EFFECT OF SEED COTTON CLEANER SPEEDS ON MACHINE PERFORMANCE

Robert G. Hardin IV
USDA-ARS Cotton Ginning Research Unit
Stoneville, MS

Abstract

Past research has shown that increasing seed cotton cleaner speeds can improve cleaning efficiency. Advances in process control may make cleaner speed control feasible; however, an improved understanding of seed cotton cleaner performance at higher operating speeds is needed. The objectives of this study were to determine the effect of cylinder cleaner speed and stick machine saw speed on cleaning performance and fiber loss and to evaluate how cleaner speeds affect fiber quality and turnout. Seed cotton was processed through the minimum recommended sequence of ginning machinery. Four cultivars were processed at five cylinder cleaner speeds and five stick machine speeds. Samples were collected from the seed cotton for determining moisture and foreign matter content. The material removed by the seed cotton cleaners was also sampled to determine fiber loss. HVI and AFIS samples were collected before and after the lint cleaner to evaluate fiber quality. Weights of all process streams were recorded to determine the proportion of material removed by each cleaner and lint turnout. Higher cleaner speeds increased material removal by the cleaner. Cylinder cleaner fiber loss was increased at higher speeds. Samples for determining fiber loss from the stick machine have not been analyzed. Leaf grades were not affected by cleaner speed; however, all speeds produced desirable leaf grades, with average leaf grades of 2.1 before and 1.2 after the lint cleaner. Higher cylinder cleaner speeds reduced AFIS dust and trash measurements, but other HVI and AFIS fiber quality parameters were not significantly affected by cleaner speed. Turnout and loan value were also not affected by cleaner speed. Further research is needed with cotton that is more difficult to clean or contains higher levels of foreign matter.

Introduction

Previous research has indicated that seed cotton cleaner speeds, other than the standard factory settings, may provide improved cleaning efficiency. Cylinder cleaner speeds have been found to have a significant effect on cleaning efficiency. Cocke (1972) found that increasing the cylinder speed from 350 rpm to 650 rpm increased the weight of trash removed by the cylinder cleaner; however, the overall seed cotton cleaning system efficiency did not change significantly. Read (1972) had similar results when increasing the cylinder speed from 400 rpm to 550 rpm. Ray (2006) tested different grid bar configurations at cylinder speeds of 480 rpm and 980 rpm. Higher cleaning efficiency occurred at 980 rpm for all grid bar configurations, while seed cotton loss increased for round and sharp grid bars. Seed cotton loss was negligible at both speeds for flat, square grid bars.

While the effect of varying stick machine saw speeds has not been reported, several researchers have studied the effect of saw speed with stripper harvester field cleaners. The design and operation of field cleaners is similar to stick machines, except for their location on the harvester, instead of in the gin. Kirk et al. (1970) determined that increasing saw speed increased cleaning efficiency, but also increased fiber loss. Wanjura et al. (2009) also found similar results.

The decreasing cost of control hardware and software may make cleaner speed control profitable for cotton gins. However, development of these control systems requires testing a greater range of cylinder and saw speeds and further investigation of the trade-off between cleaning and fiber loss for multiple cultivars. Fiber is lost from seed cotton cleaners in commercial gins; however, the quantity is unknown. Fiber loss is affected by cultivar (Hardin and Byler 2013); however, the physical properties responsible for this variation are unknown. Increasing seed cotton cleaner speeds may provide some evidence of the mechanisms of this fiber loss.

This research was conducted to gain a greater understanding of seed cotton cleaner performance at different operating speeds. The specific objectives of this work were to:

- Determine the effect of cylinder cleaner speed on cleaning performance and fiber loss
- Determine the effect of stick machine saw speed on cleaning performance and fiber loss
- Evaluate how cleaner speeds affect fiber quality and turnout

Materials and Methods

The effect of cylinder cleaner speeds and stick machine saw speeds on cleaning efficiency and fiber loss was determined when processing picker-harvested seed cotton through the minimum recommended sequence of ginning machinery (Baker, Anthony and Sutton 1994). Cotton was processed through a tower dryer, cylinder cleaner (CC1), stick machine (SM), tower dryer, cylinder cleaner (CC2), extractor-feeder (EF), gin stand and lint cleaner. The first stage dryer temperature was 38°C (100°F), while ambient air was used in the second stage dryer. The six-cylinder cleaners used were 25.4-cm (10-in.) wide (Lummus Corporation, Savannah, GA). The three-saw stick machine was a 30.5-cm (12-in.) wide version of a Continental Eagle Little David stick machine (Continental Eagle Corporation, Prattville, AL). A 35.6-cm (14-in. wide) Continental Commander extractor-feeder metered seed cotton to a 20-saw Continental Double Eagle gin stand, which was followed by a 38.1-cm (15-in.) wide version of a Continental 16-D lint cleaner (Continental Eagle Corporation, Prattville, AL). The processing rate of seed cotton through all equipment was approximately 8 kg min^{-1} (18 lb min^{-1}).

Variable-frequency drives were used to adjust the speed of both cylinder cleaners and the stick machine. Cylinder cleaner speeds tested were 480 (standard factory setting), 600, 720, 840, and 960 rpm, with both cylinder cleaners operated at the same speed. Stick machine primary saw speeds tested were 400 (standard factory setting), 500, 600, 700, and 800 rpm. Each cylinder cleaner speed was tested at the standard stick machine saw speed, and each stick machine saw speed was tested at the standard cylinder cleaner speed, resulting in nine machine speed combinations. Four cultivars grown in 2011, were used in testing: DP 161 B2RF (Monsanto, St. Louis, MO), FM 1740 B2F, ST 4427 B2RF, and ST 4554 B2RF (Bayer CropScience, Research Triangle Park, NC). DP 161 B2RF and FM 1740 B2F are smooth-leaf cottons, while ST 4427 B2RF and ST 4554 B2RF are hairy-leaf cultivars. The experiment was conducted as a factorial combination of machine speed combination and cultivar blocked by replication, with three replications used for a total of 108 ginning lots.

Before processing, a single seed cotton sample for moisture content determination (Shepherd 1972) and three samples for foreign matter content determination by pneumatic fractionation (Shepherd 1972) were collected. After sampling, each test lot was weighed. While processing each test lot, one seed cotton sample for moisture content determination and three seed cotton samples for foreign matter content determination were collected at the feeder apron. The material removed by each cleaner was also weighed and a single sample of at least 25 g collected. This sample was manually sorted into individual components: burrs, sticks, motes, leaf, fine trash, lint, and seeds. The percent lint content of this sample was multiplied by the weight of material removed by the cleaner and divided by the initial seed cotton weight to determine the amount of fiber lost as a percent of the total seed cotton weight. Two High Volume Instrument (HVI) and three Advanced Fiber Information System (AFIS) samples were collected before the lint cleaner to evaluate foreign matter content of the lint and fiber quality. Three HVI, three AFIS samples, and a single sample for lint moisture content determination (American Society for Testing and Materials (ASTM) 2007) were collected after the lint cleaner. Lint, seed, and the material removed by the lint cleaner were weighed. Lint turnout (lint weight divided by seed cotton weight) was calculated and adjusted by the weight of samples removed during processing (at the feeder apron or before the lint cleaner). Fiber loss per bale was determined by dividing the amount of fiber lost as a percent of the total seed cotton weight by the lint turnout, and multiplying by a bale weight of 227 kg (500 lb).

Two statistical analyses were conducted. One analysis determined the effects of cylinder cleaner speeds and cultivars (with the stick machine operated at the standard speed) and the other analysis examined the effects of stick machine speeds and cultivars (with the cylinder cleaner operated at standard speed). Seed cotton foreign matter content, cleaning efficiency, total material removed by the seed cotton cleaners, seed cotton loss, and fiber quality parameters were used as dependent variables in the statistical analyses. The mixed models procedure in SAS, *PROC MIXED*, was used for the statistical analyses (SAS 9.2, SAS Institute, Inc., Cary, N.C.). Least squares means of dependent variables were calculated for machine speeds and cultivars.

Results and Discussion

Cylinder Cleaner Speeds

Initial seed cotton moisture content averaged 8.1% (w.b.) and seed cotton moisture content at the feeder apron was 7.6%. Lint moisture content averaged 5.1%. Cylinder cleaner speed did not affect moisture content at any sampling location. The foreign matter content of the seed cotton before processing and at the feeder apron after all seed cotton

cleaning is shown for each cultivar in Table 1. Seed cotton foreign matter content was not affected by cylinder cleaner speed at either location.

Table 1. Foreign matter content of seed cotton before and after seed cotton cleaning for different cultivars.[a]

Cultivar	Foreign Matter Content (% by weight)	
	Initial	After EF
DP 161 B2RF	6.8a	3.1a
FM 1740 B2F	5.7b	2.6b
ST 4427 B2RF	7.7c	3.7c
ST 4554 B2RF	7.6c	3.1a

[a]Means in a column followed by the same letter were not significantly different at the 5% level.

Faster cylinder cleaner speeds resulted in more material removed by both cylinder cleaners and the entire seed cotton cleaning system (Table 2). Although the difference was small, less material was removed by the stick machine for the lots processed with faster cylinder cleaner speeds. This result was likely because the seed cotton was cleaner entering the stick machine, so less material was removed. The greater quantity of foreign matter removed at higher cylinder cleaner speeds should have been reflected in the foreign matter content determined by pneumatic fractionation. However, the expected differences in foreign matter content were too small to be significant, given the variation in samples collected for pneumatic fractionation. Cultivar had a significant effect on the amount of material removed by each machine.

Table 2. Material removed by seed cotton cleaners at different cylinder cleaner speeds. [a]

Cylinder Cleaner	Mass Removed (% of initial seed cotton weight)			
Speed (rpm)	CC1	SM	CC2	Total
480	1.41a	1.51ab	0.64a	4.41a
600	1.59b	1.61a	0.76b	4.86b
720	1.83c	1.51ab	0.96c	5.12b
840	2.07d	1.43bc	1.20d	5.51c
960	2.41e	1.32c	1.57e	6.14d

[a]Means in a column followed by the same letter were not significantly different at the 5% level.

More fiber was lost from the cylinder cleaners when operated at higher speeds (Table 3). Cultivar did not have a significant effect on fiber loss from the cylinder cleaners. A greater portion of the material removed by the second stage cylinder cleaner was fiber, as the fiber loss from each stage was similar at each speed tested, and less total material was removed by the second stage cylinder cleaner.

Table 3. Fiber loss from seed cotton cleaners at different cylinder cleaner speeds. [a]

Cylinder Cleaner	Fiber Loss (kg per 227 kg bale)	
Speed (rpm)	CC1	CC2
480	0.13a	0.17a
600	0.30a	0.32a
720	0.60a	0.64b
840	1.17b	0.84b
960	1.69b	1.31c

[a]Means in a column followed by the same letter were not significantly different at the 5% level.

Cylinder cleaner speed had no significant effect on any HVI measurement before or after the lint cleaner. The cotton tested was quite clean, even before the lint cleaner. HVI leaf grades averaged 2.1 before the lint cleaner and 1.2 after

the lint cleaner. AFIS measurements of lint dust and trash content did show significant differences between cylinder cleaner speeds (Table 4). Faster cylinder cleaner speeds reduced dust, trash, and visible foreign matter in the lint, even after the lint cleaner. Other AFIS measurements, including fiber length parameters, nep counts, maturity, and fineness, were not affected by cylinder cleaner speed.

Table 4. AFIS dust and trash measurements at different cylinder cleaner speeds. [a]

Cylinder Cleaner	Total Count/g		Dust Count/g		Trash Count/g		Visible Foreign Matter (%)	
Speed (rpm)	Before LC	After LC	Before LC	After LC	Before LC	After LC	Before LC	After LC
480	1174a	728a	974a	592a	200a	135a	3.89a	2.52a
600	1140ab	721a	947ab	585a	193ab	135a	3.71ab	2.40a
720	1046bc	625b	870bc	508b	176bc	117b	3.45bc	2.19b
840	895d	565c	736d	459c	159c	105c	3.24c	1.98c
960	950cd	579bc	786cd	473bc	164c	106c	3.37bc	2.07bc

[a]Means in a column followed by the same letter were not significantly different at the 5% level.

Cylinder cleaner speed did not have a significant effect on turnout or loan value before or after the lint cleaner. The least significant difference (LSD) for turnout between different cylinder cleaner speeds was 1.25%. The difference in the amount of material removed by the seed cotton cleaners between the lowest speed and the highest speed was only slightly larger than this LSD, and the lint cleaner partially compensated for the decreased cleaning at lower cylinder speeds. With no significant differences in turnout or HVI parameters, loan value would not be expected to differ between cylinder cleaner speeds.

Stick Machine Speeds

Initial seed cotton moisture content averaged 8.1% (w.b.) and seed cotton moisture content at the feeder apron was 7.5%. Lint moisture content averaged 5.1%. Stick machine speed did not affect moisture content at any sampling location. The foreign matter content of the seed cotton before processing and at the feeder apron after all seed cotton cleaning is shown for each cultivar in Table 5. Seed cotton foreign matter content was not affected by stick machine speed at either location.

Table 5. Foreign matter content of seed cotton before and after seed cotton cleaning for different cultivars. [a]

Cultivar	Foreign Matter Content (% by weight)	
	Initial	After EF
DP 161 B2RF	6.5a	3.5ab
FM 1740 B2F	5.9a	2.5a
ST 4427 B2RF	7.8b	3.7b
ST 4554 B2RF	7.7b	4.4b

[a]Means in a column followed by the same letter were not significantly different at the 5% level.

Higher stick machine saw speeds increased the amount of material removed from the stick machine slightly (Table 6). The same effect was observed with the second stage cylinder cleaner, although the differences are not likely to be practically important. The higher saw speeds may have more efficiently dispersed the seed cotton, allowing for better cleaning by the subsequent cylinder cleaner. The significant differences observed for the material removed by the first stage cylinder cleaner were not expected, since all test lots were processed identically though this machine. Only one speed is significantly different from the others; this difference may be due to variability in the seed cotton tested. The stick machine saw speed did not have a significant effect on the total amount of material removed by the seed cotton cleaning system.

Table 6. Material removed by seed cotton cleaners at different stick machine saw speeds. [a]

Stick Machine Primary Saw Speed (rpm)	Mass Removed (% of initial seed cotton weight)		
	CC1	SM	CC2
400	1.41a	1.51a	0.64a
500	1.59b	1.63ab	0.64a
600	1.45a	1.76bc	0.66ab
700	1.43a	1.74bc	0.69bc
800	1.39a	1.83c	0.72c

[a]Means in a column followed by the same letter were not significantly different at the 5% level.

Samples from the material removed by the stick machine have not been analyzed; consequently, there is no data on fiber loss from the stick machine. The stick machine saw speed had no effect on fiber loss from the other seed cotton cleaners.

Stick machine saw speed did not significantly affect any HVI measurement. The average leaf grade was 2.2 before the lint cleaner and 1.2 after the lint cleaner. No differences due to stick machine saw speed were observed in AFIS measurements of fiber length, maturity, nep content, or fiber dust and trash content. Since the total amount of material removed by the seed cotton cleaners and fiber quality did not vary with stick machine saw speed, no differences were observed in turnout or loan value.

Discussion

The seed cotton tested in this study had 7.0% initial foreign matter content, similar to the range observed in commercial Mid-South gins (Hardin 2012). However, all machine speeds tested produced desirable leaf grades for all cultivars, even without lint cleaning. Although extra material was removed by the cylinder cleaners and stick machine when operated at higher than standard speeds, this additional cleaning was not necessary and did not affect leaf grade. Consequently, the minimum cleaning machinery operated at standard speeds would be sufficient for all cotton tested in this study. Other factors may have contributed to these desirable leaf grades, such as an appropriate moisture content for processing, favorable weather during the 2011 growing season, effective harvest aid application, and the characteristics of the cultivars tested. For instance, ST 4554 B2RF is a hairy-leaf cultivar that typically has a higher seed cotton foreign matter content (Tables 1 and 5). However, this cultivar was efficiently cleaned and had a significantly lower leaf grade before the lint cleaner (1.25) and after the lint cleaner (1.01) than the other cultivars tested. The cultivars selected for testing may have been easier to clean than other commercial cultivars.

The most common color grades for Mid-South and Southeast cotton in 2012, were 41 and 31, while the most prevalent leaf grades were 3 and 4 (USDA-AMS 2013). Significant economic benefit results from cleaning cotton with a color grade of 31 to a leaf grade of 3 or cotton with a color grade of 41 to a leaf grade of 4. With cotton containing more foreign matter or from cultivars that are more difficult to clean, ginners may have to use two stages of lint cleaning to obtain the desired leaf grades. With some cotton, two lint cleaners are not sufficient to produce the desired leaf grade. In these situations, increasing the cylinder cleaner speed or stick machine saw speed may be useful for achieving the preferred leaf grade with a minimum number of lint cleaners. Further research is needed with cotton that produces higher leaf grades, similar to most cotton typically processed by Mid-South and Southeast gins.

Conclusions

Increasing cylinder cleaner speeds resulted in a greater quantity of material removed by the cylinder cleaners. Fiber loss from the cylinder cleaners also increased with faster cylinder speeds. This extra cleaning at faster cylinder speeds was reflected in AFIS measurements of fiber trash content; however, HVI leaf grade was not affected. Cylinder cleaner speed did not affect other HVI and AFIS measures of fiber quality, such as fiber length, nep content, or maturity. Increasing stick machine saw speeds increased the amount of material removed by the stick machine, although the differences in material removal between speeds were much smaller than with the cylinder cleaner. Stick machine saw speeds did not significantly affect any HVI or AFIS fiber quality parameter. The cotton used in this study was cleaned efficiently by all seed cotton cleaner speeds tested, as the leaf grade averaged 2.1

before lint cleaning and 1.2 after lint cleaning. The minimum recommended gin cleaning machinery operated at standard settings would have been suitable for processing the cotton tested in this study. Further research needs to be conducted with cotton that is more difficult to clean or contains more foreign matter to determine if there are situations that warrant increasing seed cotton cleaner speeds.

Acknowledgements

The author would like to thank Cotton Incorporated for their financial support of this project.

Disclaimer

Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the U.S. Department of Agriculture and does not imply approval of the product to the exclusion of others that may be available.

References

American Society for Testing and Materials (ASTM). "Standard test method for moisture in cotton by oven-drying (D2495-07)." In *Annual Book of ASTM Standards Vol. 07.01*. West Conshohocken, Pennsylvania: ASTM, 2007.

Baker, R.V., W.S. Anthony, and R.M. Sutton. "Seed cotton cleaning and extracting." In *Cotton Ginners Handbook,* 69-90. Washington, D.C., D.C.: USDA Agricultural Research Service, 1994.

Cocke, J.B. *Effect of processing rates and speeds of cylinder-type cleaners on ginning performance and cotton quality.* ARS 42-199, Washington, D.C.: USDA Agricultural Research Service, 1972.

Hardin, R.G., IV. "Seed cotton cleaning in Mid-South gins." *ASABE Paper No. 12-1336886.* Dallas, Texas: ASABE, 2012.

Hardin, R.G., IV, and R.K. Byler. "Evaluation of seed cotton cleaning equipment performance at various processing rates." *Appl. Eng. in Agric.* 29, no. 5 (2013): 637-647.

Kirk, I.W., T.E. Corley, and F.A. Kummer. "Performance relations for a saw-grid seed cotton cleaner." *Trans. ASAE* 13, no. 2 (1970): 171-176.

Ray, S.J. "Alternative configurations in a cylinder-type cleaner for seed cotton." *Appl. Eng. in Agric.* 22, no. 5 (2006): 643-649.

Read, K.H. "Cylinder cleaner speed influences cleaner efficiency." *Cotton Gin and Oil Mill Press* 72, no. 24 (1972): 6-7.

Shepherd, J.V. *Standard procedures for foreign matter and moisture analytical tests used in cotton ginning research.* Agriculture Handbook No. 422, Washington, D.C.: USDA Agricultural Research Service, 1972.

USDA-AMS. *Annual quality of cotton classed- 2012 crop.* Washington, D.C.: USDA Agricultural Marketing Service, 2013.

Wanjura, J.D., G.A. Holt, R.K. Byler, A.D. Brashears, and R.V. Baker. "Development of a high-capacity extractor cleaner for cotton stripper harvesters: machine design and optimization." *Trans. ASABE* 52, no. 6 (2009): 1821-1829.