DIAGRAMMING THE PATH OF A SEED COAT FRAGMENT ON EXPERIMENTAL LINT CLEANER GRID BARS

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Abstract

A series of tests were run to determine how seed coat fragments react after colliding with newly-designed grid bars mounted on a saw-type lint cleaner simulator. A high-speed video camera recorded the action that took place. Ten experimental grid bars were tested. The included angle of the sharp toe of the grid bars (or the clockwise angle from vertical) ranged from 30º to 105º in 15-degree increments. A rounded grid bar with about a 0.76-mm (0.030-in) radius was also included in the test. Results showed that grid bars that had an included angle of the sharp toe of the grid bar, larger than the included angle found on conventional grid bars, appeared to adequately remove a seed coat fragment. Also, grid bars that had a second corner a short distance from the toe of the grid bar appeared to do a faster and cleaner job of removing the seed coat fragment from the fiber bundle. Embedding a small groove onto the impact surface of two grid bars did not help in removing the seed coat fragment. Future work includes analyzing the velocity and acceleration of the seed coat fragment after impact with the grid bar and building and testing full-size replicas of selected experimental grid bars on a conventional saw-type lint cleaner.

Introduction

Research continues on finding methods that remove seed coat fragments during the harvesting or ginning processes. This research uses a cultivar known to have a fragile seed coat that breaks easily and contaminates ginned lint with seed coat fragments. Recent research has attempted to remove seed coat fragments at the harvester, saw gin stand, roller gin stand, and seed-cotton cleaning process. Armijo et al., (2006a) found that auxiliary rib guides on the saw gin stand did not reduce the number of AFIS (Advanced Fiber Information System) seed coat neps. The most recent studies have used AFIS seed coat neps as an indicator for the presence of seed coat fragments. In the same study by Armijo et al., (2006a), it was found that roller ginning did not reduce AFIS seed coat nep count. In another study, Armijo et al., (2006b) found that seed coat neps may be reduced by using a small diameter spindle on the picker harvester, or by ginning on a powered roll gin stand. The powered roll gin stand uses a paddle to assist turning the seed roll in the gin stand. Spinning tests on fiber from the study by Armijo et al., (2006b) have not yet been completed to substantiate the reduction in seed coat neps. Another study by Armijo et al., (2007) found that seed coat neps were not reduced by different levels of seed-cotton cleaning; seed-cotton cleaning used in this study included both inclined cylinder cleaners and stick machines.

Past studies by Mangialardi and Shepherd (1968) and Mangialardi (1987) showed that seed coat fragments were not reduced with different levels of saw-type lint cleaning. Both of these studies used conventional grid bars in the lint cleaners. Armijo et al., (2008) summarized past research that used photographic techniques to study the path that fibers take as they are drawn over a lint cleaner grid bar and described preliminary work that used a high-speed video camera to examine a fiber bundle with an attached seed coat fragment colliding with model-sized experimental grid bars mounted on a lint cleaner simulator. The most recent research continues this theme of modeling the removal of seed coat fragments using a saw-type lint cleaner simulator.

The objective of this study was to evaluate how a seed coat fragment reacts after colliding with newly-designed grid bars mounted on a lint cleaner simulator. A high-speed video camera recorded the action that took place. The study was performed at the USDA-ARS Southwestern Cotton Ginning Research Laboratory located in Mesilla Park, New Mexico in 2008.

Materials and Methods

Figure 1 shows the lint cleaner simulator and high-speed camera used in the test. The lint cleaner simulator used a 0.41-m (16-in) diameter, 6.4-mm (1/4-in) thick disk that represented the lint cleaner saw. The disk (or saw) rotated at 1000 rpm (a tangential velocity of 21.6 m/s or 4250 ft/min). A 1.1 kW (1.5 hp) variable-speed motor operated the disk. A 1.6-mm (1/16-in) diameter, 3.2-mm (0.125-in) long tube was attached to the disk; the tube represented a saw tooth. A fiber bundle containing one seed coat fragment was threaded into the tube. The distance between the tube (saw tooth) and the grid bar was about 1 mm (0.039 in). The distance between the tube and the center of the seed coat fragment was about 3 mm (0.118 in). A solenoid moved the grid bar into position to collide with the seed coat fragment at the same instant the video camera was activated.

The high-speed video camera was a Phantom V7.1 (Vision Research, Wayne, NJ). 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 seed coat fragment and grid bar. The movement between each frame was 2.16 mm (0.085 in) and the time between each frame was 100 µs. The video 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 57-90 mm (2.3-3.5 in) away from the disk.

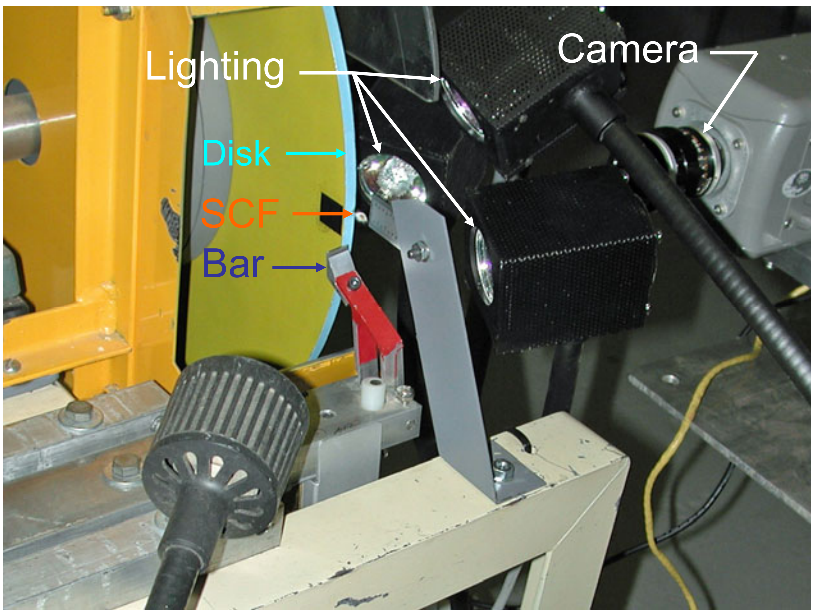

Figure 1. Lint cleaner simulator and high-speed video camera.

Figure 2 shows the designs of the 10 experimental grid bars used in the test. The included angle of the sharp toe of the grid bars (or the clockwise angle from vertical) ranged from 30º to 105º in 15-degree increments. A rounded grid bar with about a 0.76 mm (0.030 in) radius was also included in the test. The 105º, 90º, 75º, and 60º grid bars had a small surface (about 1.5 mm or 0.059 in) from the toe of the bar, giving these bars a second corner to possibly help remove the seed coat fragment. The 90ºL grid bar had a surface of 4 mm (0.157 in) from the toe of the bar, also giving this bar a second corner. The 60ºG and 45ºG grid bars had a 0.51 mm (0.020 in) groove on the surface of the bar about 1.5 mm (0.059 in) from the toe of the bar, the idea being that the seed coat fragment would fall into the groove upon impact and be removed more easily. The 45º and 30º grid bars did not have a second corner; the surface length from the toe of the grid bar on these bars was about 10 mm (0.394 in) and 15 mm (0.591 in), respectively. A commercial lint cleaner grid bar typically has an included angle of the sharp toe of about 30º on the first grid bar, and about 55º on the remaining bars.

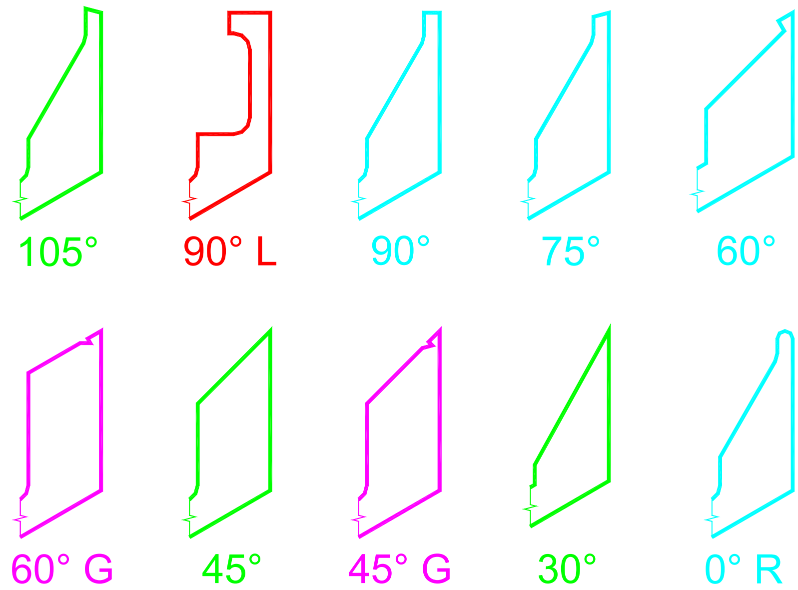

Figure 2. Cross section of experimental grid bars.

The test consisted of the 10 experimental grid bars, two types of cotton, and three replications for a total of 60 lots. The cottons included a common upland cultivar and a cultivar known to have a fragile seed coat. Both cultivars were grown in the Mesilla Valley of Southern New Mexico. The fiber bundle/seed coat fragment samples were weighed before and after impact in a controlled environmental room set at a temperature of 21º C (70º F) and humidity of 65%. The experimental design was a randomized complete block with replications serving as blocks. Analysis of variance was performed with the General Linear Model of SAS (version 9.1; SAS Institute, Inc.: Cary, NC) and differences between main effect treatment means were tested with Duncan's Multiple Range Test.

Results and Discussion

Figures 3 through 12 each show a three-frame sequence of a fiber bundle and seed coat fragment colliding with each of the grid bars shown in Figure 2. A brief description of the grid bars, along with an account of what occurred during the video are included in the caption of each figure.

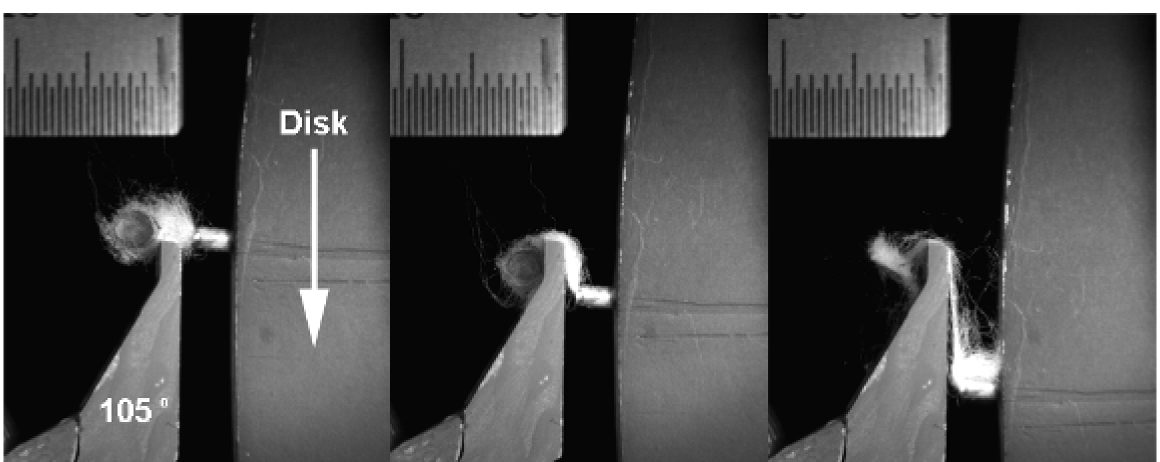

Figure 3. Grid bar: 105º. The distance from the toe to the 2nd corner is 1.55 mm (0.061 in). There is a total of 500 µs between frames. The seed coat fragment was removed on the second corner.

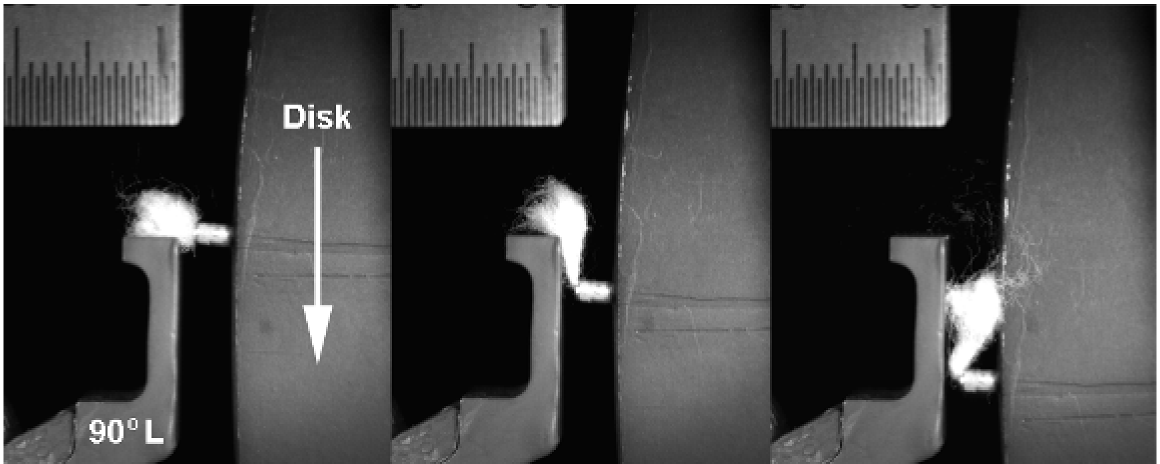

Figure 4. Grid bar: 90ºL. The distance from the toe to the 2nd corner is 4 mm (0.157 in). There is a total of 500 µs between frames. The seed coat fragment was not removed.

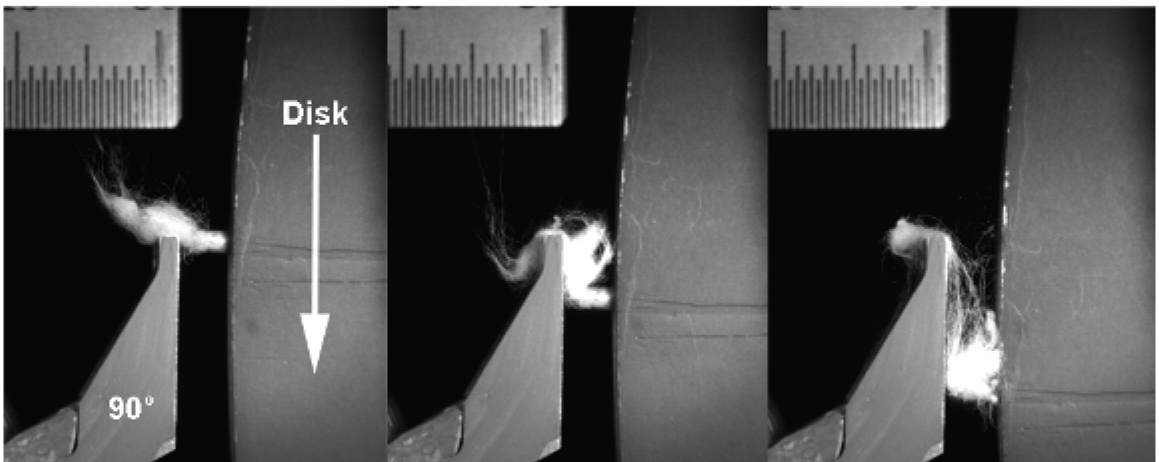

Figure 5. Grid bar: 90º. The distance from the toe to the 2nd corner is 1.5 mm (0.059 in). There is a total of 500 µs between frames. The seed coat fragment was removed on the second corner.

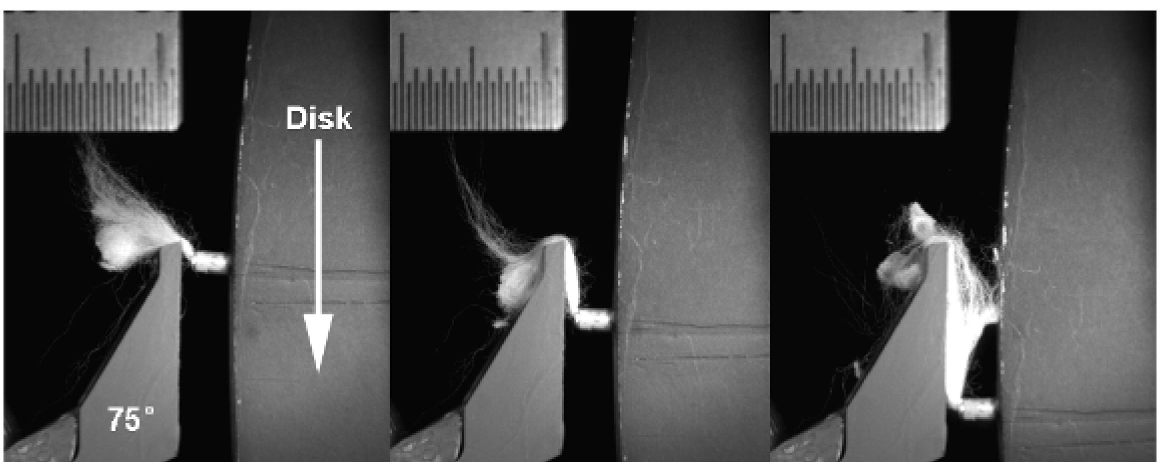

Figure 6. Grid bar: 75º. The distance from the toe to the 2nd corner is 1.55 mm (0.061 in). There is a total of 500 µs between frames. The seed coat fragment was removed on the second corner.

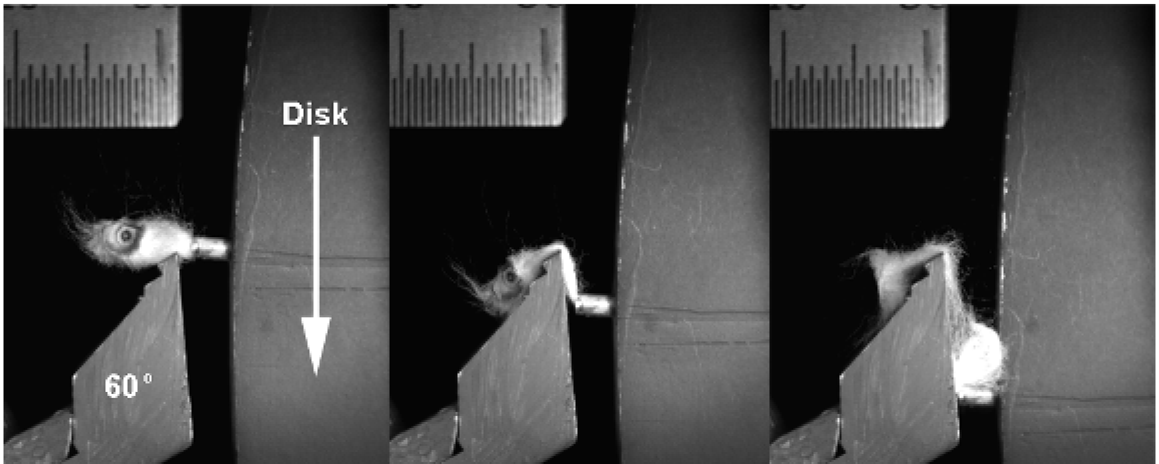

Figure 7. Grid bar: 60º. The distance from the toe to the 2nd corner is 1.6 mm (0.063 in). There is a total of 500 µs between frames. The seed coat fragment was removed on the second corner.

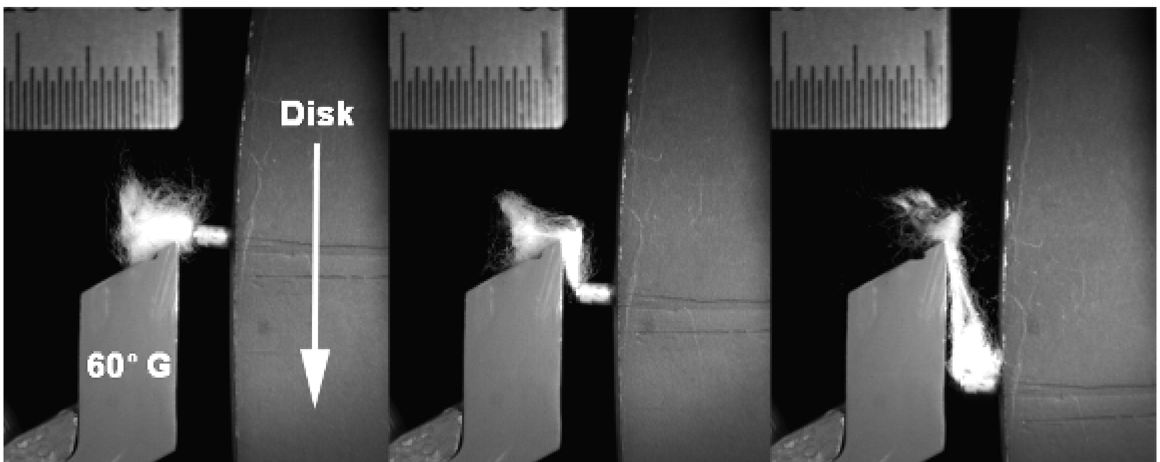

Figure 8. Grid bar: 60ºG. The distance from the toe to the 2nd corner is 1.5 mm (0.059 in). There is a total of 500 µs between frames. The seed coat fragment was not removed.

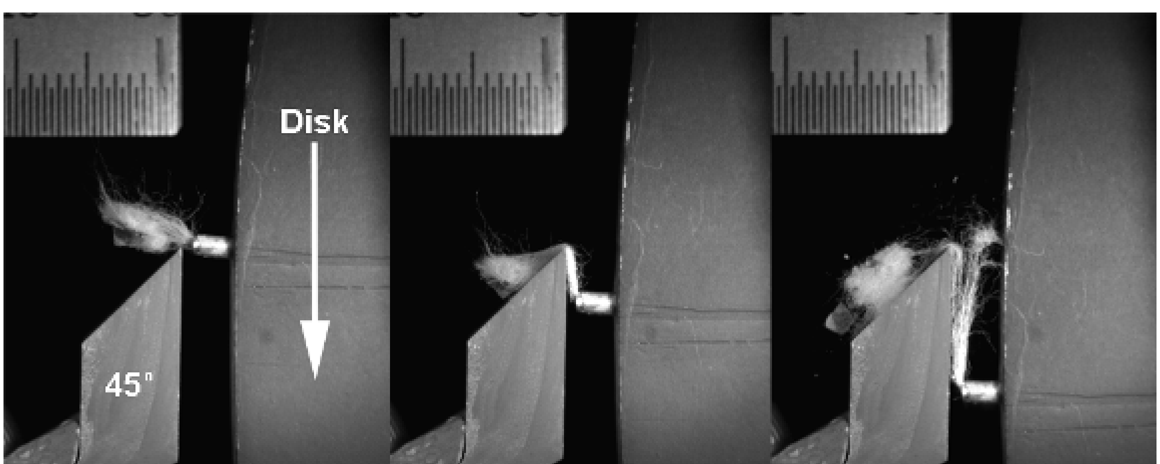

Figure 9. Grid bar: 45º. The distance from the toe to the 2nd corner is 10 mm (0.394 in). There is a total of 500 µs between frames. The seed coat fragment was removed at the toe of the grid bar.

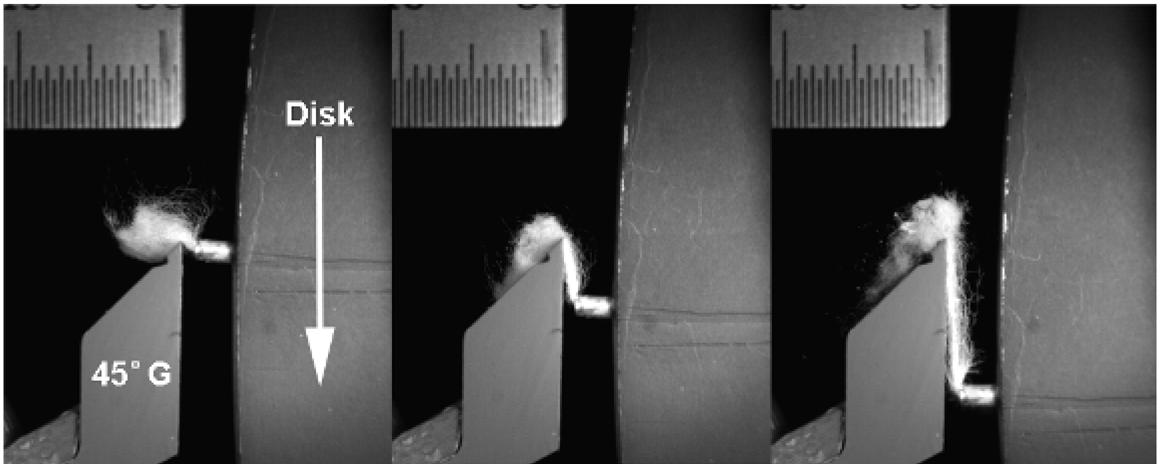

Figure 10. Grid bar: 45ºG. The distance from the toe to the 2nd corner is 1.5 mm (0.059 in). There is a total of 500 µs between frames. The seed coat fragment was not removed.

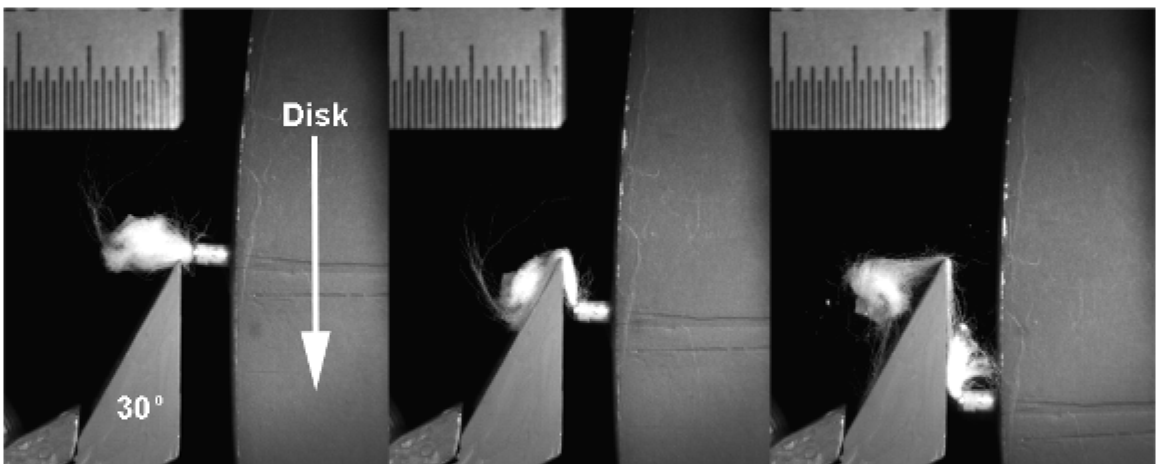

Figure 11. Grid bar: 30º. The distance from the toe to the 2nd corner is 14.9 mm (0.587 in). There is a total of 500 µs between frames. The seed coat fragment was removed at the toe of the grid bar.

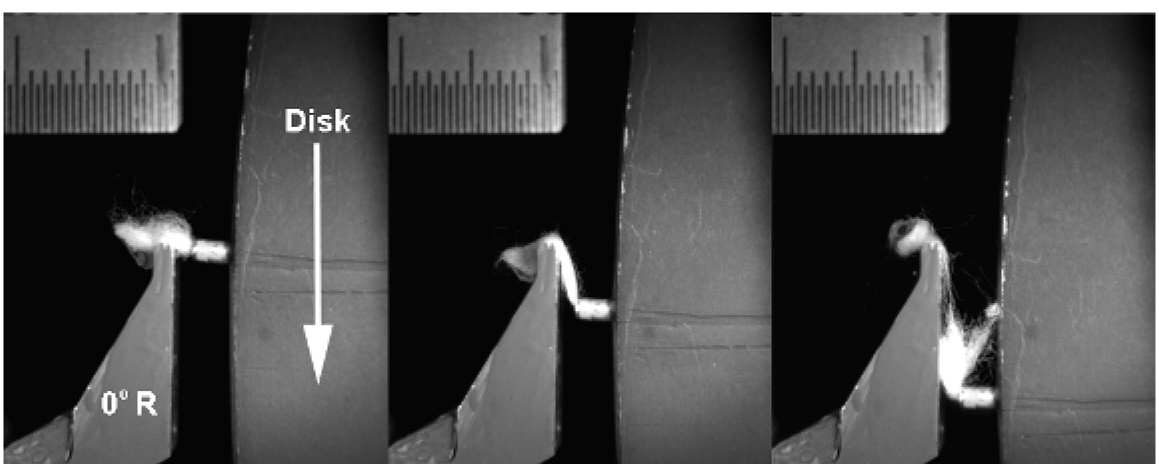

Figure 12. Grid bar: 0ºR. The arc length from the toe to the 2nd corner is 2.36 mm (0.093 in). There is a total of 500 µs between frames. The seed coat fragment was removed around the radius of the grid bar.

To help determine the performance of the grid bars, the path of the seed coat fragment was diagrammed for each of the 60 lots to show what path the seed coat followed after colliding with the grid bar. The X and Y coordinates of the seed coat fragment in relation to the grid bar were determined for each diagram with the same software that operated the high-speed camera. To show two extremes, Figures 13 and 14 show the path and center of the seed coat fragment on the 105º and 90ºL grid bar, respectively, before and after collision with the grid bar. As seen in Figure 13, the 105º grid bar removed the seed coat fragment, and sent the fragment away from the disk (or saw); this is an ideal situation, where the seed coat is removed and not re-entrained with fiber attached to the lint cleaner saw. Figure 14 shows an undesirable situation where the seed coat fragment is not removed, and continues on with the fiber in the lint cleaner.

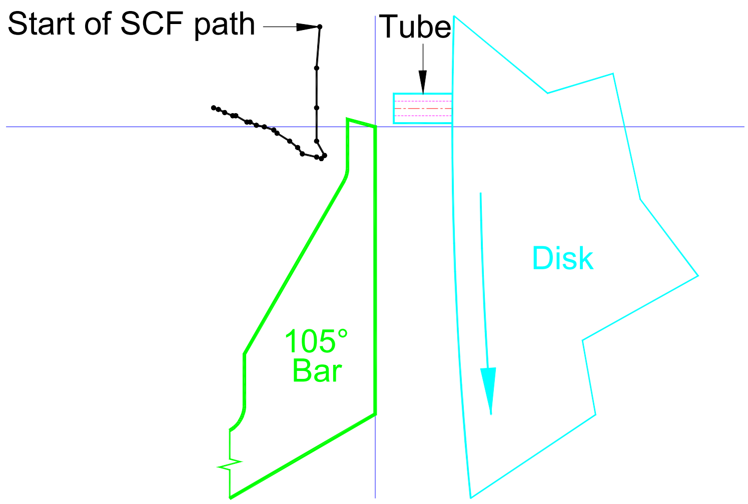

Figure 13. Path diagram of a seed coat fragment after colliding with the 105º grid bar (SCF = seed coat fragment). The fiber bundle, which is not shown, is attached to tube.

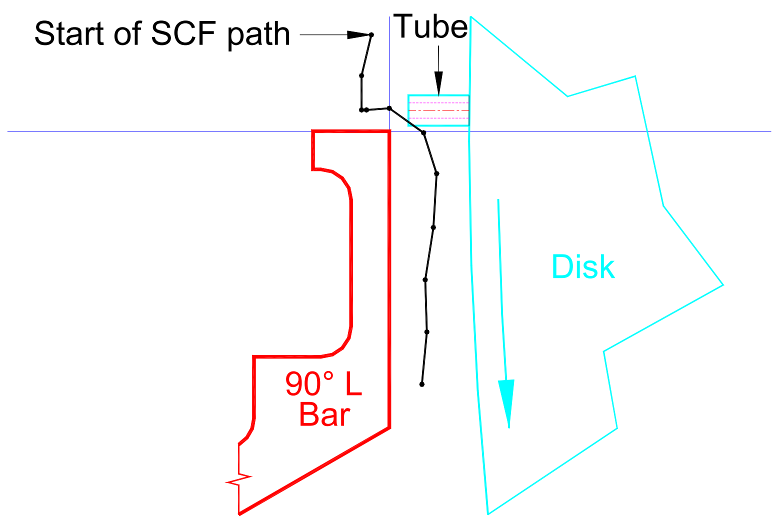

Figure 14. Path diagram of a seed coat fragment after colliding with the 90ºL grid bar (SCF = seed coat fragment). The fiber bundle, which is not shown, is attached to tube.

Figures 15, 16, and 17 show the distance, in the x-direction, the seed coat fragment traveled in 300 µs (or three video frames) after colliding with the grid bars. The figures are grouped into three categories: "poor" design grid bars (Figure 15), "better" design grid bars (Figure 16), and "best" design grid bars (Figure 17). The "poor", "better", and "best" groupings were decided upon using statistics (Duncan's Multiple Range Test at ;=0.10) and visual inspection of each plot diagram. Because statistics showed that cultivar was not different among grid bar treatments, cultivars were combined and each of the grid bar results in Figures 15, 16, and 17 are the average of 6 lots (two cultivars and three replications).

Figure 15 shows that on average, a seed coat fragment colliding with the 90ºL grid bar traveled about 2 mm (0.079 in) in the x-direction back towards the disk (or lint cleaner saw) in a 300 µs time period. The seed coat fragment was not removed from the fiber bundle. A seed coat fragment colliding with both the 60ºG and 45ºG grid bars traveled about 1 mm (0.039 in) in the x-direction away from the disk, the seed coat fragment was not removed from the fiber bundle on either of these the grid bars. As mentioned earlier, the 60ºG and 45ºG grid bars had a 0.51 mm (0.020 in) groove on the surface of the bar about 1.5 mm (0.059 in) from the toe of the bar. The groove did not help to remove the seed coat fragment, most likely because the groove was not deep enough for the seed coat to fit into. All three of the grid bars shown in Figure 15 were considered to be "poor" designs.

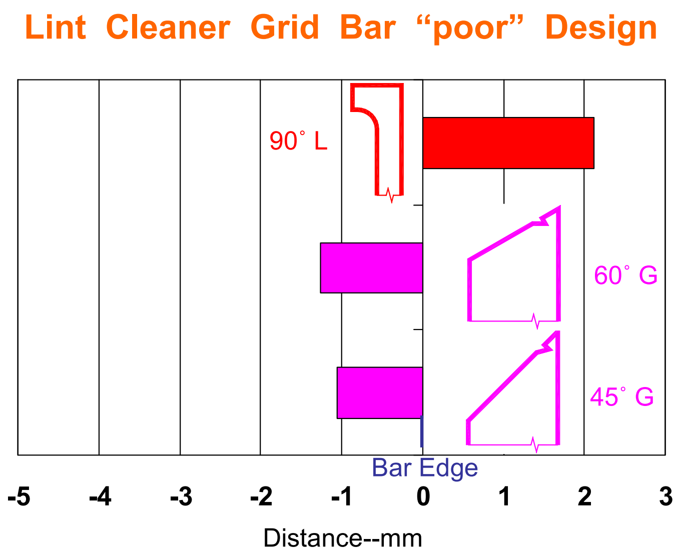

Figure 15. Distance in the x-direction that the seed coat fragment traveled in 300 µs after colliding with the 90ºL, 60ºG, and 45ºG grid bars. Negative values indicate travel away from the saw.

Figure 16 shows that on average, a seed coat fragment colliding with either the 90º, 75º, or 30º grid bars traveled 2.0 mm to 2.5 mm (0.079 in to 0.098 in) away from the disk (or lint cleaner saw) in a 300 µs time period. The seed coat fragment was removed on all three grid bar designs. On the 90º and 75º grid bars with a second corner, the seed coat fragment traveled about 0.5 mm (0.020 in) farther than the 30º grid bar with a "toe" edge.

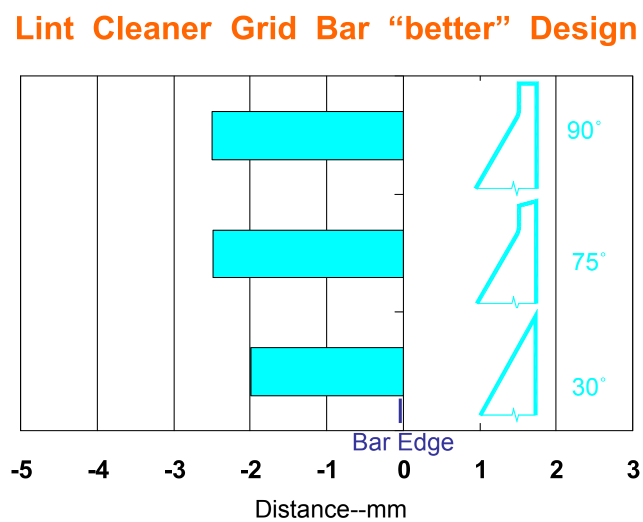

Figure 16. Distance in the x-direction that the seed coat fragment traveled in 300 µs after colliding with the 90º, 75º, and 30º grid bars. Negative values indicate travel away from the saw.

Figure 17 shows that on average, a seed coat fragment colliding with either the 105º, 60º, 45º, or 0ºR grid bars traveled 3.0 mm to 5.0 mm (0.118 in to 0.197 in) away from the disk (or lint cleaner saw) in a 300 µs time period. The seed coat fragment was removed on all four grid bar designs. Although the 0ºR grid bar resembled more of a "dull" grid bar, it was effective in removing a seed coat fragment.

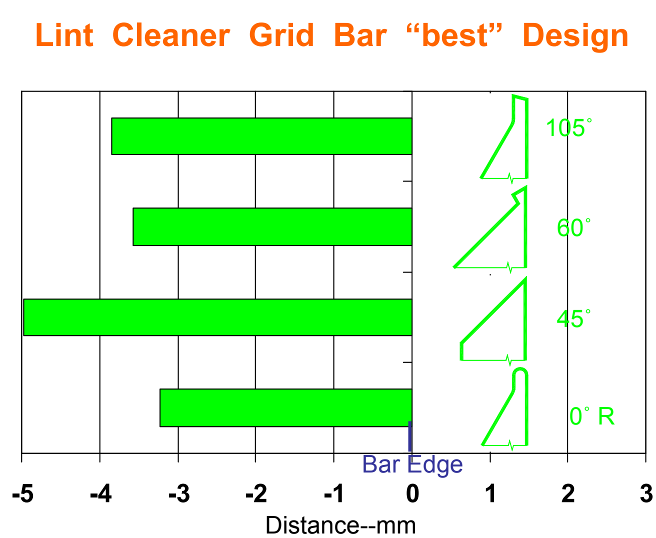

Figure 17. Distance in the x-direction that the seed coat fragment traveled in 300 µs after colliding with the 105º, 60º, 45º, and 0ºR grid bars. Negative values indicate travel away from the saw.

Conclusions

Results from a 60-lot experiment that examined the action of a seed coat fragment colliding with 10 different experimental grid bars mounted on a lint cleaner simulator were as follows:

- Grid bars that had an included angle of the sharp toe of the grid bar larger than the included angle found on conventional grid bars, appeared to adequately remove a seed coat fragment.

- Grid bars that had a second corner a short distance from the toe of the grid bar appeared to do a faster and cleaner job of removing the seed coat fragment from the fiber bundle.

- It appeared that if the seed coat fragment made a fast and clean break away from the fiber bundle, the seed coat fragment retained more energy and its momentum continued for a longer time period.

- Conversely, it appeared if fibers were slowly pulled off of the seed coat fragment (not a clean break), then the energy of the seed coat fragment was dissipated and the momentum of the seed coat fragment was reduced.

- Embedding a small groove onto the impact surface of an experimental grid bar did not help in removing the seed coat fragment.

- There was a considerable amount of variability in the data; three replications were run to ensure confidence in an overall mean of the data.

Future work includes analyzing the velocity and acceleration of the seed coat fragment after impact with the grid bar, and building and testing full-size replicas of the experimental grid bars on a conventional saw-type lint cleaner.

Acknowledgement

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Disclaimer

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