# USING HIGH-SPEED VIDEO TO EXAMINE DIFFERENTIAL ROLLER GINNING OF UPLAND COTTON

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## Abstract

A digital high-speed video camera was used to show what occurs as upland fiber is being pulled off of cottonseed at the ginning point on a roller gin stand. The study included a conventional ginning treatment and a treatment that attempted to selectively remove only the longer fibers off of cottonseed (differential roller ginning) by controlling the time seed cotton dwells at, and its proximity to, the ginning point. Results showed that by changing the surface velocity ratio between the ginning roller and the rotary knife, it was possible to control the movement of cottonseed with respect to the ginning point. The videos showed precise feed control and single locking of seed cotton are needed to prevent excessive congestion at the ginning point during differential roller ginning. In this study, fiber lengths were not different between conventional and differential ginning treatments. Further testing is needed to determine the optimum surface velocities of the ginning roller, rotary knife, and the optimum number of blades on the rotary knife for differential roller ginning.

## Introduction

Roller ginning, when compared to saw ginning, is a gentler method of ginning cotton, yielding improvements in fiber length, length uniformity, short fiber content, nep content, and lint turnout (Hughs and Lalor, 1989; Armijo and Gillum, 2007). Traditionally, roller ginning was only used to gin the extra-long-staple cottons, such as Pima, because it is a slow and expensive process. Recent advancements in high-speed roller ginning have made the processing rate of a roller gin stand comparable to a saw gin stand on a per-foot-of-width basis (Armijo and Gillum, 2007), and ginning plants in the Southwestern and Western parts of the U.S. have begun to gin upland cotton on roller gin stands to take advantage of the improved fiber properties (Armijo, 2007).

Differential roller ginning attempts to make further improvements in fiber length of upland cotton with the roller gin stand. Preliminary work in differential roller ginning looked primarily at different designs and running speeds of the rotary knife (Armijo et al., 2006). The theory of differential roller ginning is to remove only the longer fibers off of the cottonseed (primary ginning), leaving the shorter fibers on the cottonseed to be removed in a secondary ginning process. The "longer fiber" and "shorter fiber" bales may have to be baled separately. The "longer fiber" bale may have less turnout, but the improvements in fiber length from differential roller ginning may earn a substantially higher price and open up new markets for upland cotton.

The objective of this study was to clarify what occurs at the ginning point on a roller gin stand attempting to selectively remove only the longer fibers off of cottonseed (differential roller ginning) by controlling the time and proximity that seed cotton is exposed to the ginning point. A high-speed video camera helped capture the separation of fiber and cottonseed at the ginning point.

## Materials and Methods

### Theory of Differential Roller Ginning

Figure 1 shows the principle of roller ginning. The ginning point is located at the intersection of the ginning roller, rotary knife, and stationary knife. The ginning roller is pushed into the stationary knife with a high force that is adjustable. Seed cotton coming from the feeder is directed to the ginning point with the help of the rotary knife. At the ginning point, the ginning roller pulls fiber underneath the stationary knife, and the rotary knife removes ginned cottonseed. The rotary knife also removes any un-ginned seed cotton (carryover). A more detailed discussion of roller ginning can be found in the Cotton Ginners Handbook (USDA, 1994).

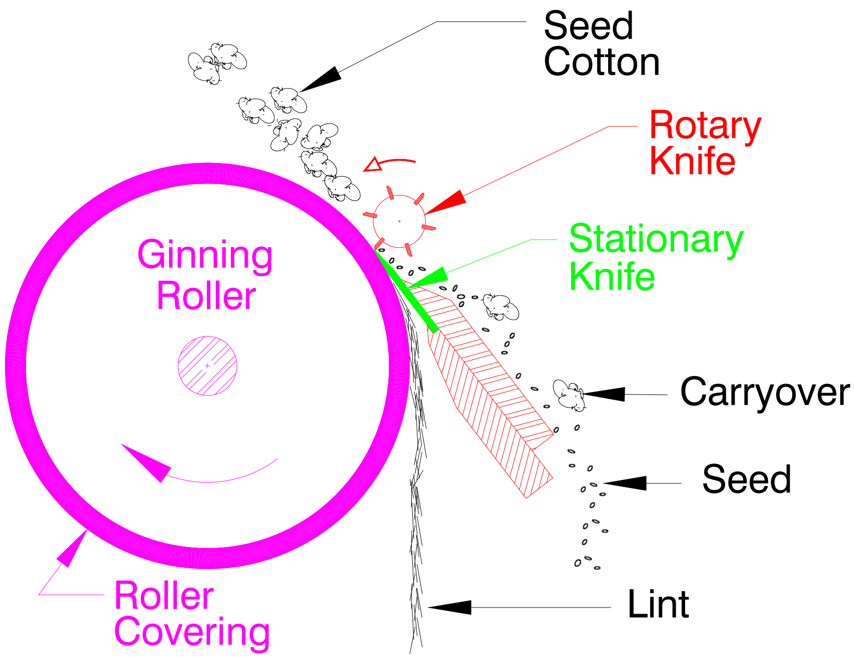


Figure 1. Principle of the rotary knife roller gin stand.

Figure 2 shows a close-up view of conventional roller ginning. The running speed of the ginning roller and rotary knife is 134 and 473 rpm, respectively. With conventional roller ginning, cottonseed remains at the tip of the stationary knife as fiber is being pulled off and all of the fiber is usually pulled off between two consecutive blade passes of the rotary knife.

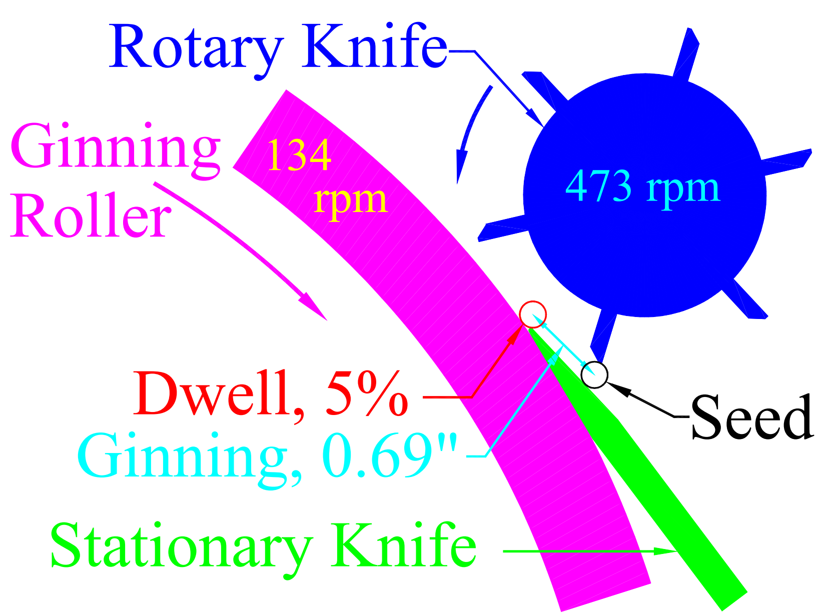


Figure 2. Close-up view of ginning point with conventional roller ginning.

In theory, differential roller ginning is accomplished by limiting the time and proximity that cottonseed is exposed to the ginning point. This is done by changing the surface velocity ratio between the ginning roller and rotary knife by varying their respective running speeds, and/or by changing the roller-movement-per-blade-pass by using various numbers of blades on the rotary knife. Figure 3 shows a close-up view of differential roller ginning. In this case, the running speed of the rotary knife has been increased from 134 to 1555 rpm, effectively changing the surface velocity ratio between the ginning roller and rotary knife from 1.55 to 0.47. Because the rotary knife is running faster, the blades of the rotary knife push cottonseed away from the tip of the stationary knife (ginning point) and do not allow cottonseed to return to the ginning point. Theoretically, the ginning roller only has enough time to pull the longer fibers off of the cottonseed before another blade of the rotary knife comes by and pushes cottonseed away from the ginning point. This back and forth action of the cottonseed may occur many times before the longer fibers have been removed. The remaining shorter fiber on the cottonseed must be removed later on in a secondary ginning process (either conventional roller ginning or saw ginning).

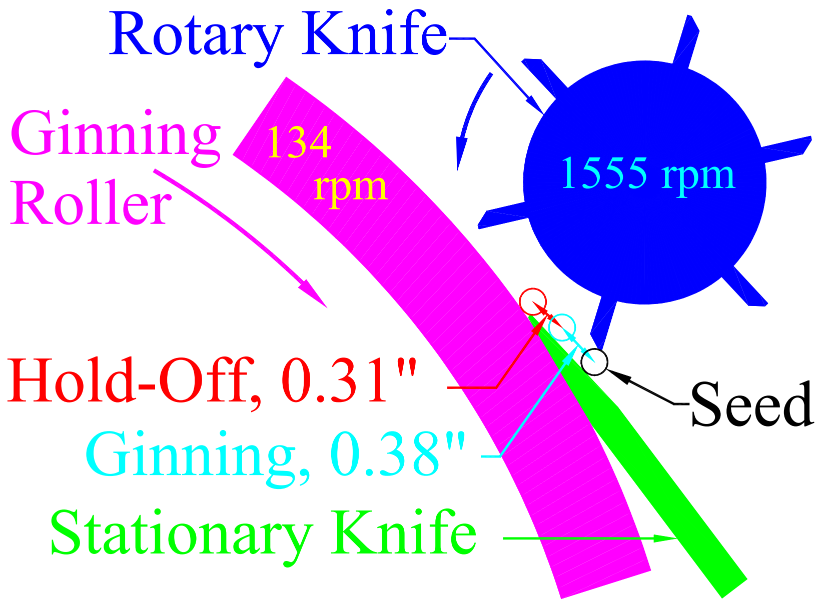


Figure 3. Close-up view of ginning point with differential roller ginning.

**Test Design**

A 40-inch-wide modified Hardwicke-Etter roller gin stand was used in this study. A piece of the side plate of the gin stand was cut out to allow viewing of the gin point with a digital high-speed video camera. Figure 4 shows the setup of the camera. The settings of the high-speed camera for the study were as follows:

- 4,800 ISO/ASA monochrome sensitivity
- 50 microsecond shutter speed
- Framing rate of 2,000 frames per second at 800x600 resolution
    - Rotary knife movement of 0.034 inches between each frame for conventional roller ginning
    - Rotary knife movement of 0.112 inches between each frame for differential roller ginning
- 5,900 frames of memory for a maximum of 2.95 seconds of run time
- 16-160 f 2.0 zoom lens with a 20 mm extension tube at f-stop of 11 (allowed an adequate depth of field)

Figure 4. Setup of digital high-speed video camera.

Figure 5 shows a close-up view of the ginning point. A smaller bearing was installed on the shaft of the rotary knife to facilitate viewing. The clearance between the tip of the stationary knife and a blade of the rotary knife was 0.012 inches (manufacturer specification is 0.010 inches).

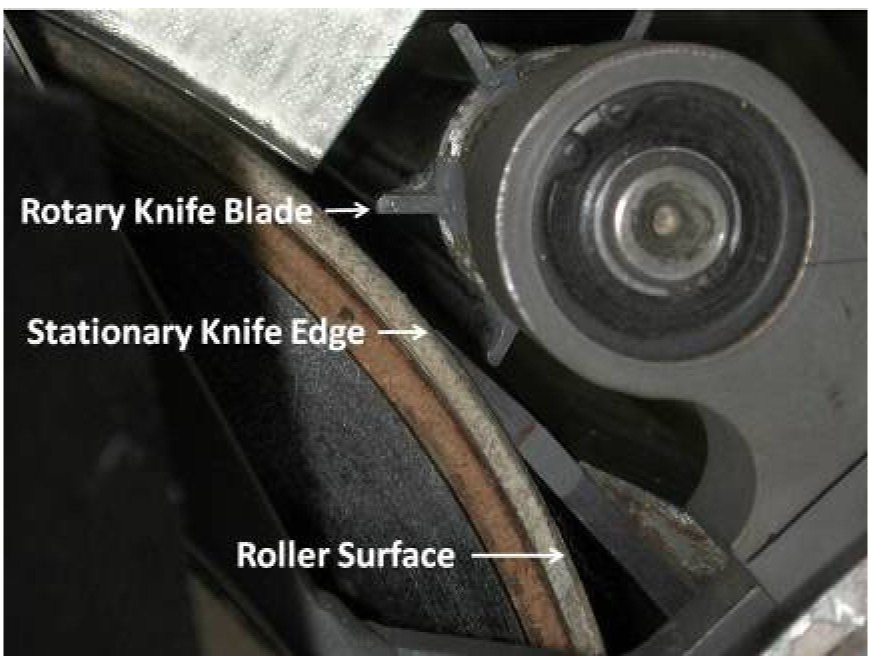


Figure 5. Close-up view of ginning point.

Figure 6 shows the slide that was positioned in front of the gin stand to feed seed cotton to the stand. The slide was 6 inches wide, 3 inches deep, and 60 inches long, and angled downward at 30 degrees. A stick with a block of wood attached on the end pushed seed cotton above the rotary knife where the seed cotton was then directed to the ginning point.

Figure 6. Setup used to feed seed cotton to the gin stand.

Although differential roller ginning centers on upland cotton, extra-long-staple (ELS) cotton was included in the study to gain more knowledge about how fiber is pulled off of ELS cottonseed (ELS fiber has a lower strength of attachment to the cottonseed than upland cotton). The cultivars used in the study included Acala 1517-99W (upland) and Delta Pine 340 (Pima). The Pima cotton was included in the test for video purposes only; it was not used in the analysis. Seed cotton lot weight was 40 g. Seed cotton was hand picked and pre-cleaned with two passes through a Lummus 700 feeder. There was no lint cleaning. A sample of the upland cotton was ginned on a model-sized 8-saw gin stand for unofficial comparison purposes only.

The two ginning treatments included conventional roller ginning and differential roller ginning. The same roller speed (134 rpm) was used for both ginning treatments. The running speed of the rotary knife was 473 and 1555 rpm for the conventional and differential ginning treatment, respectively. This equated to a surface velocity ratio between the ginning roller and rotary knife of 1.55 and 0.46 for the conventional and differential ginning treatment, respectively.

There were two cultivars, two ginning treatments, and three replications for a total of 12 ginning lots. The statistical design was a randomized complete block, blocked by replication. Analysis of variance was performed with the General Linear Model of SAS at the 5% level of significance (version 9.1; SAS Institute, Inc.; Cary, NC). The test was run in December of 2009, at the USDA-ARS Southwestern Cotton Ginning Research Laboratory in Mesilla Park, NM. A Fibrograph tester (Spinlab, Knoxville, TN) was used to determine fiber length.

## Results and Discussion

Figure 7 shows the ginning of one cottonseed with conventional roller ginning. In Figure 7A, a single lock of seed cotton is positioned at the tip of the stationary knife (the ginning point) above rotary-knife-blade "1". A red arrow is pointing to the lock of seed cotton located at the ginning point. In figure 7B (seven frames later in the video), rotary-knife-blade "1" has moved past the tip of the stationary knife about 0.25 inches, and the ginning roller has begun to pull fiber underneath the stationary knife. In Figure 7C, rotary-knife-blade "1" has turned about another 0.25 inch, and the lock of seed cotton has remained at the ginning point. Rotary-knife-blade "2" is also coming into view in Figure 7C. Fiber continues to be pulled off of the lock of seed cotton in Figure 7D. In Figure 7E, most of the fiber has been ginned off of the cottonseed and the cottonseed is now visible. In Figure 7F, all of the fiber has ginned off of the cottonseed, and rotary-knife-blade "2" will be sweeping the cottonseed away from the ginning point. The important observations in Figure 7 are that with conventional roller ginning, the cottonseed remains at the ginning point (tip of the stationary knife) while the ginning roller pulls the fiber off of the cottonseed, and all of the fiber is pulled off between the movements of two blades of the rotary knife.

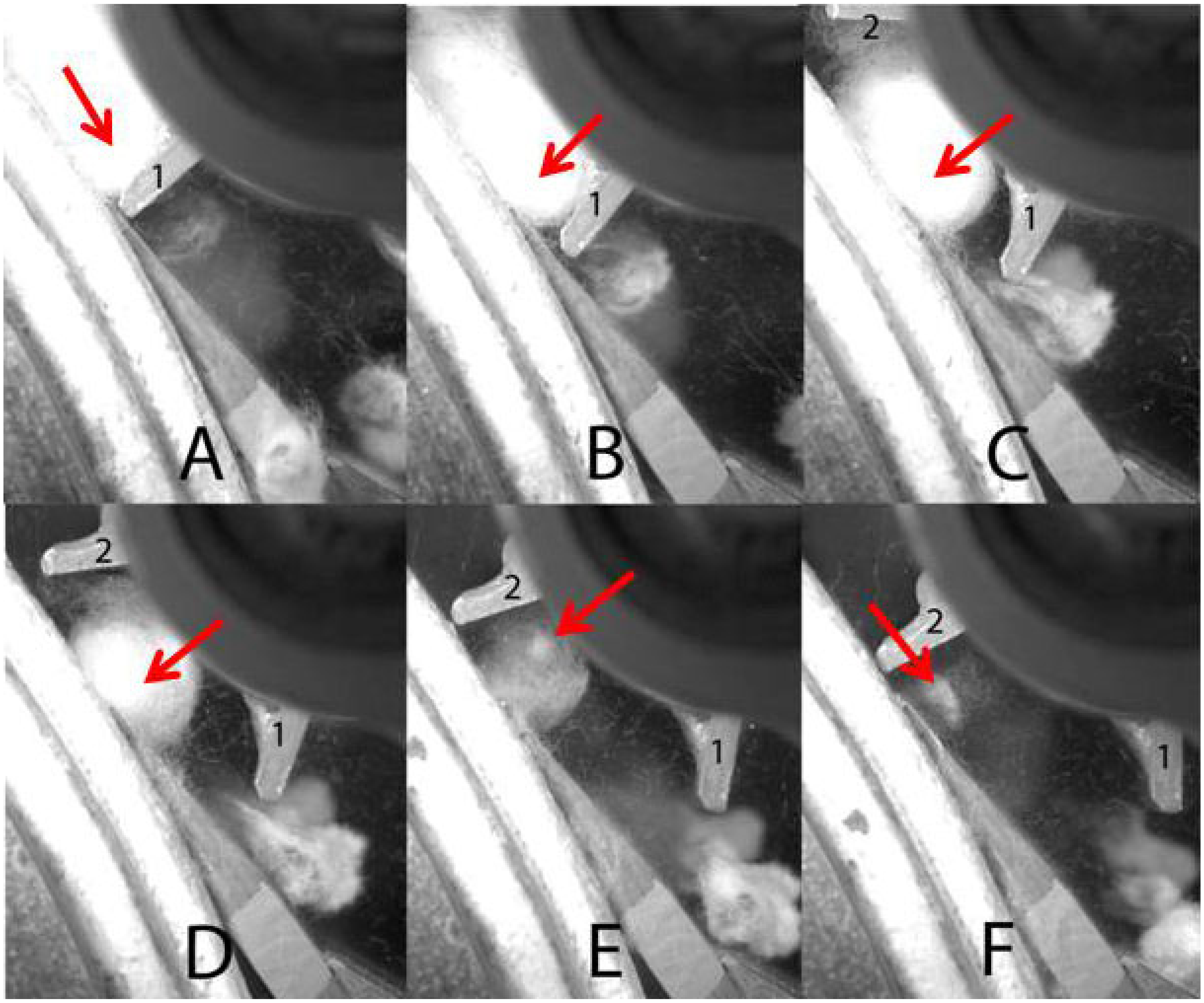

Figure 7. Process of conventional roller ginning.

The software of the high-speed camera was able to divide the movement of a cottonseed into the horizontal (x) and vertical (y) directions. Figure 8 is a graphical representation of the movement of a single cottonseed in the vertical direction with conventional roller ginning. Figure 8 shows that as fibers were being pulled off of the cottonseed at the ginning point, the cottonseed did not travel in the vertical direction. The center of the cottonseed was located about 0.10 inches above the edge of the stationary knife, and it took about 20 ms to pull all of the fiber off of the cottonseed. After all of the fiber was pulled off of the cottonseed, the cottonseed then continued in the vertical direction away from the ginning point.

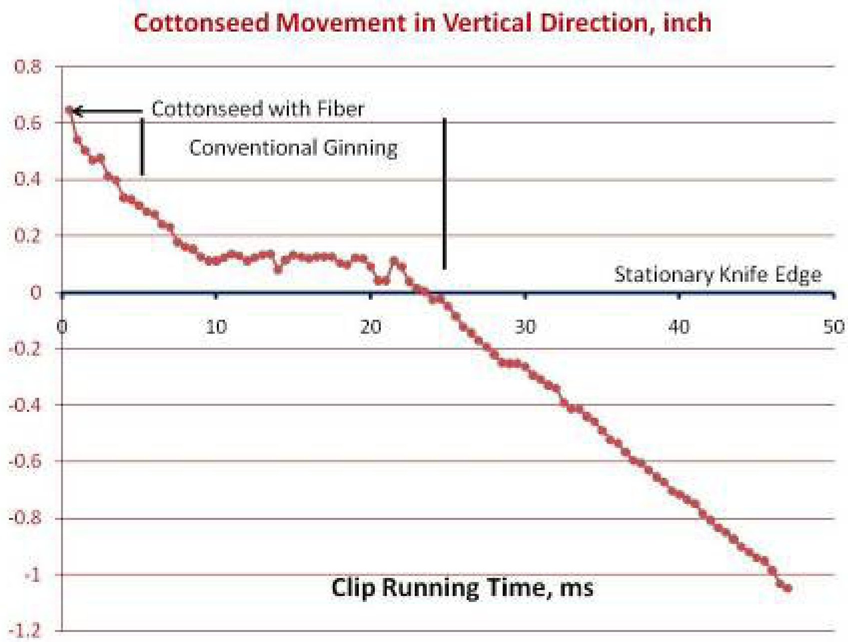

Figure 8. Cottonseed movement in vertical direction with conventional roller ginning.

Figure 9 shows the ginning of one cottonseed with differential roller ginning. Recall that the rotary knife is running faster with differential roller ginning. In Figure 9A, a single lock of seed cotton has been pushed past the ginning point (the tip of the stationary knife) by rotary-knife-blade "1" and is between rotary-knife-blades "1" and "2". A red arrow is pointing to the lock of seed cotton. In Figure 9A, the ginning roller has already begun to pull fiber off of the cottonseed. In figure 9B (seven frames later in the video), rotary-knife-blade "2" is moving the cottonseed away from the ginning point after only a few fibers (theoretically long fibers) have been removed. Figure 9C shows that rotary-knife-blade "2" has released the cottonseed, and because the ginning roller is still pulling fiber underneath the stationary knife, the cottonseed is traveling back towards the ginning point. Figure 9D shows that before the cottonseed has traveled back to the ginning point, rotary-knife-blade "3" has begun to push the cottonseed away from the ginning point. By not allowing the cottonseed to return to the ginning point, shorter fibers were not able to be pulled off of the cottonseed. Figure 9E shows that rotary-knife-blade "3" has released the cottonseed, and again, because the ginning roller is still pulling fiber underneath the stationary knife, the cottonseed is traveling back towards the ginning point. Figure 9F shows rotary-knife-blade "4" pushing the cottonseed away from the ginning point, not allowing shorter fibers to be ginned off. Figures 9G and 9H show the same scenario: not allowing the cottonseed to return to the ginning point, thereby not allowing shorter fibers to be pulled off. Figures 9H and 9I finally show that all of the longer fibers have been ginned off the cottonseed, and rotary-knife-blade "5" has swept the cottonseed away. The cottonseed in Figure 9I still has shorter fiber attached. The important observations in Figure 9 are that with differential roller ginning, the cottonseed is not allowed to return to the tip of the stationary knife (the ginning point) while the ginning roller pulls the fiber off of the cottonseed; theoretically, only the longer fibers are being pulled off, and the shorter remains on the cottonseed.

Figure 10 is a graphical representation of the movement of a single cottonseed in the vertical direction with differential roller ginning. Figure 10 shows that as longer fibers were being pulled off of the cottonseed by the ginning roller at the tip of the stationary knife, the cottonseed traveled either up or down towards the edge of the stationary knife. The cottonseed moved upwards about 0.4 inches as the ginning roller pulled fiber off of the cottonseed, and downwards about the same distance as a blade of the rotary knife pushed the cottonseed away from the tip of the stationary knife. It took about 27 ms to pull the longer fiber off of the cottonseed. After the longer fiber was pulled off of the cottonseed, the cottonseed then continued in the vertical direction away from the tip of the stationary knife with shorter fiber still attached.

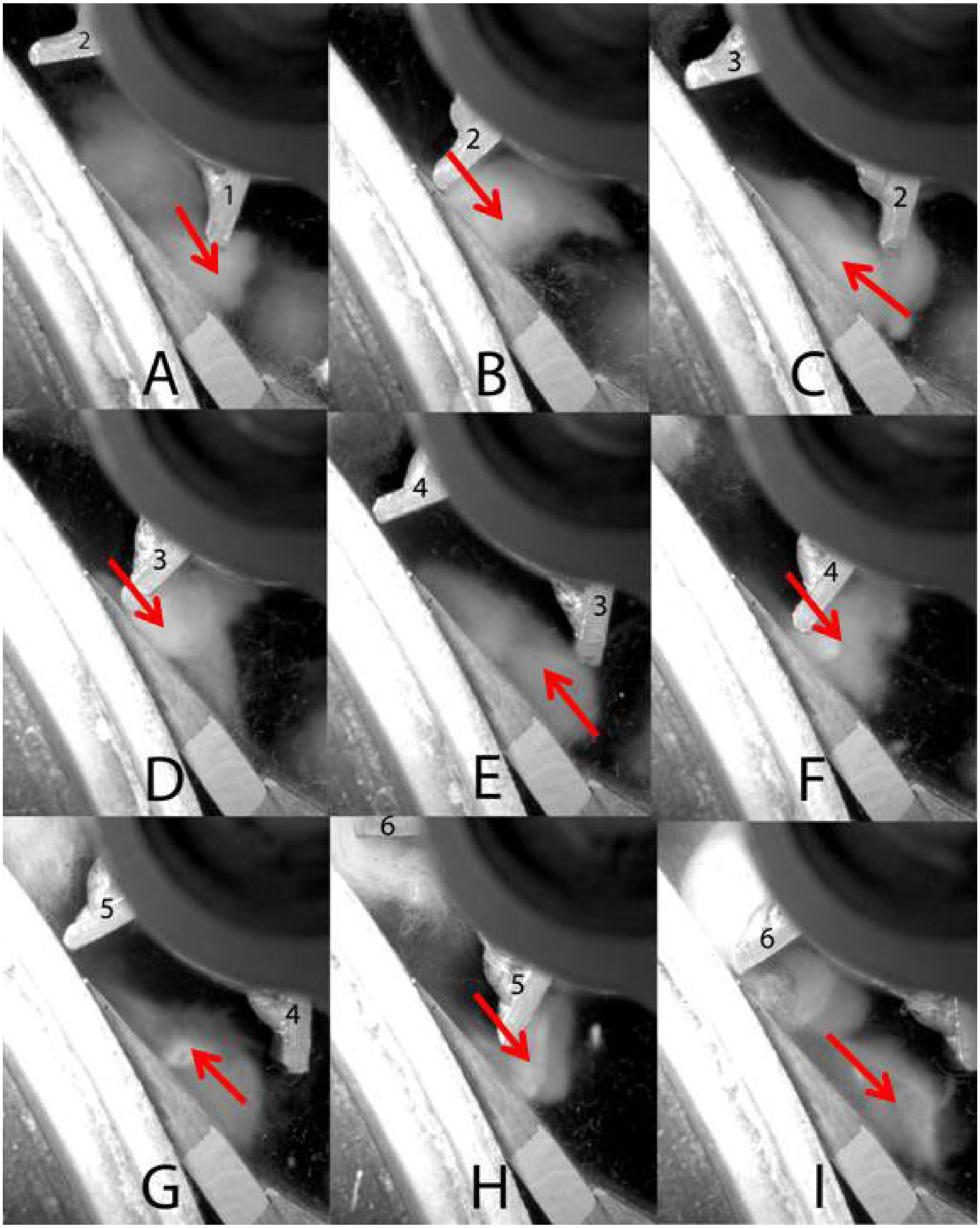


Figure 9. Process of differential roller ginning.

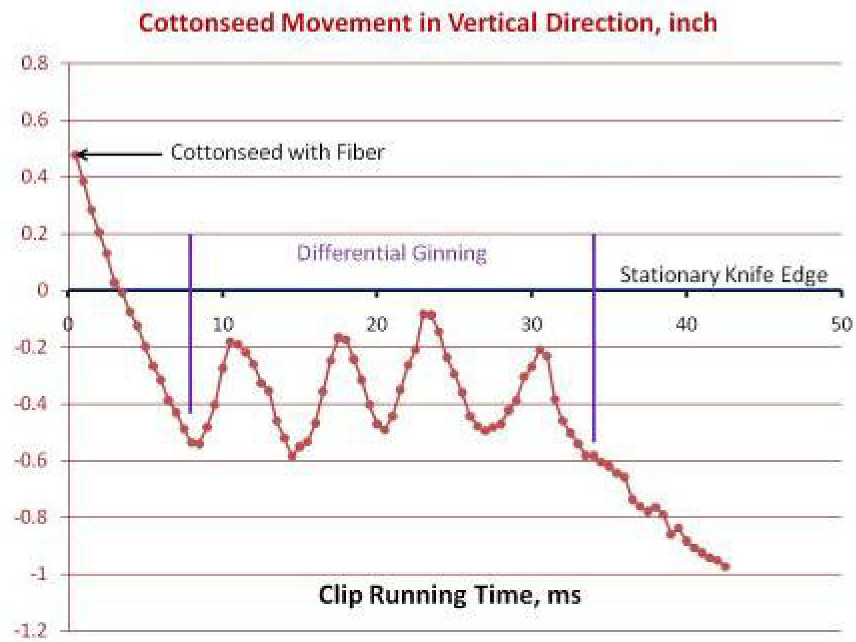


Figure 10. Cottonseed movement in vertical direction with differential roller ginning.

Table 1 shows that seed cotton was processed at a rate of 1.7 and 1.3 bales/hour on the conventional and differential roller ginning treatment, respectively. The lower ginning rate for differential roller ginning was due to cottonseed remaining at the ginning point about 35% longer than conventional roller ginning and a portion of seed cotton not being ginned (carryover). Carryover was 1.0 and 22.3 % on the conventional and differential roller ginning treatment, respectively. Higher carryover rates with differential roller ginning were expected because cottonseed remained longer at the ginning point and did not allow some of the incoming seed cotton to be ginned as rapidly as conventional roller ginning. The high-speed camera showed quite a bit of congestion at the ginning point of differential roller ginning, suggesting that precise feed control and single locking of seed cotton is even more important with differential roller ginning.

Table 1 also shows that both the conventional and differential roller ginning treatments had about 0.09 inch (three staple lengths) longer fiber than the saw-ginned sample. This was expected as the benefits of roller ginning versus saw ginning have been well documented. However, there was no difference in the 50 or 2.5% span length between conventional and differential roller ginning. The roller ginning treatments overall averaged 0.63 and 1.23 inches for the 50 and 2.5% span length, respectively. Other preliminary tests running at different surface velocity ratios between the ginning roller and rotary knife have shown that differential roller ginning has the potential of producing longer fiber. In this study, feeding seed cotton at too high a rate caused congestion at the ginning point and may have limited the amount of differential roller ginning that occurred. Hopefully, the high-speed video camera will now help determine relationships between surface velocity ratio of the ginning roller and rotary knife, and fiber length.

Table 1. Ginning rate, carryover, and Fibrograph results.

| | Saw Gin | Conventional Roller Gin | Differential Roller Gin |
|---|---|---|---|
| Ginning rate, bales/hour | - | 1.7 | 1.3 |
| Carryover, % | - | 1.0 | 22.3 |
| 50% span length, inch | 0.55 | 0.64 | 0.62 |
| 2.5% span length, inch | 1.17 | 1.23 | 1.22 |
| 50/2.5% uniformity | 47.0 | 52.0 | 50.8 |

## Summary

The high-speed video camera allowed researchers to view the separation of cottonseed and fiber at the ginning point on a roller gin stand. Conventional and differential roller ginning of upland cotton was studied. Results showed that by changing the surface velocity ratio between the ginning roller and the rotary knife, it was possible to control the movement of cottonseed with respect to the ginning point (differential roller ginning). In this study, fiber lengths were not different between conventional and differential ginning treatments. The videos showed that precise feed control and single locking of seed cotton is necessary to prevent excessive congestion at the ginning point. More testing is needed to determine the optimum surface velocities of the ginning roller and rotary knife, and the optimum number of blades on the rotary knife.

## Acknowledgements

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## Disclaimer

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

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