DEVELOPMENT OF AN AIR-BAR LINT CLEANER

Ruixiu Sui
USDA-ARS Crop Production Systems Research Unit
Stoneville, Mississippi
Richard Byler
USDA-ARS Cotton Ginning Research Unit
Stoneville, Mississippi

Abstract

Saw-type lint cleaners are now the most common lint cleaners used at gins because of their higher cleaning efficiency. Saw-type lint cleaning improves the grade of the fiber and increases the market value for the farmer. However, during the cleaning process the saw-type lint cleaners damage fiber in creating short fibers and neps. An innovative air-bar cotton lint cleaner (ABLC) was designed and built. The ABLC used pressurized air to remove non-lint materials from cotton fiber while the cotton fiber batt was on a rotating saw cylinder. Thus, non-lint materials attached to the fiber were blown off the fiber without fiber making mechanical contact with a solid object, such as a grid bar. So, the fiber quality could be preserved by reducing the damage from mechanical impact of the fiber against grid bar during the lint cleaning process. Preliminary testing of the ABLC prototype was conducted. Compared with cotton cleaned using the conventional saw-type lint cleaner, cotton cleaned using the ABLC had better fiber quality properties, including less short fiber content, less trash content, longer fiber length by number, less immature fiber content, lower yellowness, and less lint content in the lint waste.

Introduction

U.S cotton is machine-harvested and contains about 13 to 35% foreign matter (Funk et al., 2005). It is desirable for as much foreign matter as possible, within fiber-damage constraints, to be removed from cotton fiber at the gin. The process to remove the foreign matter at gin involves cylinder cleaners and stick machines before fiber-seed separation to remove large particles of the foreign matter from the seed cotton and lint cleaners after fiber-seed separation to remove smaller particles that remain in cotton. Two general types of lint cleaners 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 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). The scrubbing action is a harsh mechanical process in which fibers in the thinned batt are pulled rapidly across the edges of the grid bars, possibly causing some fibers to break and potentially resulting in lower grades for fiber length and length uniformity (Thomasson and Sui, 2007). While it is likely that some fiber damage occurs at the transition between feeder roll and saw cylinder (Gordon and Bagshaw, 2007), it is reasonable to assume that most damage occurs at the grid bars. In fact, the new technology to reduce fiber damage reported by Anthony (2000) was successful in reducing short fiber content simply by disengaging some of the grid bars in the lint cleaners. Over the years, almost all the significant attempts at developing new lint cleaning technologies have involved variations on this standard saw-type of lint cleaner: controlling the number of lint cleaners (Griffin, et al., 1982), controlling the number of grid bars in contact with the fiber (Anthony, 2000), controlling fiber moisture content so the lint cleaners don't cause excessive fiber damage (Byler, 2003). There have also been minor modifications to this basic design, such as changes in tooth configuration of the saw cylinder, adding air assist, and adding brushes (Baker, et al., 1992; Delhom and Byler, 2009). However, today the ginning industry basically uses the same cleaning principles that were developed in the 1940s.

Objective of this research is to create a novel lint cleaning method and use it to develop a new type of cotton lint cleaner that removes non-lint materials in cotton with less damage and loss of cotton fiber.

Materials and Methods

Invention Concept

A novel concept device for cotton lint cleaning at gins was created (Sui, 2010). The concept device could be stated as follows: While cotton fiber batt is on a rotating saw cylinder, non-lint materials attached on the fiber can be blown off by pressured airflow and the fiber held by saw teeth of the saw cylinder will remain on the cylinder. In such a manner the non-lint materials in cotton can be removed without mechanical contact with the cotton fiber so that the fiber will not be damaged during the cleaning process. A nozzle array or similar devices can be configured with compressed air to generate a layer of concentrated airflow to jet toward the cotton batt on the saw cylinder. Pressure and direction of the airflow and the distance between the nozzle array and the saw cylinder are crucial parameters to be adjusted for optimizing the cleaning efficiency.

System Design

Based on the concept described above, an experimental air-bar device was developed for a new type of lint cleaner (air-bar lint cleaner or ABLC, Figs. 1a, 1b, and 1c). The air-bar device was mainly a nozzle array made of eight flat nozzles and two manifolds. Each manifold contained four nozzles (Model No. 394, Silvent Advanced Air Nozzle Technology, Potage, IN). Air inlets in two manifolds were connected via a three-way connector, and air entry was connected to compressed air source through an air hose. Maximum operating pressure of the nozzle array was 1.0 Mpa (143.0 psi). Blowing force of each nozzle is 4.7N (17 oz) with air consumption of 26 Nm^3/h (15.3 scfm) at air pressure of 413.7kPa (60 psi). The nozzle array was mounted onto an aluminum alloy plate with one metal bracket at each end. The bracket was designed to adjust airflow direction of the nozzle array and the distance from the array to the saw cylinder. Dimension of the air-bar is 483L X 127W X 51D mm (19"L X 5"W X 2"D). To build the ABLC prototype, one of the conventional flow-through saw-type lint cleaners at the micro-gin (Anthony and McCaskill, 1972) was modified by replacing the first grid bar with the air-bar device. Horizontal distance between the tip of the nozzle array and the saw teeth was 9.5mm (0.375"). The angle of the nozzle array toward the saw cylinder was adjusted to zero for the test reported herein.

An air compressor (Ingersoll Rand, www.ingersollrand.com) was used to provide pressured air for the air-bar. An air regulator was implemented between the compressor and the air-bar to control the air pressure.

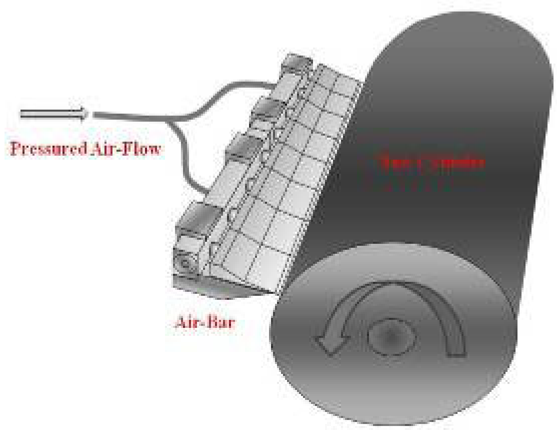

Figure 1a. Air-bar device and the saw cylinder

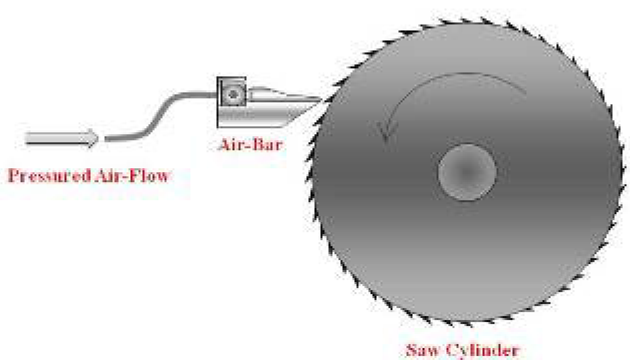

Figure 1b. Air-Bar device and the saw cylinder (side-view)

Figure 1c. Air-bar device as installed in cotton lint cleaner.

ABLC Test

To evaluate the ABLC prototype, a preliminary test was conducted at USDA-ARS Cotton Ginning Research Unit (CGRU) at Stoneville, Mississippi, on 6 Oct 2010. To compare the performance of the ABLC with the conventional saw-type lint cleaner (STLC), another STLC identical to the ABLC except for the first grid bar, was employed in the test. The ABLC and the STLC were arranged allowing either of them to be selected for use with ginned samples. Ten bags of seed-cotton (variety: Stoneville-4427 B2RF) were randomly selected as samples for the test. Each bag weighed about 20kg. One bag was ginned at each run. After a bag was ginned with the ABLC, and the next bag was ginned with the STLC. This resulted in a total of five runs with the ABLC and five with the STLC. In the ginning process only one lint cleaner (ABLC or STLC) was used, and all ginning equipment and conditions involved, except the lint cleaner, were identical for all runs. The sequence included dryer 1, cylinder cleaner, stick machine, dryer 2, cylinder cleaner, extractor feeder gin stand, and ABLC or STLC. No heat was added in the dryers. For each run, five subsamples of lint were collected after lint cleaning for Advance Fiber Information System (AFIS) analysis, five subsamples for High Volume Instrument (HVI) test, and five samples for moisture content (MC) measurement. Additionally, lint cleaner waste was collected and total lint of each sample was weighed. AFIS and MC analysis of the subsamples were conducted in the lab of CGRU. The HVI test was made at USDA-ARS Southern Regional Research Center (SRRC) at New Orleans, LA. The lint cleaner waste was analyzed using Shirley Trash Separator at CGRU.

Data Analysis

The data from AFIS and HVI tests of the samples were analyzed using One-way ANOVA and a Tukey post-hoc test with SAS to compare the effect of the ABLC and the STLC on fiber quality. The ratio of lint waste weight to lint weight was calculated for each sample. Shirley separation data of the lint waste were analyzed for the ratio of trash to lint to find the effect of the ABLC on the lint waste in comparison with the STLC.

Results

AFIS Test

Table 1 indicates means and significant differences between lint cleaner treatments by AFIS measurement. A one-way ANOVA test revealed the short fiber content (SFC) in the samples differed significantly as a function of the lint cleaner ($F(1, 48) = 7.59$, $p = 0.0083$). The ABLC generated lower SFC ($M = 9.81$, $SD = 0.58$) than the STLC ($M = 10.28$, $SD = 0.62$). The one-way ANOVA test also indicated the effect of the lint cleaner on the trash content ($F(1, 48) = 5.82$, $p = 0.0197$), immature fiber content ($F(1, 48) = 8.7$, $p = 0.0049$), and fiber length by number ($F(1, 48) = 4.19$, $p = 0.0462$) were significant. There was less trash ($M = 126.28$, $SD = 22.50$) in samples cleaned by ABLC than that ($M = 142.24$, $SD = 24.24$) in the samples by the STLC. The samples cleaned by ABLC contained less immature fiber ($M = 8.06$, $SD = 0.46$) than that by STLC ($M = 8.42$, $SD = 0.40$). Mean of the fiber length by number of the samples cleaned by the ABLC ($M = 0.74$, $SD = 0.01$) was greater than that of the samples by the STLC ($M = 0.73$, $SD = 0.01$). However, the effect of the lint cleaner on the fiber length by weight was not significant at 0.05 level ($F(1, 48) = 2.67$, $p = 0.1090$). No Significant effect on the nep size was found ($F(1, 48) = 0.23$, $p = 0.6313$).

Table 1. Effect of the lint cleaners on the selected AFIS fiber quality. Means in rows with the same letter were not significantly different at 0.05 level. (n=25).

AFIS fiber property	ABLC Prototype		Saw-Type Lint Cleaner		Pr > F
	Mean	SD	Mean	SD	
Nep size (µm)	680.00[a]	13.10	681.96[a]	15.50	0.6313
Nep by weight (count/g)	255.40[a]	28.41	258.64[a]	22.37	0.6562
Total trash (count/g)	595.76[a]	90.05	662.60[b]	113.77	0.0256
Dust (count/g)	469.28[a]	69.79	520.48[b]	92.84	0.0323
Trash (count/g)	126.28[a]	22.50	142.24[b]	24.24	0.0197
Visible foreign matter (%)	2.16[a]	0.39	2.48[b]	0.45	0.0116
Fiber length by weight (in)	0.92[a]	0.01	0.92[a]	0.01	0.1090
Short fiber content by weight (%)	9.81[a]	0.58	10.28[b]	0.62	0.0083
Fiber length by number (in)	0.74[a]	0.01	0.73[b]	0.01	0.0462
Short fiber content by number (%)	28.10[a]	1.30	29.03[b]	1.25	0.0126
Fiber fineness (millitex)	162.16[a]	1.72	160.84[b]	2.06	0.0175
Immature fiber content (%)	8.06[a]	0.46	8.42[b]	0.40	0.0049
Maturity ratio	0.87[a]	0.01	0.86[b]	0.01	0.0023

HVI Test

Selected HVI test results are illustrated in Table 2. A one-way ANOVA test indicated the micronaire in the samples did not differ significantly as a function of the lint cleaner ($F(1, 48) = 0$, $p = 0.9454$). The mean of the micronaire with both the ABLC and STLC was 4.00. However, the effect on the short fiber index ($F(1, 248) = 6.67$, $p = 0.0104$) and the yellowness ($F(1, 248) = 25.03$, $p<0.001$) were significant. Mean of the short fiber index of samples with the ABLC (M = 9.42, SD = 1.07) was lower than that with the STLC (M = 9.79, SD = 1.19). Mean of the yellowness with the ABLC (M = 8.58, SD = 0.25) was lower than that with the STLC as well (M = 8.73, SD = 0.23). No other quality measurements were significant.

Table 2. Effect of the lint cleaners on the selected HVI fiber quality. Means in rows with the same letter are not significantly different at 0.05 level. (n=125).

HVI fiber property	ABLC		STLC		Pr > F
	Mean	SD	Mean	SD	
Micronaire	4.00[a]	0.08	4.00[a]	0.07	0.9454
Short fiber index (%)	9.42[a]	1.07	9.79[b]	1.19	0.0104
Yellowness (+b)	8.58[a]	0.25	8.73[b]	0.22	<0.0001

Shirley Separation

The results of analysis of lint waste data are illustrated in Table 3. The ABLC had a higher turnout than the STLC. Mean of the ratio of lint waste weight to lint weight with the ABLC (M = 0.0172, SD = 0.0170) was less than that with the STLC (M = 0.0243, SD = 0.0059). Shirley data showed that there was 43% less lint in the lint waste using the ABLC than that using the STLC. 35% of lint waste from the ABLC was lint compared with 50% from the STLC.

Table 3. Results of Shirley separation of lint waste.

Lint Cleaner	Run	Lint waste/ lint	Lint waste (g)	Cleaned lint (g)	Visible waste (g)	Cleaned lint/ lint waste
ABLC	1	0.0103	74.53	26.7	46.56	0.3582
	2	0.0141	123.94	44.62	77.3	0.3600
	3	0.0047	29.37	8.93	19.93	0.3041
	4	0.0100	69.5	24.73	43.34	0.3558
	5	0.0470	339.17	128	205.24	0.3774
STLC	1	0.0249	173.2	78.76	91.56	0.4547
	2	0.0183	121.97	62.79	57.2	0.5148
	3	0.0215	161.01	81.04	76.92	0.5033
	4	0.0160	140.85	72.59	66.42	0.5154
	5	0.0310	227.12	115.93	109.38	0.5104

Discussion

STLC is now the most common lint cleaner because of its higher cleaning efficiency ability to improve the grade classification of the cotton fiber and increase the market value in the current marketing system. However, STLC damages fiber in creating short fibers and neps and reduces bale weights (Mangialardi and Anthony, 1998). Operation principle of the ABLC reported in this article has a fundamental difference from the STLC. The ABLC removed the non-lint materials without mechanical contact between the fiber and the air-bar so that the fiber is not damaged at the bar. Preliminary test results indicated that the ABLC was superior to the conventional STLC in terms of preserving fiber quality including SFC, turnout, and fiber length.

The ABLC used in this test only replaced one grid bar by the air-bar. More than one air-bar can be used in one ABLC, and a better performance can be expected with multi-air-bar lint cleaner. The operation efficiency and effectiveness of the ABLC could be affected by many factors such as the pressure and direction of the airflow, distance between the air-bar nose and the saw cylinder, and physical properties of the saw teeth. This paper reported only on the first phase of ABLC development -- proof of concept. In the next phase of this study, the ABLC will be systematically evaluated under different conditions. The system will be refined accordingly.

Summary and Conclusions

An air-bar lint cleaner (ABLC) has been developed at USDA-ARS-CGRU at Stoneville, MS. The ABLC is a new type of lint cleaner that uses pressured airflow to remove non-lint materials from lint cotton at the gin. There is no mechanical interaction between the fiber and the air-bar of the ABLC in the lint cleaning process so that no fiber damage occurs at the bar. Preliminary tests of the ABLC prototype were conducted and superior results were indicated compared with the conventional saw-type lint cleaner (STLC) in terms of preserving cotton fiber quality at the same production rate. Cotton cleaned using the ABLC had better fiber quality properties, including less short fiber content, less trash content, longer fiber length by number, less immature fiber content, lower yellowness, and less lint content in the lint waste compared with cotton cleaned using the STLC. Those promising results suggested that the ABLC has significant potential to be used in the cotton industry. More tests and adjustments of relevant parameters of the ABLC will be needed to improve its performances in the next phase of study.

Acknowledgements

The authors would like to extend their appreciation to the staff at USDA-ARS CGRU at Stoneville, MS and Chris D. Delhom of SRRC at New Orleans, LA, for their assistance in this study.

Disclaimer

Mention of a commercial product is solely for the purpose of providing specific information and should not be construed as a product endorsement by the authors or the institutions with which the authors are affiliated.

References

Anthony, W.S. 2000. Methods to reduce lint cleaner waste and damage. *Trans. ASAE* 43(2): 221-229.

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

Anthony, W.S., and O.L. McCaskill. 1972. Development of a model cotton ginning system. *ASABE paper*, presented at Southeastern Regional Meeting, St. Joseph, Mich.: ASABE.

Baker, R.V., S.E. Hughs, and G.J. Mangialardi. Lint cleaning: Basic principles and new developments. 1992. In *Proc. Beltwide Cotton Conf.* pp. 538-542. Memphis, Tenn.: Nat. Cotton Council. Am.

Byler, R.K. 2003. Moisture restoration for seed cotton, two approaches. In *Proc. Beltwide Cotton Conf.* pp. 767-771. Memphis, Tenn.: Nat. Cotton Council. Am.

Delhom, C.D., and R.K. Byler. 2009. Study of a wire brush grid bar replacement for saw-type lint cleaners. In *Proc. Beltwide Cotton Prod. Res. Conf.*, pp.487-491. Memphis, TN: National Cotton Council.

Funk, P.A., C.B. Armijo, A.T. Hanson, Z.A. Samani, M.A. Macias-Corral, G.B. Smith, and J.T. Riordan. 2005. Converting gin and Dairy wastes to methane. *Transactions of ASAE*, Vol. 48(3):1197-1201.

Griffin, A.C., G.J. Mangialardi, Jr., and J.D. Bargeron, III. 1982. Six-stage lint cleaning: Effect on fiber and spinning quality parameters. In *Proc. Beltwide Cotton Prod. Res. Conf.*, 164-167. Memphis, TN: National Cotton Council.

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.* pp. 1977-1982. Memphis, Tenn.: Nat. Cotton Council. Am.

Mangialardi, G.J., Jr. and W.S. Anthony. 1998. Field evaluations of air and saw lint cleaning systems. J. Cotton Sci. 2:53–61.

Sui, R., 2010. Unpublished material. USDA-ARS, Cotton Ginning Research Unit, Stoneville, MS.

Thomasson, J. A., R. Sui, and P. Popov. 2007. Modeling cotton fiber dynamics in a lint cleaner. In *Proc. Beltwide Cotton Conf.* pp. 967-973. Memphis, Tenn.: Nat. Cotton Council. Am.