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INITIAL EVALUATION OF A MODIFIED CYLINDER-TYPE CLEANER FOR SEED COTTON

Samuel Ray
Stoneville, MS
W. Stanley Anthony
U.S. Cotton Ginning Laboratory
Stoneville, MS

Abstract

The effectiveness of eight grid bar/speed treatments of a gravity-fed inclined six-cylinder cleaner equipped with "paddles" was evaluated for cleaning seed cotton, based on cleaning efficiency and fiber wastage. The conventional grid bar configuration with round grid bars was analyzed, as well as 3/8" and 1/4"-wide square bars, with 1/4" and 3/8"-gaps, respectively. The square grid bar configurations included both flat square bars, in which the sides of the square bars were tangential to cotton flow, and sharp square bars, with the corner tangential to the flow of cotton. A cylinder speed of 480 rpm (conventional) was evaluated for all grid bar configurations, and a speed of 980 rpm was evaluated for all configurations except the thin square bars. Also, half the seed cotton was pre-cleaned before testing, so both first and second stage cleanings could be simulated. The study also included a performance evaluation of the first three and second three grid sections by capturing the wastes from each separately. Results indicated that the flat, square 3/8"-bars at a cylinder speed of 980 rpm performed the best in overall cleaning performance and first and second stage cleaning performance. Analysis of the first three and second three grid sections revealed that the flat, square 1/4"-bars at a cylinder speed of 480 rpm performed the best on the first threes sections, while the flat, square 3/8"-bars at a cylinder speed of 980 rpm performed the best on the second three sections.

Introduction

Ginners of mechanically harvested cotton are faced with balancing drying, cleaning, and fiber loss to yield the highest returns for the producer, which is a function of lint quality and the ratio of ginned lint to raw seed cotton (turnout). While high levels of lint cleaning may remove an impressive amount of foreign matter, it also increases the short fiber content and nep count and slightly reduces the staple of the ginned lint (Columbus, 1993). Two lint cleaners are commonly used after the gin stand to reduce the foreign matter content to a desired level. The current recommended machine sequence used to clean spindle harvested cotton is: Drier, six-cylinder cleaner, stick machine, drier, six-cylinder cleaner, extractor-feeder, gin stand, and two lint cleaners (Baker et al., 1994). Columbus and Anthony (1991) considered substituting some lint cleaning with increased seed cotton cleaning in an effort to maintain fiber length and avoid excessive nep formation. They found that using three additional seed cotton cleaners in lieu of a secondary lint cleaner maintained the market grade of the ginned lint and increased the monetary returns for the producer by increasing the turnout. The resulting ginning sequence was: Drier, six-cylinder cleaner, stick machine, six-cylinder cleaner, stick machine, Trashmaster, impact cleaner, extractor-feeder/gin stand, and one lint cleaner. Too much seed cotton cleaning, however, can cause the fiber to become ropy and rough to gin. The importance of improving the efficiency of individual seed cotton cleaning machines may be emphasized in an effort to reduce the number of machines used.

Several factors affect seed cotton cleaning efficiency, such as initial foreign matter content of the seed cotton, nature of the foreign matter, fiber moisture content, varietal characteristics, machinery type and sequence, condition of equipment, operating parameters, processing rate, and the uniformity of cotton flow. The inclined six-cylinder cleaner is the most common machine used in the seed cotton cleaning sequence. The cleaners consist of six spiked cylinders that rotate and scrub raw seed cotton across concave surface usually composed of wire mesh or grid bars. Fine foreign particles are agitated from the fiber and fall through the screen or grid sections, while the cleaned seed cotton passes to the next machine. The normal processing rates range from 1.5 to 2.5 bales/hr per foot of cylinder length, and the cylinder speeds are typically near 480 rpm. The most common scrubbing concave surface is a configuration of 3/8" diameter grid bars with a 3/8" gap between them oriented perpendicular with the cotton flow.

Cylinder speed affects both the momentum at which the seed cotton is scrubbed across the grid bars and the batt thickness at a constant feed rate. The momentum increases linearly with cylinder speed, while the batt thickness linearly decreases. Baker et al. (1982) showed that increasing the cotton processing rate reduces the cleaning performance of stripper harvested seed cotton in an air-fed six-cylinder cleaner. A few studies have targeted the effect of cylinder speed on seed cotton cleaning efficiency. Cocke (1972) reported that the cleaning efficiency of a seven-cylinder cleaner increased with cylinder speed, but did not significantly change the overall efficiency of the entire seed cotton cleaning sequence. Test speeds ranged from 350 to 650 rpm. Cocke went on to state that the increased speed had no noticeable effect on lint loss, staple length, or the color of the cleaned seed cotton. Read (1972) also performed a study evaluating cylinder speeds and found that increasing the speed from 400 – 425 rpm to 550 rpm increased the efficiency of a six-cylinder cleaner. He presented the results over three separate ginning seasons and calculated the cleaning efficiency of each individual machine and the incremental cumulative values after each machine in the ginning process. In the first year, the increased efficiency of the cylinder cleaner resulted in a significantly higher efficiency at the extractor-feeder, but the cumulative efficiency was lost after passing through a saw-type lint cleaner. The second year, the increased cumulative efficiency was apparent after a stick machine followed by a bur machine, but was lost at the extractor-feeder. The third season revealed an increased cumulative efficiency after the entire ginning process. Contrary to the findings of Cocke (1972) and Read (1972), Whitelock and Anthony (2003) reported no significant difference in the percentage of trash collected from a six-cylinder cleaner when cylinder speeds were 480 and 1100 rpm. The grid bars used in the study were 3/8” diameter bars; however, the gaps between the bars were only 1/8” which is a quarter inch narrower than conventional spacing. The seed cotton lots in the test were only fed through a drier and the cylinder cleaner being evaluated.

Researchers have also analyzed the effect of various grid bar configurations as related to seed cotton cleaning efficiency of cylinder cleaners. Laird, et al. (1984) compared grid bars with 1/4”, 3/8” (conventional), and 1/2” diameters, and each diameter with 1/4”, 3/8”, and 1/2” gaps. Screen grid sections with 1/2”, 5/8”, and 3/4” square openings were also evaluated. Results indicated that the 1/2” screen grid section was the most efficient of all configurations when considering both foreign matter removal and fiber loss. However, Laird, et al. (1984) stated that screens are much less durable than grid bars and are rarely used in industry. The 1/4” and 3/8” diameter bars each with a 3/8” gap were the most efficient grid bar configurations with little fiber loss. Whitelock and Anthony (2003) compared five different grid section configurations: 1) 3/8” diameter bars with 3/8” gap (conventional), 2) 3/8” diameter bars with 1/8” gap, 3) square 1/4” width bars oriented with the flat side of the rod parallel to the flow of cotton (flat) with 3/8” gap, 4) square 1/4” width bars oriented with the corner of the rod parallel to the flow of cotton (sharp) with 3/8” gap, and 5) perforated metal with 1/4” diameter holes at 3/8” centers. They found that the square grid bars provided more aggressive cleaning and removed more trash than the others, but the lint loss was higher, especially when the sharp square grid bar was used. They recommended narrowing the gap of the flat grid bar configuration in future research.

Anthony (U.S. Patent 6325215, and U.S. Patent 6539585) suggested adding “paddles” on some or all the spiked cylinders to improve the separation of fibrous materials from non-fibrous materials, such as lint cotton, lint cleaner waste, and flax from foreign material, and polyester fiber from rubber particles. Anthony found that the paddles were beneficial for increasing the cleaning efficiency. However, no research has targeted the use of paddled cylinders in cleaning seed cotton.

This study evaluated the seed cotton cleaning efficiency and lint loss of a gravity-fed inclined six-cylinder cleaner equipped with paddles. The treatments consisted of various combinations of grid bar configurations and cylinder speeds. The objectives were: 1) determine which treatments were most effective overall, averaging over two varieties and two levels of cleaning, 2) determine which treatments were most effective at the first and the second stage of cleaning, and 3) determine which treatments were most effective at the lower three and upper three grid sections. Based on Whitelock and Anthony’s (2003) recommendation, narrowing the gap of the flat square grid bar sections was incorporated into the study. The results of this work can be a useful tool in improving seed cotton cleaning with minimal machinery to avoid using a secondary lint cleaner.

Methods and Materials

The experiment was conducted in the microgin at the USDA-ARS Cotton Ginning Laboratory in Stoneville, Mississippi. The test incorporated two cotton varieties and two levels of initial foreign matter content. The varieties used in the test were Delta and Pine Land 105 (smooth-leaf) and Stoneville 4892 (hairy-leaf). Each variety was harvested within a single day and was from the same field. The seed cotton was prepared by sacking 48 lots of each variety. The two levels of foreign matter content were obtained by pre-cleaning half the lots from each variety through an inclined six-cylinder cleaner and a stick machine. The pre-cleaned cotton served as both an additional level of initial foreign matter content and as a representation of the “second stage” of cylinder cleaning. All lots ranged from 30 to 40 lb and were conditioned for four days in a controlled environment at 50% RH and 75º F before processing.

Five grid bar configurations were evaluated: 1) round 3/8” diameter bars with 5/16” gaps, 2) square 1/4” wide bars with 3/8” gaps with flat side of bars tangential to the flow of cotton, 3) square 3/8” wide bars with 1/4” gaps with flat side of bars tangential to the flow of cotton, 4) square 1/4” wide bars with 3/8” gaps with corners of the square bars tangent to the flow of cotton, and 5) square 3/8" wide bars with 1/4” gaps with corners of the square bars tangent to the flow of cotton. Two cylinder speeds of 480 and 980 rpm were evaluated with each grid bar configuration, except the square-flat and square-sharp with the 1/4” bars were only tested at 480 rpm, leaving a total of eight grid bar/speed treatments. The grid bar descriptions and the cylinder speeds tested for each are summarized in Table 1, and the grid bar cross-sections are illustrated in Figure 1. The treatment ID’s are indicated in the format:

grid bar type (bar width,gap size,cylinder speed)

Each of the eight treatments was replicated three times for each of the four combinations of variety and foreign matter content, adding to a total of 96 test runs. The experimental design was a randomized complete block, set up as a split-split plot design. Grid bar configuration was the main unit, cylinder speed was the sub-unit, and a 2 by 2 factorial of variety and foreign matter content was the sub-sub-unit.

All 96 lots of seed cotton were processed through the feed control, one tower drier (set at 150 F), and the experimental inclined six-cylinder cleaner (Figure 2). The feed rate was approximately 14 lb/min per foot of cylinder length. The cylinder cleaner was conventionally oriented at 30º, and the diameter of the cylinder drums was 11-3/16” with 1-3/8” spikes, with a density of approximately 56 spikes per foot of cylinder length. Each cylinder was also equipped with three orthogonal paddles running the length of the cylinder and extended to the same height as the spikes (Figure 3). The tip speeds of the spiked cylinders were 29 and 60 ft/sec at 480 and 980 rpm, respectively. Approximately 40 lb of extra seed cotton was used for warm-up after downtimes exceeding 15 minutes.

Five observations per lot were taken for fractionation analysis before and after processing, and five moisture observations were also taken per lot as the seed cotton exited the cylinder cleaner. The waste expelled by the first three cylinders and the second three cylinders were captured separately to indicate more specifically where the primary cleaning and cotton wastage occurred for each treatment. All waste was retained for fractionation.

Moisture contents were determined by the standard oven drying method, and foreign matter contents were determined from pneumatic fractionation (Shepherd, 1972). The results were broken down into good seed cotton and total foreign matter, and the foreign matter was further broken in to subcategories of hulls, sticks/stems, grass, motes, small leaf, and pin trash. Cleaning efficiency (η) was calculated by:

$$\eta = \frac{\text{fm1}}{\text{fm1} + \text{fm2}} * 100\%$$

where: fm1 = mass of foreign matter in the waste expelled from experimental cylinder cleaner
fm2 = mass of foreign matter in seed cotton after cleaning.

This method of calculating efficiency was chosen rather than the conventional method of determining efficiency based on the trash contents of the seed cotton before and after processing. The primary reason was because the above method revealed a higher degree of sensitivity to changes in treatments.

The fiber expelled in the trash was labeled as fiber wastage (fw), and was normalized to be expressed as lb/bale:

$$\text{fw} = \frac{\text{fiber loss}}{\text{uncleaned s.c.}} * 1500$$

where: fiber loss = weight of fiber expelled with waste (lb),
uncleaned s.c. = seed cotton (lb), and
1500 = constant assuming 1500 lb of raw seed cotton per 500-pound bale of ginned lint (lb/bale).

Results

Seed cotton moisture contents are summarized in Table 2. The average seed cotton moisture content of all the treatments was 6.2% w.b. There were no significant differences among any treatments, except for treatment *sharp (3/8,1/4,980)* and *round (3/8,5/16,480)*, which were not considered to be large enough to affect the cleaning efficiency.

Fractionation of the seed cotton before cleaning revealed a mean total foreign matter content of 4.8%, with no significant differences among treatments (Table 3). Nearly three quarters of the foreign matter consisted of motes and small leaf particles. The fractionation of the raw seed cotton also revealed significant differences among all four combinations of variety and initial foreign matter content (Table 4). The hairy-leaf variety (STV 4892) contained more foreign matter than the smooth-leaf variety (DPL 105) probably because of the inherent nature of the 'fuzzy' particles to bond more securely with the cotton fibers. Pre-cleaning reduced the foreign matter content of each variety by about 40%. The foreign matter contents and statistical results of each constituent after cleaning are listed in Table 5. Treatments *flat (3/8,1/4,480)* and *round (3/8,5/16,480)* had significantly higher total foreign matter contents than all other treatment. Sticks/stems, motes, small leaf particles, and pin trash revealed at least three levels of significant differences.

Overall seed cotton cleaning efficiencies achieved with the experimental cylinder cleaner ranged from 19.2% for treatment *flat (3/8,1/4,480)* to 36.7% for *round (3/8,5/16,980)* and are listed in Table 6. Treatments *round (3/8,5/16,980)* and *sharp (3/8,1/4,980)* removed a significantly higher percentage of foreign matter than all other treatments. The higher efficiency was attributed to the more aggressive cleaning action of the round and sharp, square bars in combination with the high cylinder speed. However, the *flat (3/8,1/4,980)* only cleaned at an efficiency of 28.3% and was considered much gentler than the round and the sharp grid bar configurations tested at the higher speeds. No significant differences occurred among treatments *sharp (1/4,3/8,480)*, *flat (1/4,3/8,980)*, and *flat (1/4,3/8,480)*, but were all significantly higher than *round (3/8,5,16,480)*, *sharp (3/8,1/4,480)*, and *flat (3/8,1/4,480)*. Treatment *flat (3/8,1/4,480)* removed significantly less foreign matter than all other treatments. All treatments at the higher cylinder speed of 980 rpm resulted in significantly higher cleaning efficiencies than the corresponding grid bar configurations at 480 rpm. At the conventional cylinder speed of 480 rpm, the sharp grid configuration with 1/4"-bars achieved the highest cleaning efficiency of 29.5%, which was not significantly different from the flat grid configuration with 1/4"-bars. Both square configurations with 1/4"-bars were significantly higher than the conventional round grid bars at the lower speed.

The fiber wastages for all treatments were also evaluated (Table 6). The fiber losses ranged from essentially no loss for treatments *flat (3/8 1/4,480)* and *flat (3/8,1/4,980)* to 4.7 lb/bale for treatment *sharp (3/8,1/4,980)*. Treatments *sharp (3/8,1/4,980), round (3/8,5/16,980),* and *sharp (1/4,3/8,480)* expelled substantially more fiber than the other treatments, with the latter two treatments losing 3.3 and 2.6 lb/bale, respectively. The remaining treatments lost less than 0.67 lb/bale. Considering both overall cleaning efficiency and fiber wastage, the most effective treatment was *flat (3/8,1/4,980)*.

The foreign matter contents after cleaning, cleaning efficiencies, and fiber wastages for each variety are presented in Table 7. The foreign matter contents of the smooth-leaf variety were substantially lower than the hairy-leaf variety, primarily due to the differences in the initial seed cotton. The cleaning efficiencies of the hairy-leaf variety, however, were noticeably higher than the smooth-leaf, though efficiencies over all treatments were positively and linearly correlated between varieties ($r^2 = 0.96$). The correlation indicates that a better treatment for either one of the varieties is also a better treatment for the other variety. The fiber wastages among treatments were similar and were also positively and linearly correlated ($r^2 = 0.98$).

Data from the study was also analyzed to compare the effectiveness of the experimental cylinder cleaner as a first stage cleaner versus a second stage cleaner. Cleaning efficiencies were separately calculated for both the non pre-cleaned test lots (first stage) and the pre-cleaned test lots (second stage) (Table 8). As a first stage cleaner, cleaning efficiencies ranged from 21.1% for *flat (3/8 1/4,480)* to 38.4% for *round (3/8,5/16,980)*. Treatments *round (3/8,5/16,980)* and *sharp (3/8,1/4,980)* were significantly higher than all other treatments, while treatment *flat (3/8,1/4,480)* was significantly lower than all others. Cleaning efficiencies for the second stage analysis ranged from 17.3% for *flat (3/8,1/4,480)* to 36.7% for *sharp (3/8,1/4,980)*. The relationship among the treatments in both stages were nearly the same, with treatments *round (3/8,5/16,980)* and *sharp (3/8,1/4,980)* significantly higher and treatment *flat (3/8,1/4,480)* significantly lower than all other treatments. During both stages, values for treatments with a cylinder speed of 980 rpm were consistently higher than the corresponding grid bars at a cylinder speed of 480 rpm. The first stage cleaning efficiencies were generally higher than second stage efficiencies because the level of difficulty to remove trash increases as the foreign matter content of the seed cotton decreases. From this analysis, variations in cleaning efficiency were slightly more sensitive to changes in grid bar configuration and cylinder speeds in the second stage of cleaning than the first stage.

The fiber wastages from each treatment for both the first and second stage cleaning can be observed in Table 8. The fiber wastages from both stages of cleaning were unacceptable for treatments *sharp (3/8,1/4,980), round (3/8,5/16,980),* and *sharp (1/4,3/8,480)*, and the second stage of cleaning for these treatments expelled about twice the amount of good fiber than the first stage. Treatment *flat (3/8,1/4,980)* was considered the most effective treatment for both stages of cleaning because essentially no loss of good fiber occurred, and relatively good cleaning efficiencies of 29.6% and 27.0% for the first and second stages of cleaning, respectively, were maintained.

The cleaning efficiencies of the first three and second three grid sections in the cylinder cleaner were also evaluated (Table 9). The lower three grid sections consistently experienced higher cleaning efficiencies than the upper three grid sections because the foreign matter content of the seed cotton was highest at the entrance of the cylinder cleaner. Cleaning efficiencies of the first three grid sections ranged from 12.7% for treatment *flat (3/8,1/4,480)* to 23.0% for treatment *round (3/8,5/16,980)*, each significantly different from all other treatments. The second three grid sections experienced cleaning efficiencies ranging from 6.5% for treatment *flat (3/8,1/4,480)* to 16.5% for treatment *sharp (3/8,1/4,980)*, each also significantly different from the all other treatments.

The fiber wastages for each treatment from the first three and second three grid sections are listed in Table 9. Fiber wastage was excessive for treatments *sharp (3/8,1/4,980), round (3/8,5/16,980),* and *sharp (1/4,3/8,480)* for both the first three and second three grid sections, but the fiber loss from all other treatments was acceptable. The most effective treatment for the first three grid sections was *flat (1/4,3/8,480)*, which processed with a cleaning efficiency of 20.2% and the fiber loss was only 0.33 lb/bale. Treatment *flat (3/8,1/4,980)* proved to be the most effective configuration of the second three grid sections, with a cleaning efficiency of 11.3% and virtually no fiber wastage. These results suggest that using treatment *flat (1/4,3/8,480)* on the first three grid sections and treatment *flat (3/8,1/4,980)* on the second three grid sections may offer potential to improve the overall cleaning performance of the modified inclined six-cylinder cleaner.

Summary and Conclusions

The effectiveness of eight grid bar/speed treatments of a gravity-fed inclined six-cylinder cleaner equipped with "paddles" was evaluated. The effectiveness of each treatment was analyzed in terms of cleaning efficiency and fiber wastage, which was performed from three perspectives: 1) overall effectiveness, which was averaged over two varieties and two levels of cleaning, 2) first stage cleaning versus second stage cleaning, and 3) first three grid sections versus second three grid sections.

In all three cases, treatments *sharp (3/8,1/4,980), round (3/8,5/16,980),* and *sharp (1/4,3/8,480)* wasted excessive fiber and were not considered adequate, regardless of the cleaning efficiency. Treatment *flat (3/8,1/4,480)* performed at a significantly lower cleaning efficiency in all cases, and was considered inadequate. The most effective treatment in the overall analysis, as well as in the first and second stage cleaning analysis, was *flat (3/8,1/4,980)*. However, treatment *flat (1/4,3/8,480)* had the best performance when evaluating the first three grid sections, while treatment *flat (3/8,1/4,980)* proved to better than the other treatment in the second three grid sections.

The results indicate that if only one treatment was to be used, the *flat (3/8,1/4,980)* would be the recommended configuration. However, the evaluation of the first three and second three grid sections suggest that it may be beneficial to combine treatments within a cylinder cleaner to increase cleaning efficiency, while minimizing fiber loss. From this study, the preferred combination of treatments would be *flat (1/4,3/8,480)* on the first three grid sections and *flat (3/8,1/4,980)* on the second three grid sections.

Future work will include repeating this study using conventional cylinders (no paddles) with the same treatments to compare the effectiveness of the paddles, and ultimately, to determine which overall treatment or treatments will yield the best performance.

Disclaimer

Mention of a trade name, proprietary product, or specific machinery 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.

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Table 1. Description of grid bars and cylinder speeds.

	Grid bars				
Treatment ID[1]	Cross-section tangential to cotton flow	Width (in.)	Gap (in.)	Bars per section (cleaning points)	Cylinder speed (rpm)
round (3/8,5/16,480)	round	3/8	5/16	19	480
round (3/8,5/16,980)	round	3/8	5/16	19	980
flat (1/4, 3/8, 480)	square	1/4	3/8	21	480
flat (3/8,1/4,480)	square	3/8	1/4	21	480
flat (3/8,1/4,980)	square	3/8	1/4	21	980
sharp (1/4, 3/8,480)	square offset 45º	1/4	3/8	17	480
sharp (3/8, 1/4,480)	square offset 45º	3/8	1/4	19	480
sharp (3/8, 1/4,980)	square offset 45º	3/8	1/4	19	980

[1] Treatment ID indicates *grid bar type (bar width,gap size,cylinder speed).*

Table 2. Moisture content by treatment.

Treatment ID[1]	MCwb (%)[2][3]
sharp (3/8,1/4,980)	6.4 a
flat (1/4,3/8,480)	6.3 ab
flat (3/8,1/4,980)	6.3 ab
flat (3/8,1/4,480)	6.3 ab
sharp (3/8,1/4,480)	6.3 ab
round (3/8,5/16,980)	6.3 ab
sharp (1/4,3/8,480)	6.0 ab
round (3/8,5/16,480)	6.0 b

[1] Treatment ID indicates *grid bar type (bar width,gap size,cylinder speed).*

[2] Moisture contents followed by the same letter are not significantly different (p = 0.05).

[3] Values averaged over two varieties, two initial foreign matter contents, and three replications (n = 12).

Table 3. Fractionation data for seed cotton before processing through the experimental cylinder cleaner.

	Foreign matter content (%)[2][3]						
Treatment ID[1]	Total foreign matter	Hulls	Sticks and stems	Grass	Motes	Small leaf	Pin
round (3/8,5/16,480)	4.96 a	0.85 a	0.40 a	0.03 a	2.55 a	1.04 a	0.10 a
sharp (3/8,1/4,980)	4.95 a	0.84 a	0.42 a	0.05 a	2.60 a	0.95 ab	0.10 a
sharp (3/8,1/4,480)	4.83 a	0.73 a	0.40 a	0.03 a	2.61 a	0.96 ab	0.11 a
flat (1/4,3/8,480)	4.80 a	0.70 a	0.39 a	0.09 a	2.58 a	0.94 ab	0.10 a
sharp (1/4,3/8,480)	4.74 a	0.80 a	0.40 a	0.06 a	2.46 a	0.93 b	0.09 a
flat (3/8,1/4,480)	4.72 a	0.79 a	0.35 a	0.03 a	2.50 a	0.95 ab	0.10 a
round (3/8,5/16,980)	4.72 a	0.77 a	0.37 a	0.05 a	2.49 a	0.96 ab	0.10 a
flat (3/8,1/4,980)	4.59 a	0.70 a	0.38 a	0.03 a	2.46 a	0.93 b	0.09 a

[1] Treatment ID indicates *grid bar type (bar width,gap size,cylinder speed).*
[2] Numbers followed by the same letter within the same column are not significantly different ($p = 0.05$).
[3] Values averaged over two varieties, two initial foreign matter contents, and three replications ($n = 12$).

Table 4. Foreign matter content prior to processing through the experimental cylinder cleaner.

Variety	Pre-cleaned	FMC (%)[1][2]
DPL 105	No	4.8 b
DPL 105	Yes	2.7 d
STV 4892	No	7.2 a
STV 4892	Yes	4.4 c

[1] Foreign matter contents followed by the same letter within the same column are not significantly different ($p = 0.05$).
[2] Values averaged over eight treatments and three replications ($n = 24$).

Table 5. Fractionation data for seed cotton after processing through the experimental cylinder cleaner.

	Foreign matter content (%)[2][3]						
Treatment ID[1]	Total foreign matter	Hulls	Sticks & stems	Grass	Motes	Small leaf	Pin trash
flat (3/8,1/4,480)	3.65 a	0.71 ab	0.35 a	0.03 ab	1.92 a	0.60 a	0.04 ab
round (3/8,5/16,480)	3.57 a	0.73 a	0.28 bc	0.01 b	1.92 a	0.59 ab	0.04 abc
flat (1/4,3/8,480)	3.34 b	0.73 ab	0.28 bc	0.02 ab	1.81 bc	0.48 d	0.03 c
sharp (3/8,1/4,480)	3.32 b	0.54 b	0.27 bc	0.02 a	1.88 ab	0.57 bc	0.04 abc
sharp (1/4,3/8,480)	3.32 b	0.68 ab	0.29 ab	0.03 ab	1.79 bc	0.50 d	0.03 bc
flat (3/8,1/4,980)	3.29 b	0.68 ab	0.23 bcd	0.02 ab	1.77 c	0.55 c	0.03 bc
round (3/8,5/16,980)	3.26 b	0.59 b	0.22 cd	0.01 b	1.85 abc	0.55 c	0.04 abc
sharp (3/8,1/4,980)	3.25 b	0.64 ab	0.20 d	0.03 ab	1.76 c	0.58 ab	0.04 a

[1] Treatment ID indicates *grid bar type (bar width,gap size,cylinder speed).*
[2] Foreign matter contents followed by the same letter within the same column are not significantly different (p = 0.05).
[3] Values averaged over two varieties, two initial foreign matter contents, and three replications (n = 12).

Table 6. Cleaning efficiency of experimental cylinder cleaner.[1][2]

Treatment ID[3]	Cleaning efficiency (%)	Fiber wastage (lb/bale)
rnd (3/8,5/16,980)	36.7 a	3.29 b
shrp (3/8,1/4,980)	36.6 a	4.74 a
shrp (1/4,3/8,480)	29.5 b	2.64 c
flt (3/8,1/4,980)	28.3 b	0.00 e
flt (1/4,3/8,480)	28.2 b	0.66 d
rnd (3/8,5/16,480)	23.7 c	0.17 e
shrp (3/8,1/4,480)	23.4 c	0.14 e
flt (3/8,1/4,480)	19.2 d	0.00 e

[1] Numbers followed by the same letter within the same column are not significantly different (p = 0.05).
[2] Values averaged over two varieties, two initial foreign matter contents, and three replications (n = 12).
[3] Treatment ID indicates *grid bar type (bar width,gap size,cylinder speed).*

Table 7. Foreign matter content, cleaning efficiency, and fiber wastage by variety.[1][2]

	DPL 105 (smooth-leaf)			STV 4892 (hairy-leaf)		
Treatment ID[3]	FMC after cleaning (%)	Cleaning efficiency (%)	Fiber wastage (lb/bale)	FMC after cleaning (%)	Cleaning efficiency (%)	Fiber wastage (lb/bale)
flt (3/8,1/4,480)	2.92 a	15.9 e	0.00 e	4.38 a	22.5 d	0.00 f
rnd (3/8,5/16,480)	2.87 ab	20.8 d	0.14 e	4.27 ab	26.6 c	0.21 e
flt (1/4,3/8,480)	2.86 ab	23.8 bc	0.63 d	3.83 c	32.5 b	0.69 d
shrp (1/4,3/8,480)	2.72 ab	25.9 b	2.78 c	3.92 c	33.1 b	2.51 c
shrp (3/8,1/4,980)	2.71 ab	32.1 a	5.63 a	3.79 c	41.0 a	3.84 a
flt (3/8,1/4,980)	2.61 ab	23.3 c	0.00 e	3.97 c	33.3 b	0.00 f
rnd (3/8,5/16,980)	2.58 b	32.8 a	3.69 b	3.94 c	40.7 a	2.89 b
shrp (3/8,1/4,480)	2.57 b	20.8 d	0.12 e	4.08 bc	26.1 c	0.17 ef

[1] Numbers followed by the same letter within the same column are not significantly different (p = 0.05).
[2] Values averaged over two initial foreign matter contents, and three replications (n = 6).
[3] Treatment ID indicates *grid bar type (bar width,gap size,cylinder speed).*

Table 8. Cleaning efficiency of experimental cylinder cleaner by seed cotton cleaning stage.[1][2]

	First stage cleaning[4]		Second stage cleaning[5]	
Treatment ID[3]	Cleaning efficiency (%)	Fiber wastage (lb/bale)	Cleaning efficiency (%)	Fiber wastage (lb/bale)
rnd (3/8,5/16,980)	38.4 a	2.36 b	35.1 a	4.23 b
shrp (3/8,1/4,980)	36.4 a	3.27 a	36.7 a	6.20 a
shrp (1/4,3/8,480)	31.7 b	1.69 c	27.4 b	3.60 c
flt (1/4,3/8,480)	31.2 b	0.59 d	25.1 c	0.73 d
flt (3/8,1/4,980)	29.6 b	0.00 e	27.0 bc	0.00 e
rnd (3/8,5/16,480)	26.6 c	0.11 e	20.9 d	0.24 e
shrp (3/8,1/4,480)	25.4 c	0.11 e	21.5 d	0.18 e
flt (3/8,1/4,480)	21.1 d	0.00 e	17.3 e	0.00 e

[1] Numbers followed by the same letter within the same column are not significantly different (p = 0.05).
[2] Values averaged over two varieties, and three replications (n = 6).
[3] Treatment ID indicates *grid bar type (bar width,gap size,cylinder speed).*
[4] Seed cotton in the first stage cleaning was only processed through a drier and the experimental cylinder cleaner.
[5] Seed cotton in the second stage cleaning was processed through a conventional cylinder cleaner and a stick machine, and then reprocessed through a drier and the experimental cylinder cleaner.

Table 9. Cleaning efficiency and fiber wastage from first three and second three grid sections.[1][2]

	First three grid sections		Second three grid sections	
Treatment ID[3]	Cleaning efficiency (%)	Fiber wastage (lb/bale)	Cleaning efficiency (%)	Fiber wastage (lb/bale)
rnd (3/8,5/16,980)	23.0 a	1.46 a	13.7 b	1.83 b
flt (1/4,3/8,480)	20.2 b	0.33 c	8.0 e	0.33 d
shrp (1/4,3/8,480)	20.2 b	1.10 b	9.3 d	1.54 c
shrp (3/8,1/4,980)	20.1 b	1.43 a	16.5 a	3.31 a
flt (3/8,1/4,980)	17.0 c	0.00 d	11.3 c	0.00 e
rnd (3/8,5/16,480)	16.3 c	0.09 d	7.5 e	0.08 de
shrp (3/8,1/4,480)	15.5 c	0.09 d	8.0 e	0.06 de
flt (3/8,1/4,480)	12.7 d	0.00 d	6.5 f	0.00 e

[1] Numbers followed by the same letter within the same column are not significantly different (p = 0.05).
[2] Values averaged over two varieties, two initial foreign matter contents, and three replications (n = 12).
[3] Treatment ID indicates *grid bar type (bar width,gap size,cylinder speed).*

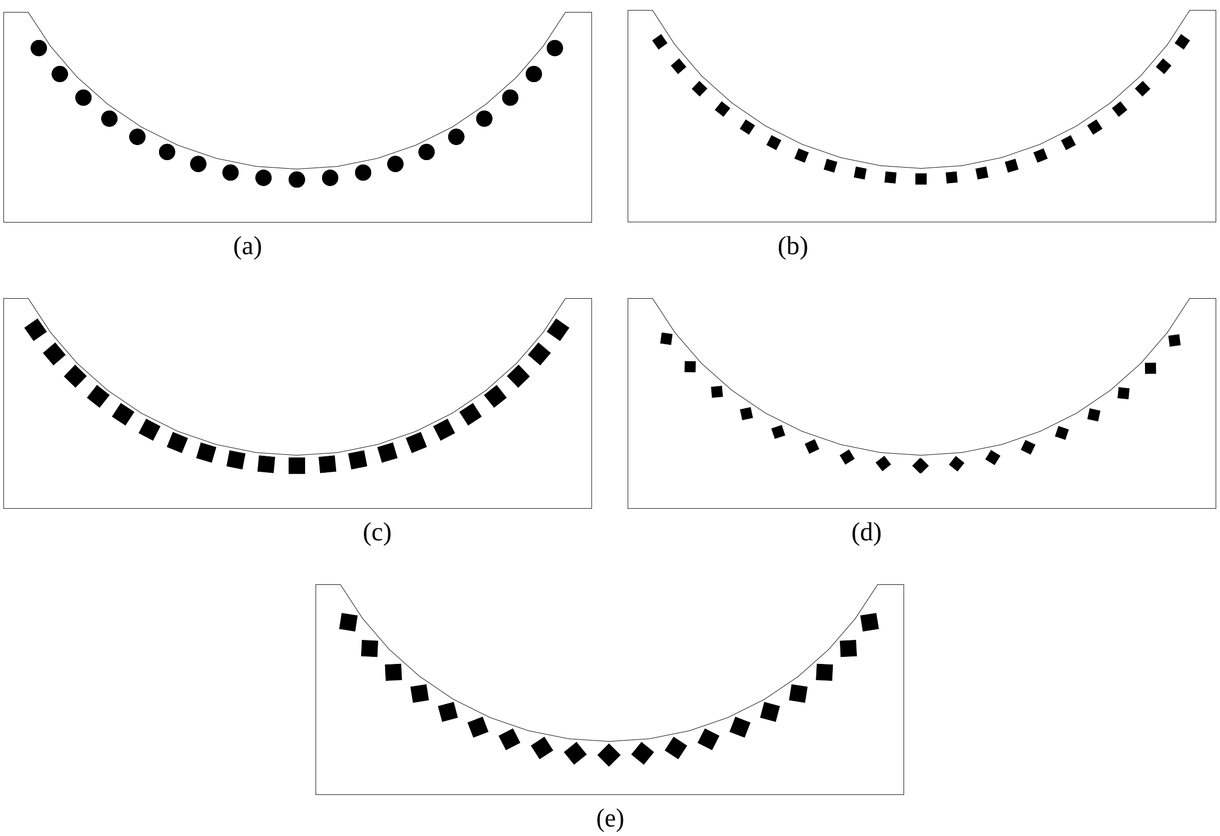

Figure 1. Cross-section of grid bar segments indicated as *grid bar type, bar width, gap size.* (a) round, 3/8" dia., 5/16"-gaps; (b) square-flat, 1/4" wide, 3/8" gaps; (c) square-flat, 3/8" width, 1/4" gaps; (d) square-sharp, 1/4" width, 3/8" gaps; (e) square-sharp, 3/8" width, 1/4" gaps.

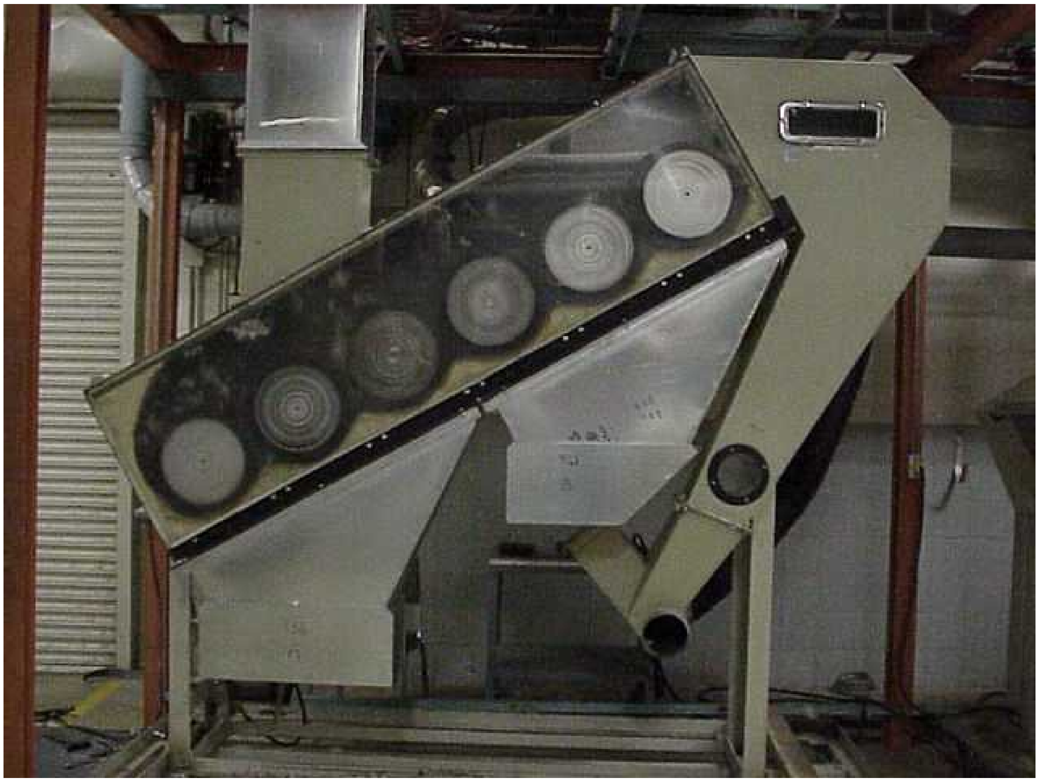

Figure 2. Experimental inclined six-cylinder cleaner. Waste from the first (lower) three cylinders and the second (upper) three cylinders were captured separately.

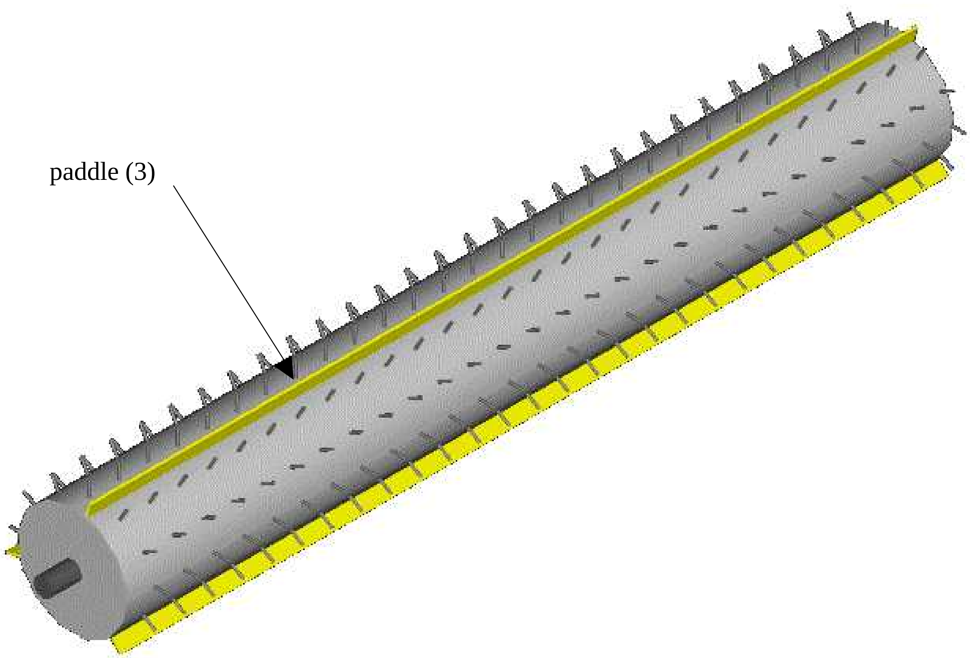

Figure 3. Cylinder of inclined seed cotton cleaner equipped with ‘paddles’.