning or a stand alone lint cleaner. Working as the first stage of a two stage lint cleaning operation, the MBSLC may allow a second stage saw-type lint cleaner to do a better job of combing and cleaning the cotton than two stages of saw-type lint cleaning. As a stand alone lint cleaner that replaces saw-type lint cleaning, the MBSLC needs to do a better job of removing foreign matter without adversely effecting fiber properties. Recent studies, just completed, evaluated various pin patterns and pin densities using three cotton varieties with varying trash levels. Samples from this most recent test have been sent for fiber property and spinning analyses. Based on the findings from this latest test, future studies may focus on optimizing the operational settings of the most promising pin patterns/pin densities patterns evaluated.

Acknowledgement

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