OBSERVING THE MOTION OF SEED COAT FRAGMENTS ON A SAW-TYPE LINT CLEANER Carlos B. Armijo Derek P. Whitelock Sidney E. Hughs USDA-ARS Southwestern Cotton Ginning Research Laboratory Mesilla Park, NM Edward M. Barnes Cotton Incorporated Cary, NC Marvis N. Gillum USDA-ARS Southwestern Cotton Ginning Research Laboratory Mesilla Park, NM

Abstract

A study was conducted to observe how seed coat fragments (in ginned lint) reacted after colliding with grid bars mounted on a full-size saw-type lint cleaner. A high-speed video camera recorded the collision. A 45° and 105° grid bar were used in the study. The 45° grid bar resembled a conventional grid bar used in commercial lint cleaners. The 105° grid bar was an experimental design that had a second edge a short distance from the toe of the grid bar.

The 105° grid bar was more effective than the 45° grid bar in removing seed coat fragments (SCFs). Eight percentage points more SCFs were removed by the 105° grid bar. SCFs that were removed had very few fibers attached, and velocity decayed to about one-half the saw speed before the SCF was removed. SCFs that were not removed had many fibers attached, and the velocity of the SCF decayed to zero before reversing direction as fibers still attached to the SCF pulled the SCF back to the edge of the grid bar. The clearance between the grid bar and lint cleaner saw or the position of the grid bar (1st or 2nd) did not have any effect on the number of SCFs removed.

Future work includes continuing to use the high-speed video camera in real time on the full-size lint cleaner. The high-speed camera is a valuable tool that helps in understanding the interaction between grid bar design and grid bar-to-saw clearance. A formal experiment will be rerun to determine the effectiveness of different grid bar designs.

Introduction

Seed coat fragments (SCFs) in ginned lint are a problem for the textile mill, especially during the dyeing of yarn or cloth. SCF's appear as white or dark specks in the finished fabric (Bel and Xu, 2011). One project at the USDA-ARS Southwestern Cotton Ginning Research Laboratory focuses on trying to alleviate SCFs at the saw-type lint cleaner with newly-designed grid bars. Past studies by Mangialardi and Shepherd (1968) and Mangialardi (1987) showed that SCFs were not reduced with different levels of saw-type lint cleaning, but both of these studies used conventional grid bars in the lint cleaners.

Recent research has shown that newly-designed lint cleaner grid bars may be effective in removing a SCF (Armijo et al., 2009 and Armijo et al., 2011a). This research tested 10 model-sized grid bars mounted on a lint cleaner simulator. A fiber bundle with an attached SCF was subjected to the grid bars, and a high-speed video camera recorded the action that took place as the SCF collided with the grid bar. Armijo et al. (2009) found that four out of the 10 experimental grid bars performed best in removing a SCF from the fiber bundle. These four experimental grid bars were tested in 2010 (Armijo et al., 2011b). Because of problems encountered with the 2010 study, it was decided to rerun the experiment with treatments that set the grid bars closer to the lint cleaner saw, and use a control set of grid bars mounted on the same lint cleaner as the experimental grid bars. While machine pieces were being fabricated for the rerun, some interim experiments were conducted where videos were recorded with the high-speed camera of fiber/SCFs passing over two (out of the four) experimental grid bar designs with different grid bar-to-lint cleaner saw clearances. The videos were recorded on the full-size commercial lint cleaner which had a prism mounted on the second (out of five) grid bar. The prism showed simultaneous views in the radial and axial directions of the fiber and SCFs striking the grid bar. These videos are the subject of this report.

The objective of this study was to determine how SCFs interacted with two experimental grid bars mounted on a full-size lint cleaner. A high-speed camera and prism was used to determine the displacement of SCF's as they collided with the grid bars. The study was performed at the USDA-ARS Southwestern Cotton Ginning Research Laboratory in Mesilla Park, New Mexico in 2011.

Materials and Methods

Figure 1 shows a cross section of the four experimental grid bars tested in 2010 by Armijo et al. (2011b) and scheduled to be tested in another experiment. The four grid bars were labeled as follows: 105°, 60°, 45°, and 0°R. The label of the grid bars describes the included angle from the sharp toe (or the clockwise angle from vertical) that the grid bar makes. The 0°R grid bars, the 105° and 45° degree, were used in this study reported here. The 105° grid bar had a small surface of 1.7 mm (0.065 in) from the toe of the bar, giving this bar a second active edge to help remove the SCF. The 45° grid bar did not have a second active edge; the surface length from the toe of the grid bar was about 14 mm (0.563 in). The 45° grid bar is similar in design to a grid bar found on conventional lint cleaners. The 105° and 45° grid bars were 1.64 m (64.375 in) in length and were made out of aluminum.



Figure 1. Close-up side view of the tip of four grid bar designs used in a previous study. This study focused on the 105° and 45° grid bars.

Figures 2 and 3 show how the 105° and 45° grid bar, respectively, were situated in relation to the lint cleaner saw. A commercial Continental Moss/Gordin Lodestar saw-type lint cleaner was used in the test. The Lodestar was 1.7-m (66-in) wide, had a 406-mm (16-in) diameter saw cylinder that ran at 21.3 m/s (4190 ft/min or 1000 rpm), and contained five grid bars. The distance from the feed plate to the lint cleaner saw was 1.6 mm (0.063 in), from the feed roller to the feed plate was 0.25 mm (0.010 in) (floating-spring-loaded), and from the grid bar to the saw was 1.6 mm (0.063 in). The Lodestar had a 457-mm (18-in) diameter doffing brush. Saw-type lint cleaners typically use a combing ratio (the ratio between the rim speed of the saw and the rim speed of the feed roller) between 16 and 28 (USDA, 1994). A target combing ratio of 25 was used during the test.



Figure 2. Side view of 105° grid bars in relation to the lint cleaner saw.



Figure 3. Side view of 45° grid bars in relation to the lint cleaner saw.

Figure 4 shows the overall setup of the lint cleaner, high-speed camera, prism, and chute used to feed the fiber/SCFs to the lint cleaner. The high-speed camera was a Phantom V7.1 (Vision Research, Wayne, NJ) with a 16-160 mm zoom lens and 15 mm extension tube. The video camera was set to record at 10000 frames per second. This recording rate allowed a 512x384 pixel resolution. The exposure time on the camera was set at 2 µs. The camera had 14509 frames of memory in which to capture the collision of the SCF and grid bar. The distance of saw travel between each frame was 2.13 mm (0.084 in) and the time between each frame was 100 µs. The camera had a 4800

ISO/ASA monochrome sensitivity, which reduced the lighting requirements. Lighting consisted of three 250 W high intensity tungsten halogen lamps located 0.2-0.25 m (8-10 in) away from the prism. Figure 5 shows how the camera was situated with respect to the grid bar and prism.



Figure 4. Overall setup of the lint cleaner, high-speed camera, prism, and chute used to feed fiber/SCFs to the lint cleaner.



Figure 5. Placement of high-speed video camera with respect to the grid bar and prism.

A right angle prism (Figure 6) that measured 40 mm (1.6 in) square was mounted on the 2nd grid bar (counting from the top). The prism could not be mounted on the 1st grid bar because the camera would then be mounted almost vertical and interfere with the feed rolls and condenser. The prism was used to bend the image path of fiber/SCFs at 90° which allowed views in both the radial and axial directions of the grid bar. A scale target (seen in Figure 6) was mounted about 25 mm (1 in) axially from the prism. The scale target was used to determine distances travelled by SCF's. A focus target placed in-between the prism and scale target was used to focus the camera. The camera was focused to allow about a 25 mm (1 in) depth of field view. The focus target was removed during the run. A chute that fed the fiber/SCFs to the lint cleaner measured 1.5-mm (60-in) long by 152-mm (6-in) wide by 76-mm (3-in) deep (Figures. 4 and 5). Each lot of fiber/SCFs weighed about 40 g (0.09 lb) and filled one-half of the chute. It took about one second to feed the lot to the lint cleaner. This equated to the same loading rate as a conventional Continental/Moss Gordin lint cleaner.



Figure 6. Prism was used to bend the image path of fiber/SCFs at 90°.

The videos were analyzed with software provided by the camera manufacturer (Phantom 649 software, Vision Research, Wayne, NJ). SCFs from three segments of each video (or lot) were counted. The fragment count was put into one of two categories: "return" or "trash". If the SCF was not removed by the grid bar and instead went back with the fiber attached to the lint cleaner saw, the fragment was put into the "return" category. If the SCF was removed by the grid bar and continued on with the other trash particles into the trash bin, the fragment was put into the "trash" category. Each counting segment of video consisted of three minutes of observation time at a viewing rate of 2.5 frames per second for a total of 450 frames per segment.

The test consisted of two grid bar designs $(105^{\circ} \text{ and } 45^{\circ})$, two grid bar-to-saw clearances (0.8 and 1.6 mm or 0.031 and 0.063 in), two grid bar positions (1st and 2nd), and three replications for a total of 24 lots. The Cotton Ginners Handbook specifies a grid bar-to-saw toe clearance of 0.8 mm (0.031 in), but a clearance of 1.6 mm (0.063 in) was also used in the test. Because the prism had to be mounted on the 2nd grid bar, videos were taken with both the 1st grid bar installed and then removed. This allowed the 2nd grid bar to sometimes act as if it were the first grid bar. The cotton used in the test was a cultivar known to have a fragile seed coat which may be more sensitive to differences in grid bar design. The cotton was grown in the Mesilla Valley of Southern New Mexico. The seed cotton was not pre-cleaned and ginned on a 0.2-m (8-in) diameter 8-saw breeder gin. Some of the cottonseed was cracked prior to ginning to assure that SCFs would be present in the viewing area of the high-speed camera in the short time period used on each lot. The experimental design was a randomized complete block with replications

serving as blocks. Analysis of variance was performed with the General Linear Models procedure of SAS (version 9.1; SAS Institute, Inc.: Cary, NC).

Results and Discussion

Figure 7 shows one frame of video using the 45° grid bar. The frame comes from a test lot that had all five grid bars installed and a grid bar-to-saw toe clearance of 1.6 mm (0.063 in). The "front view" looks directly at the grid bar (the radial view). The "end view" is 90° from the front view and shows a view in the axial direction of the lint cleaner. The scale target used to measure displacement of SCF's is seen in the end view.



Figure 7. One frame of video using the 45° grid bar.

Figures 8 and 9 show two situations of SCF's impacting with the 45° grid bar. Figure 8 shows a SCF that was removed by the grid bar and deposited with the lint cleaner trash. The SCF travelled about 30 mm (1.2 in) in the y-direction (x-y coordinate system) in 3 ms time. The SCF did not have many attached fibers. The velocity (data not presented) of the SCF decayed to about one-half the velocity of the lint cleaner saw in the 3 ms time period (from 21.3 m/s (4190 ft/min) to 10.6 m/s (2095 ft/min)). Figure 9 shows a SCF that was not removed with the aid of the 45° grid bar. The SCF only travelled about 15 mm (0.6 in) in the y-direction in 18 ms. The SCF had many attached fibers. The velocity of the SCF decayed to zero before reversing direction and being pulled back into the lint cleaner saw by attached fibers.



Figure 8. Path of SCF as it is removed with the aid of the 45° grid bar.



Displacement of SCF, Front View

Figure 9. Path of SCF after impacting the 45° grid bar. The SCF was not removed.

Figure 10 shows one frame of video using the 105° grid bar. As with the 45° bar discussed earlier, the frame comes from a test lot that had all five grid bars installed and a grid bar-to-saw toe clearance of 1.6 mm (0.063 in). And as before, the "front view" looks directly at the grid bar (the radial view) and the "end view" is 90° from the front view

and shows a view in the axial direction of the lint cleaner. The target used to measure displacement of SCF's is seen in the end view.



Figure 10. One frame of video using the 105° grid bar.

Figures 11 and 12 show two situations of SCF's impacting with the 105° grid bar. Figure 11 shows a SCF that was removed by the grid bar and deposited with the lint cleaner trash. The SCF travelled about 30 mm (1.2 in) in the y-direction (x-y coordinate system) in 3 ms time. The SCF did not have many attached fibers. The velocity (data not presented) of the SCF decayed to about one-half the velocity of the lint cleaner saw in the 3 ms time period (from 21.3 m/s (4190 ft/min) to 10.6 m/s (2095 ft/min)). Figure 12 shows a SCF that was not removed with the aid of the 105° grid bar. The SCF only travelled about 15 mm (0.6 in) in the y-direction in 10 ms. The SCF had many attached fibers. The velocity of the SCF decayed to zero before reversing direction and being pulled back into the lint cleaner saw by attached fibers.

Displacement of SCF, Front View



Figure 11. Path of SCF as it is removed with the aid of the 105° grid bar.

Displacement of SCF, Front View



Figure 12. Path of SCF after impacting the 105° grid bar. The SCF was not removed.

The manner in which SCF's were either removed with the aid of the grid bar or not removed and returned to the lint cleaner saw was similar with both the 45° and 105° grid bars. The SCF's that were removed had very few fibers attached, and conversely, SCF's that were not removed had many attached fibers. However, there was a significant

difference in the proportion of SCF's removed between grid bar design (Table 1). The 105° grid bar removed more SCF's. Based on three separate counts (replications) of 450 frames per count, the 105° grid bar removed 21.2% of the SCF's and the 45° bar removed 13.2%. As reported by Armijo et al. (2011a), the 105° grid bar may be more effective in removing SCF's due to the 105° grid bar having a larger (than conventional) included angle of the sharp toe of the grid bar, and having a second corner (edge) a short distance from the toe of the grid bar. Table 1 also shows that the number of SCF's removed was not affected by the clearance between the grid bar and the lint cleaner saw nor the position of the grid bar (1st or 2nd position).

	SCF's	SCF's	SCF's	SCF's	
	Removed	Removed	Removed	Removed	
	1st count	2nd count	3rd count	Overall	
	%	%	%	%	
		Lint Cleaner Treatment			
105° Grid Bar	29.2	24.8	15.8	21.2	
45° Grid Bar	13.3	14.4	10.3	13.2	
	<u>(</u>	Observed Significance Leve	el ^[z]		
Bar Angle	0.0117	0.0414	NS	0.0039	
Bar Clearance	NS	NS	NS	NS	
Bar Position	NS	NS	NS	NS	

[z] NS = not statistically significant at (P>0.05).

<u>Summary</u>

A 105° grid bar was more effective than the 45° grid bar in removing SCFs. Eight percentage points more SCFs were removed by the 105° grid bar. SCFs that were removed had very few fibers attached to the SCFs, and velocity decayed to about one-half the saw speed before the SCF was removed. SCFs that were not removed had many fibers attached to the SCF, and the velocity of the SCF decayed to zero before reversing direction as fibers still attached to the SCF pulled the SCF back to the edge of the grid bar. Neither the clearance between the grid bar and lint cleaner saw or the position of the grid bar (1st or 2nd) had any effect on the number of SCFs removed.

Future work includes continuing to use the high-speed video camera in real time on the full-size lint cleaner. The high-speed camera is a valuable tool that helps in understanding the interaction between grid bar design and grid bar-to-saw clearance. A formal experiment will be rerun to determine the effectiveness of 105°, 60°, 45°, and 0°R grid bars. The experiment will use a control set of grid bars mounted on the same lint cleaner as the experimental grid bars.

Acknowledgements

The authors would like to thank Cotton Incorporated, Cary, NC, for their assistance on this project.

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