INNOVATIVE TECHNIQUE TO EVALUATE LINT CLEANER GRID BAR DESIGNS

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Abstract

Photographic techniques were used to show the path that fibers attached to a gin saw take as they are drawn over a lint cleaner grid bar. A 1979 study showed that fibers were swept backwards, closer to the saw, as saw speed increased. The angle between the tip of the saw tooth and the fibers ranged from 55º at 1060 rpm to 73.5º at 2000 rpm, but there were no clear relationships between angles and saw speed. A 1988 study showed that fibers attached to a gin saw formed a "z" shape as they were drawn over a grid bar. The fiber slid about 4.8 mm (3/16 in) down the back side of the grid bar when forming the "z". The length of the "z" shape of fibers was dependent on the density of the fiber bundle. A 1991 study showed in a triple exposure photograph the action of a fiber bundle and seed coat fragment attached to a rotating disk hitting a lint cleaner grid bar. The photograph showed the seed coat fragment being ginned off of the fiber bundle, but the photographic technique was cumbersome. A 2007 study used a high-speed video camera to show a fiber bundle and seed coat fragment attached to a rotating disk whipping across model-sized experimental lint cleaner grid bars. The angle that the fiber bundle curves back towards the disk was decreased compared to fiber alone due to the attached seed coat. The videos showed that many parameters are involved in removing a seed coat fragment from a bundle fiber: the distance between the saw and edge of the grid bar, the distance between the saw and the seed coat, the size and weight of the fiber bundle and seed coat, and the shape of the grid bar. The high-speed video camera greatly simplified viewing the action that occurs at the edge of a lint cleaner grid bar. Future studies will test the effectiveness of removing seed coat fragments using full-sized experimental grid bars.

Introduction

Renewed interest in lint cleaner grid bar designs came about because of research that began in 2004, to find ways that reduce seed coat fragments in ginned lint. The studies used a cultivar that had a fragile seed coat which had a tendency to break very easily and contaminate a bale with seed coat fragments. In an initial study, Armijo, et al. (2006a) found that neither saw ginning with auxiliary rib guides, nor roller ginning, reduced the number of AFIS (Advanced Fiber Information System) seed coat neps. (Seed coat neps were used as an indicator for the presence of seed coat fragments.) In a second study, Armijo, et al. (2006b) found that using a small diameter spindle during picker harvesting, or using a paddle to assist turning the seed roll in the saw gin stand may help to reduce seed coat fragments, but further spinning tests have yet to be completed to support this. In a third study, Armijo, et al. (2007) found that different levels of seed-cotton cleaning did not help manage seed coat fragments.

Another machine in the ginning process that may reduce seed coat fragments in lint is the saw-type lint cleaner. Mangialardi and Shepherd (1968) found that lint cleaning did not reduce fragment number significantly, and a considerable number of fragments remained in the lint even after four stages of lint cleaning. Mangialardi (1987) found that lint cleaning did not remove seed coat fragments after two stages of lint cleaning, and that lint cleaning may break up larger fragments into smaller ones, actually increasing the number of fragments after lint cleaning.

The studies by Mangialardi and Shepherd (1968) and Mangialardi (1987) used conventional grid bars in the lint cleaners. Using a lint cleaner grid bar that has a different shape than the traditional sharp-edged bar may help to reduce seed coat fragments. Past unpublished research used a lint cleaner simulator to help understand the path that fiber takes as it passes over the grid bar, but the photographic technique used was not very suitable. Recent advancements with high-speed video cameras now allow researchers to better understand the dynamics of very high speed systems such as cotton fiber attached to a lint cleaner saw. The objective of this study was to give a brief history of photographic techniques that researchers used to learn about the path that fibers take as they are drawn over a lint cleaner grid bar, and to describe in more detail recent work that used a high-speed digital camera to capture video of a fiber bundle with an attached seed coat fragment whipping across experimental lint cleaner grid bars. The studies were performed at the USDA-ARS Southwestern Cotton Ginning Research Laboratory located in Mesilla Park, New Mexico, between 1979 and 2007.

Background

1979

Work began in 1979, with using photographic techniques to determine the angle created between the tip of a lint cleaner saw tooth at the horizontal and a bundle of fiber that is attached to the same tip on the saw as the saw is turning at different speeds. Figure 1 shows the test stand that was used to mount either a 0.30-m (12-in) diameter saw mandrel with three saws, or a 0.41-m (16-in) diameter saw mandrel with three saws. The saws were driven by a variable speed DC motor with a silicon controlled rectifier (SCR) control. A General Radio Company (Cambridge, MA) type 1539-A Stroboslave light with 3 μs flash duration and 18 x 10^6 beam candles @ 1-m (39.4-in) peak light intensity single flash was used for lighting. The flash was mechanical/electrical synchronized with one contact closure per revolution. Photographs were taken with a 4 x 5 black and white negative film camera and Polaroid adapter (prints).

The procedure to determine the angle between the tip of the saw tooth and the fiber bundle was as follows:

1. Snag four cotton fiber specimens on separate gin saw teeth when photographing radially.
2. Snag five cotton fiber specimens on separate gin saw teeth when photographing axially.
3. Accelerate the saw mandrel to the desired speed (some specimens were lost). Saw speeds of 200, 400, 800, 1060, 1200, 1600, 2000 and 2400 rpm were tested.
4. Photograph the specimens with a single flash in a dark room.
5. Draw lines on the axially-viewed prints to measure the angle.

Observations from the work in 1979, showed that the radially-viewed specimens were swept backwards, closer to the saw, as saw speed increased. The axially-viewed specimens (Figure 2) showed that the angle between the tip of the saw tooth and the fiber bundle was significantly different between saw diameters and overall averaged 63º and 67º for the 0.30 m (12 in) and 0.41 m (16 in) saw, respectively. The angles ranged from 55º at 1060 rpm to 73.5º at 2000 rpm, but there were no clear relationships between angles and saw speed. As the specimens lost fiber due to the constant spinning of the saw, the fiber continued to curve backwards towards the saw, increasing the angle between the fiber and the saw radius. This phenomenon was likely due to the loss of mass from fiber loss and subsequent reduction in centrifugal force relative to drag force.

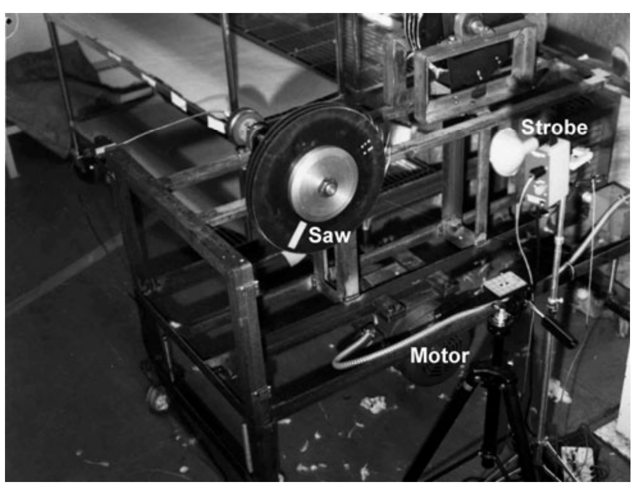

Figure 1. Photographic test stand.

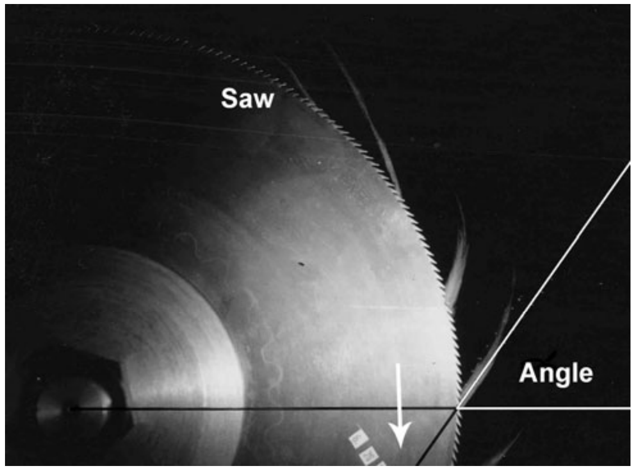

Figure 2. Axial view of the angle between the tip of the saw tooth and the fiber bundle.

1988

Work resumed in 1988, with photographing the path that a fiber bundle, attached to a saw tooth, followed as it whipped across a lint cleaner grid bar. The test stand was the same as that used in the 1979 study, except only the 0.41-m (16-in) diameter saw mandrel with one saw was used. A 30º (measured from the vertical) grid bar marked with 3.2 mm (0.125 in) graduation marks was placed 1.6 mm (0.0625 in) away from the saw (Figure 3). Light synchronizing included a General Radio type 1536-A photoelectric pickoff that activated one pulse per revolution, and a General Radio type 1531-P2 flash delay that operated between 100 µs and 0.8 s. A 35 mm Cannon F1 camera with a 70-200 mm zoom lens, 4X close-up filter, and Ektachrome slide (reversal) film was used.

The procedure to determine the path that a fiber bundle takes as it whips over a grid bar was as follows:

1. Tape a fiber bundle that measures about 19 mm (0.75 in) long (stretched out) to the gin saw teeth.
2. Accelerate the saw mandrel to about 1025 rpm.
3. Adjust the strobe flash delay to provide the desired view of the position of the fiber bundle hitting the grid bar.
4. Photograph the specimen in a dark room using a single flash, a camera f-stop of 4-8, and a shutter speed of 0.5 s.

Figure 3 shows a resulting photograph. The fibers attached to the gin saw formed a "z" shape as they were drawn over the bar. The fiber slid about 4.8 mm (3/16 in) down the back side of the grid bar when forming the "z". In other photographs using the same grid bar, less dense fiber bundles formed a smaller "z" due to a larger angle formed between the tip of the bar in the horizontal and the fiber bundle as it was swept backwards towards the saw.

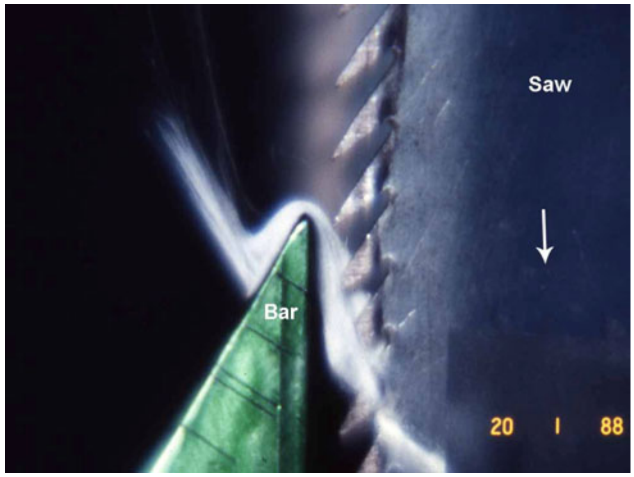

Figure 3. Fiber bundle whipping over a grid bar.

1991

Work in 1991, continued with still photographs of a fiber bundle whipping over a lint cleaner grid bar, but a 0.41-m (16-in) diameter, 6.4-mm (1/4-in) thick disk was used in place of the saw, and the fiber bundle was attached thru a 1.6-mm (1/16-in) diameter, 3.2-mm (0.125-in) long tube that represented the saw tooth (Figure 4). The disk was installed on the same test stand used in previous years work. A 1.5kW (2 hp) variable speed drive motor drove the disk, and a solenoid moved the grid bar into the path of the fiber bundle just before the photograph was taken. A 60º grid bar (measured from the vertical) was positioned 1 mm (0.040 in) away from the end of the tube. For these tests, a piece of a seed coat was attached to the fiber bundle.

Photographic lighting included three General Radio Company Strobes: 1) type 1538-A, single flash, 1.2 µs flash duration, 5 x 10^6 lux @ 1-m (39.4-in) peak light intensity; 2) type 1531-A, single flash, 3.0 µs flash duration, 4.2 x 10^6 lux @ 1-m (39.4-in) peak light intensity; and 3) type 1539-A, single flash, 1.2 µs flash duration, 3.5 x 10^6 lux @ 1-m (39.4-in) peak light intensity. The three strobe lamps were placed 0.28 m (11 in), 0.20 m (8 in), and 0.18 m (7 in) away from the grid bar. A three-switch control box that incorporated a General Radio type 1536-A photoelectric pickoff that activated one pulse per revolution, and a General Radio type 1531-P2 flash delay that operated between 100 µs and 0.06 s was used to time the flash sequence. A 35 mm Canon T90 with a 200 mm macro lens Ektachrome ASA 400 slide (reversal) film was used.

The procedure for taking a triple exposure photograph of a fiber bundle, with an attached seed coat fragment, hitting a grid was as follows:

1. Mount into the tube holder a fiber about 40-mm (1.5-in) long, weighing about 17 mg (0.0006 oz), leaving about 6.3 mm (0.25 in) of fiber bundle/seed coat fragment extended.
2. Spin the disk containing the sample to about 1000 rpm.
3. Set the camera to a shutter speed of 0.5 s.
4. Activate a switch on the strobe light control box to enable the timing cycle.
   - On the next revolution of the disk, a pulse from the photo pickup activates the solenoid, and the grid bar moves into the path of the disk and tube holding the sample.
   - On the next revolution of the disk, a pulse from the photo pickup starts the lighting sequence which sends out three pulses.
   - The three pulses activate the three strobe lights, and a triple exposure is taken.
5. Deactivate the switch on the strobe light control box to deactivate the solenoid and move the grid bar out of the path of the disk.

Figure 4 shows a triple exposure photograph. The exposures labeled "1", "2", and "3" correspond to the position of the tube with the attached sample and position of the seed coat fragment. In position "1", the fiber bundle and attached seed coat fragment are just above the grid bar. Position "2" shows that the seed coat has been ginned off of the fiber bundle, and is contact with the grid bar. Position "3" shows that the seed coat has moved above the grid bar. The triple exposure photograph was difficult to take, and the results were not available immediately.

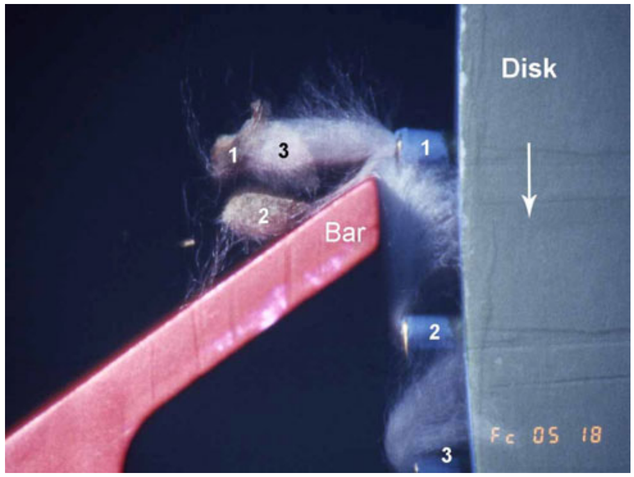

Figure 4. Triple exposure of fiber bundle with attached seed coat fragment.

2007

Work in 2007, used the same photographic test stand (disk and tube) that was used in the 1991 study, but used a Phantom V7.1 high-speed video camera (Vision Research, Wayne, NJ) to capture the action of a fiber bundle and a seed coat fragment whipping over a lint cleaner bar. Figure 5 shows the test stand and high-speed camera. Because the high-speed camera allowed a "timing window" to take the video, the elaborate light and timing sequence that was used in the 1991 study was not needed. Instead, lighting consisted of two 250 W high intensity tungsten halogen lamps placed about 100 mm (4 in) away from the disk. The specifications of the high-speed video camera were as follows:

1. 4800 ISO/ASA monochrome sensitivity (which reduced the lighting requirements).
2. Global (snap shot) shuttering to 2 μs.
3. 4800 frames per second at 800x600, and 10000 frames per second at 512x384 pixel resolution (150000 frames per second maximum).
4. A window of 5900 frames in which to time to synchronize moving the grid bar in the path of the sample.

The lint cleaner simulator used a disk (saw) speed of 1000 rpm and a gap of about 1 mm (0.040 in) between the fiber bundle and grid bar. The video camera was set to a recording rate of 4000 frames per second and an exposure time of 2 μs. The tangential velocity of the disk was about 70 feet per second (very fast). The movement between frames was 0.213 inches.

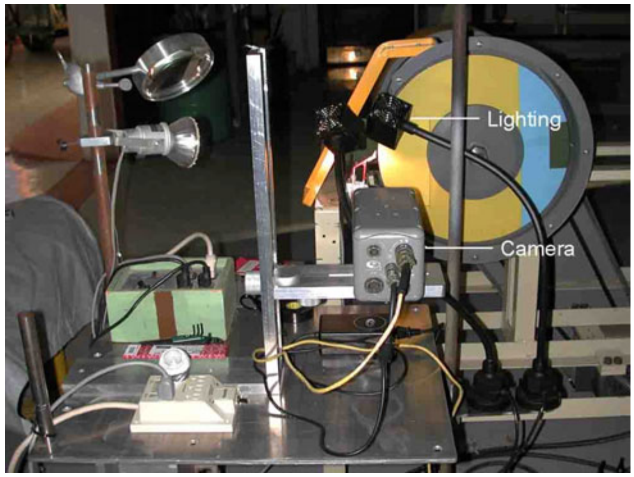

Figure 5. Test stand with high-speed camera and 250 W tungsten halogen lamps.

Discussion

The discussion will be limited to work that took place in 2007. Many experimental grid bar designs were videoed. Figures 6 through 12 each show a three-frame sequence of a fiber bundle and seed coat fragment hitting different style grid bars. 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.

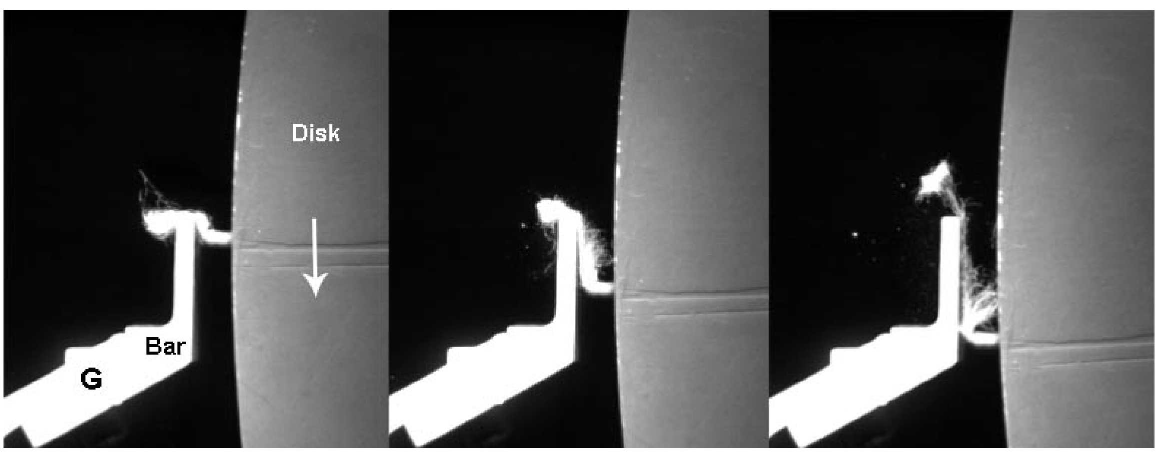

Figure 6. Grid bar "G" had a top surface length of 2mm (0.0787 in or about 1/16 in), and two 90º corners. The seed coat was ginned on the back side of the grid bar. The ginned seed coat traveled upwards parallel to the saw, and some short fibers were created.

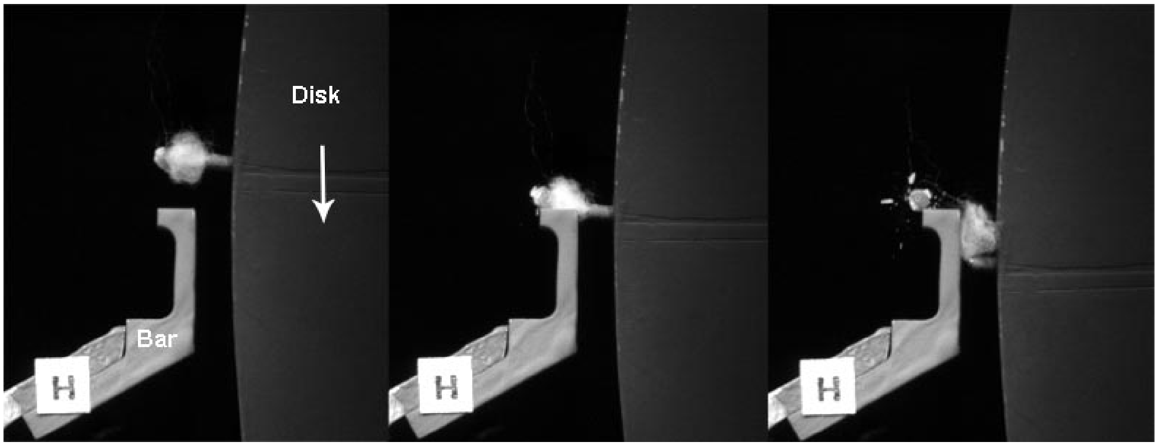

Figure 7. Grid bar "H" had a top surface length of 4mm (0.157 in or about 1/8 in) and three 90º corners. The seed coat hit only the top edge of the grid bar, and did not whip around the backside of the grid bar. Only a portion of the seed coat was ginned.

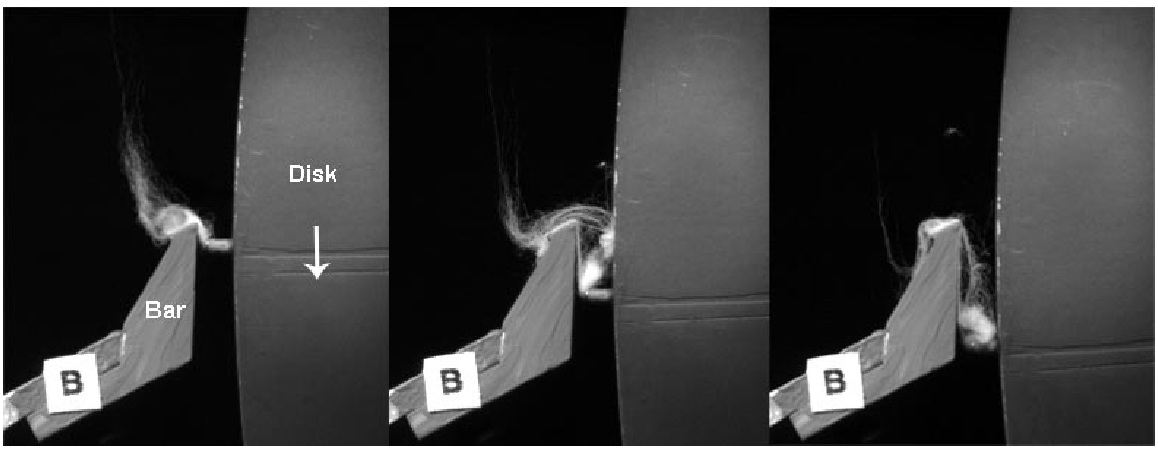

Figure 8. Grid bar "B" had a top surface length of 3.4 mm (0.134 in or about 1/8 in) and a 60º corner. The seed coat was not ginned, and the fiber bundle was stretched.

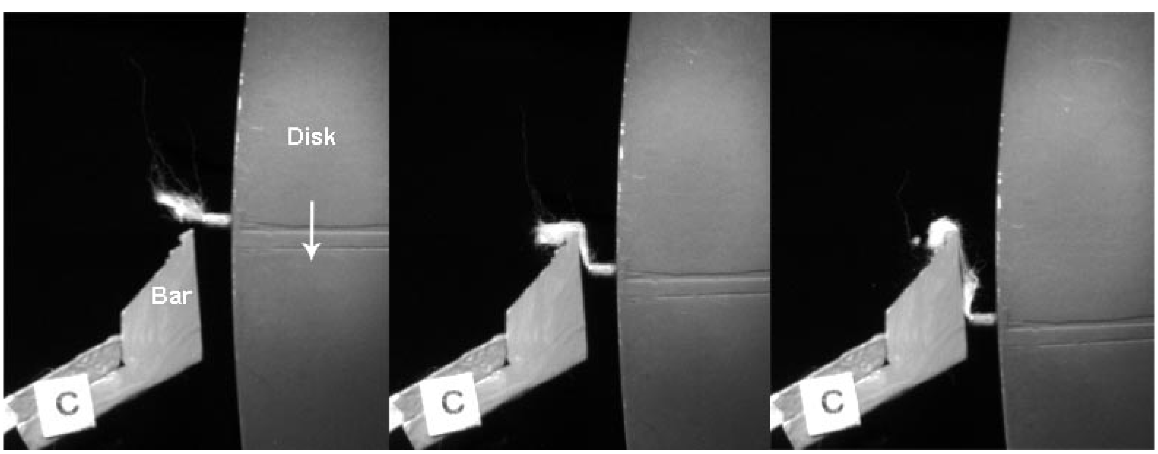

Figure 9. Grid bar "C" had a top surface length of 1.6 mm (0.063 in or about 1/16 in) and a 60º degree corner. The seed coat was ginned at the edge of the grid bar.

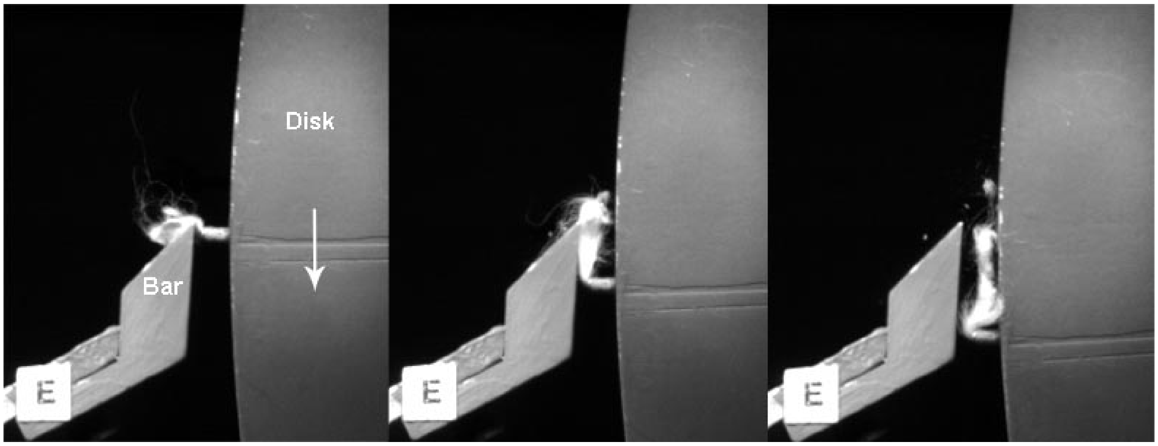

Figure 10. Grid bar "E" had a top surface length of 11 mm (0.434 in or about 7/16 in) and about a 41º corner. The seed coat was fractured at the edge of the grid bar, but did not gin and more seed coats were created.

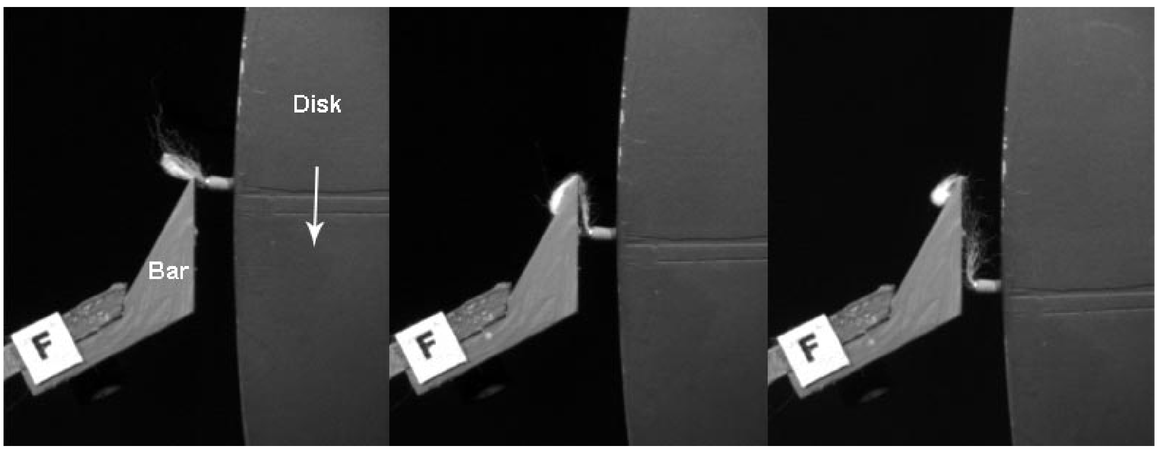

Figure 11. Grid bar "F" had a top surface length of 15 mm (0.588 inches or about 9/16 inch) and about a 29º corner. The seed coat was ginned at the edge of the grid bar.

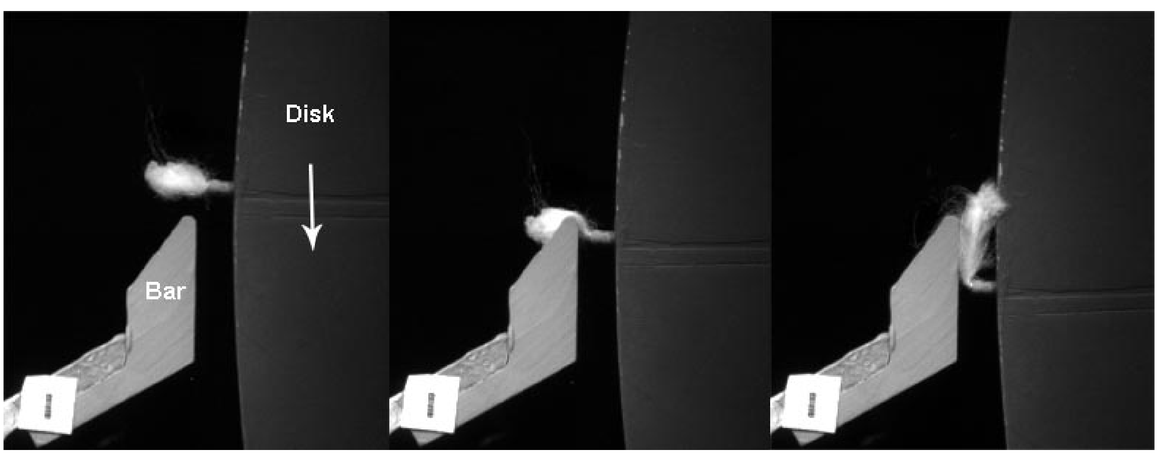

Figure 12. Grid bar "I" had a top surface length of 9.3 mm (0.367 in or about 3/8 in) and a radius of 0.9 mm (0.035 in) with a 36º corner (rounded grid bar). The seed coat was not ginned.

Other observations from the videos included the following:

1. The fiber bundle forms a "z" shape at the edge of the grid bar.
2. The fiber bundle whips from the edge of the grid bar after the "z" shape ends.
3. The angle that the fiber bundle curves back towards the saw increases as the bundle becomes less dense.
4. The angle that the fiber bundle curves back towards the saw decreases if the bundle has a seed coat attached to it (the seed coat is perpendicular to the saw).
5. There appears to be adequate force to gin a seed coat if the fiber bundle remains attached to the saw.

Critical parameters observed from the videos included the distance between the saw and edge of the grid bar, the distance between the saw and the seed coat, the size and weight of the fiber bundle and seed coat, and the shape of the grid bar.

Future work using the lint cleaner simulator and video camera will include running more replications of the grid bars already tested. Physical and dynamic measurements will be used to study the relationships among the fiber bundle and seed coat properties, grid bar design and position, and seed coat extraction. Full-size replicas of experimental grid bar designs that extract seed coat fragments will be manufactured and tested on a conventional lint cleaner using a cultivar that has high levels of seed coat fragments.

Disclaimer

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References

Armijo, C. B., S. E. Hughs, M. N. Gillum, and E. M. Barnes. 2006a. Ginning a cotton with a fragile seed coat. Journal of Cotton Science 10:46-52.

Armijo, C. B., G. A. Holt, K. D. Baker, S. E. Hughs, E. M. Barnes, and M. N. Gillum. 2006b. Harvesting and ginning a cotton with a fragile seed coat. Journal of Cotton Science 10:311-318.

Armijo, C.B., K.D. Baker, S.E. Hughs, E.M. Barnes, and M.N. Gillum. 2007. Effects of harvesting and seed-cotton cleaning on a cotton with a fragile seed coat. In Proc. Beltwide Cotton Conf., New Orleans, LA. 9-12 Jan. 2007. Natl. Cotton Council. Am., Memphis, TN.

Mangialardi, G. J. and J. V. Shepherd. 1968. Seed coat fragment and funiculus distribution in ginned lint as affected by lint cleaning. ARS Report 42-145, June 1968. United States Department of Agriculture, Agricultural Research Service, Beltsville, MD.

Mangialardi, G. J. 1987. Relationship of lint cleaning to seed coat fragments. p. 535-536. *In* Proc. Beltwide Cotton Prod. Res. Conf., Dallas, TX. 4-8 Jan. 1987. Natl. Cotton Counc. Am., Memphis, TN.