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ENGINEERING & GINNING

Evaluating a Fiberglass Roller Covering on a Roller Gin Stand

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ABSTRACT

An experimental ginning roller covering, made from woven fiberglass, was tested on a roller gin stand to evaluate its ginning performance and effect on fiber quality. The experimental covering was much more aggressive than the standard covering; it ginned at twice the rate (2.4 vs. 1.2 bales per hour) at a much lower automatic feed-rate control setting and resulted in reduced roller heating (32.7 vs. 67.2 °C [91 vs. 153 °F] average). Higher levels of trash, based on HVI and AFIS measurements, were found in the lint from the experimental roller, but no significant differences were detected between the two coverings in the other raw fiber measurements or the white speck counts for dyed fabric. However, in a commercial roller gin, the covering failed after only six hours of normal ginning.

In 1964, V.L. Stedronnsky, the Research Leader of the USDA-ARS Southwestern Cotton Ginning Research Laboratory in Mesilla Park, New Mexico, said the following concerning the then new high capacity roller gins:

"Even though there has been a major breakthrough made in roller ginning capacities, one of the age-old problems with roller gins is not only still with us but has been even magnified with the advent of the new roller gins. That problem is in the very heart of the gin, the roller itself. The roller construction, types of covering, and methods of application have always been of major concern to the roller gin operators" (Stedronsky, 1964, p. 47).

The issues with roller covering and construction still exist today and are again "magnified" by the recent development of high-speed roller ginning (Gillum, 1985; Armijo and Gillum, 2007).

Pima cotton is roller ginned to preserve fiber quality (Gillum et al., 1994). Roller-ginning rate (about 1.5 bales per hour for a 101.6-cm [40-in.] wide roller) is limited by the rate that fibers adhere to the roller and slip under the stationary knife. Increasing roller speed increases ginning rate, but also produces higher roller temperatures due to friction (Gillum, 1985). Recent tests showed that additional cooling allowed higher ginning rates without excessive roller heating (Armijo and Gillum, 2007). Currently, roller covering material is made from layers of woven cotton fabric bonded together with a rubber compound (Fig. 1) that is spool-wound onto the roller core with the fabric layers perpendicular to the roller surface, so only the fabric ends are exposed to the stationary knife.

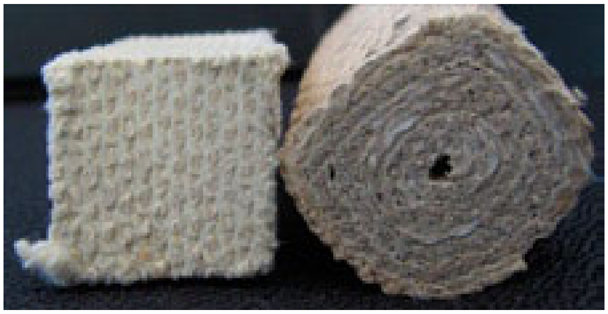

Figure 1. Cross-section of the standard roller covering (left) and the experimental roller covering (right).

Earlier research showed that rollers with the covering applied in strips length-wise in a one-turn spiral, and with 3.8 to 5.1 cm (1.5 to 2 in.) spaced v-shaped grooves that make one diagonal turn cut into the roller, have higher ginning rates (Townsend, 1941; Stedronsky, 1964). These practices have been abandoned, because spool winding roller covering is faster and cheaper and grooving the roller is costly and tends to cause increased roller wear.

Gillum (1974) tested 16 different gin rollers constructed from six different materials (fabric and rubber packing, leather, cotton, rubber, rubber and cork, and fluorinated ethylene propylene) to define how the covering's physical properties affect energy consumption and ginning rate. The rubber and cork covering had a high wear rate and lint contamination. The fluorinated ethylene propylene roller was

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quickly destroyed during ginning. Of the other roller types, the fabric and rubber packing-type rollers performed better. Optimum roller covering characteristics were defined: 56 type DO durometer hardness, 6.7 layers of fabric per cm (17 layers per in.), and 0.8 mm (0.03 in.) of fiber bristle protrusion beyond the rubber surface through the life of the roller material.

A more aggressive roller cover may pull more fiber under the stationary knife, increasing ginning rates at normal roller speeds and reducing heating at higher roller speeds. The objective of this research was to evaluate the roller ginning performance of an experimental ginning roller covering made from rolled woven fiberglass bonded with a rubber compound and to ascertain its effect on fiber quality.

MATERIALS AND METHODS

Ginning tests were conducted at the USDA-ARS Southwestern Cotton Ginning Research Laboratory (SWCGRL) in Mesilla Park, New Mexico on side-by-side roller gin stands: one stand, a Continental Phoenix Rotobar, with the standard ginning roller covering and the other stand, a Consolidated HGM, with the experimental ginning roller covering (Table 1). Although different gin stands were used, the two models are very similar in construction and operation. The main difference in the gin stand configurations was in the feeder design. However, this slight difference was assumed to be negligible. It could be argued that testing on two different gin stands added variability to the test, subsequently effecting the results. It was decided that using two gin stands with different rollers would introduce less variability than using one gin stand for both treatments where the gin roller would need to be removed, reset, and adjusted multiple times.

The test entailed ginning 181-kg (400-lb) lots of Pima seed cotton (DPL744, Delta and Pine Land Co., Scott, MS) on each of the two roller coverings. Each ginning treatment was replicated six times (six lots on each roller covering or approximately one and one half 218-kg [480-lb] bales of ginned lint total per roller covering). Seed cotton cleaning was the same for all test runs and included two inclined cylinder cleaners, one stick machine, and the gin stand extractor feeder. The target ginning rate for all tests was typical for roller gins (1 to 1.5 bales per hour). No lint cleaning was performed to prevent the masking or leveling effect that lint cleaning might have on the fiber properties or contamination results.

Two seed-cotton samples per lot were taken at the conveyor/distributor prior to the gin-stand feeder and two lint samples per lot were taken at the lint slide just prior to the bale press. The remaining lint from different roller covering treatments was pressed into separate bales to avoid cross contamination and ginning lots were separated within the bales by adding butcher paper dividers at the tramper box before each lot was ginned. Seed cotton was analyzed at the SWCGRL for foreign matter content by the pneumatic fractionator method and moisture content by the standard oven drying method (Shepherd, 1972). Raw lint fiber property tests, performed at the USDA-ARS Cotton Quality Research Station (CQRS) in Clemson, South Caro-

Table 1. Characteristics of Test Roller Gin Stands.

	Roller Covering	
	Experimental	**Standard**
Gin Stand Model	**Consolidated HGM**	**Continental Phoenix Rotobar**
Roller Covering Width, cm (in.)	**100.3 (39.5)**	**115.9 (45.625)**
Roller Diameter, cm (in.)	**38.1 (15)**	**38.1 (15)**
Rotary Knife Diameter, cm (in.)	**7.0 (2.75)**	**6.9 (2.726)**
Roller Durometer Hardness^z, no.	**55.1**	**52.2**
Roller Speed^z, rpm	**124**	**132**
Rotary Knife Speed^z, rpm	**416**	**394**
Roller to Rotary Knife Surface Speed Ratio^z, no.	**1.62**	**1.84**
Roller to Stationary Knife Force^z, N mm^{-1} (lb in^{-1})	**11.1 (63.6)**	**12.0 (68.3)**

^{z} Average of six measurements taken during tests.

lina, included High Volume Instrument (HVI) measurements and Advanced Fiber Information System (AFIS) measurements. Spinning performance, yarn properties, and dyed cloth white speck analyses were also performed at the CQRS. Samples were ring spun for a 22/1 count yarn with front roller speed, spindle speed, and yarn twist at 237 rpm, 13,000 rpm, and 3.50 T.M., respectively.

The test was designed as a randomized complete block, blocked by replication. Statistical analysis was performed using the SAS General Linear Models procedure, Proc GLM (SAS Institute, Inc. Ver. 9.1. Cary, NC). Differences among treatment means were evaluated at the 5% significance level.

RESULTS AND DISCUSSION

The results showed that there was no difference in seed-cotton moisture content and seed-cotton foreign matter content between the standard and experimental roller covering treatments. The measured ginning parameters for the experimental and standard covering revealed some surprising differences (Table 2). The ginning rate on both gin stands was automatically controlled with electronic controllers that regulate the seed-cotton feed rate based on the rotary knife power consumption (Gillum and Armijo, 1998). For the first replication, the side-by-side gin stand's controllers were adjusted to a setting that corresponded to normal ginning rates (1 to 1.5 bales per hour). It was soon discovered that the gin stand with the experimental covering was ginning at a much faster rate than the standard covering gin stand. In an effort to equalize the ginning rates of the two gin stands, the controller for the experimental covering gin stand was adjusted to slow down the ginning rate and the controller for the standard covering gin stand was adjusted to increase the ginning rate. By the end of the second replication the controller for the experimental covering gin stand was adjusted to the lowest setting (510 W) and the controller for the standard covering gin stand was adjusted to about 715 W. Despite these adjustments, the experimental roller covering ginned cotton at more than twice the rate of the standard covering (2.40 [0.73] and 1.02 [0.31] bales per hour per meter [foot] of roller width, respectively). One reason for the higher ginning rate may be that the experimental roller working surface was much rougher and thus more aggressive than the standard roller (Fig. 2). Another important difference measured was roller temperature. The experimental covering had significantly lower average and maximum temperatures while ginning than the standard covering. Due to wear from ginning two bales, the experimental roller decreased in diameter by about 0.38 mm (0.015 in.), while the standard roller did not show any measurable wear. These wear observations were based on one set of measurements before and after the experiment and, thus, the difference could not be tested statistically.

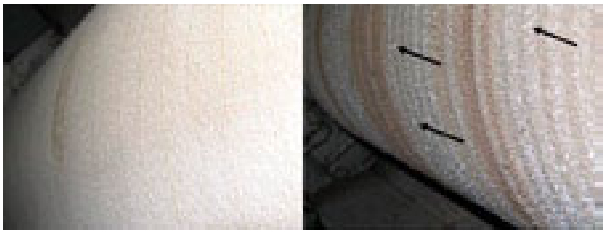

Figure 2. Standard roller covering (left) and experimental roller covering (right) installed in roller gin stands. Note: Fiberglass fibers protruding from experimental roller.

Table 2. Average[x] ginning parameters.

	Roller Covering		
	Experimental	**Standard**	**P-value[y]**
Controller Set-point, W	**543.8**	**705.7**	**<0.01**
Ginning Rate, bales h^{-1} m^{-1} (bales h^{-1} ft^{-1})	**2.40 (0.73)**	**1.02 (0.31)**	**<0.01**
Roller Temperature			
Average, °C (°F)	**32.7 (90.9)**	**67.2 (152.9)**	**<0.01**
Maximum, °C (°F)	**41.3 (106.3)**	**76.9 (170.5)**	**<0.01**
Change in Roller Diameter[z], mm (in.)	**0.38 (0.015)**	**0**	**---**

[x] **N = 6**

[y] **P-value for significance test of equivalence of parameters between roller coverings.**

[z] **Due to wear - calculated difference in roller diameter measurements taken before and after ginning.**

Fiber analyses showed very few differences in HVI and AFIS parameters between the experimental roller covering and the standard roller covering (Table 3). The main differences revealed were in those parameters that quantify foreign matter in the lint fiber. HVI leaf grade was almost an entire grade higher for the experimental cover (4.6) than for the standard cover (3.8). AFIS nep size, total trash count, dust count, and visible foreign matter were all significantly higher for the experimental roller covering (649.6 µm, 802.8 g^{-1}, 731.2 g^{-1}, and 1.66%, respectively) than for the standard roller covering (621.2 µm, 621.4 g^{-1}, 557.7 g^{-1}, and 1.23%, respectively). The reason for these differences in trash content could have been a result of the aggressiveness and roughness of the experimental roller that allowed more trash to be pulled under the stationary knife with the lint, but was more likely due to the fact that the extractor feeder feeding the gin stand with the standard roller removed more than four times the amount of trash than the extractor feeder feeding the experimental roller (1.42 kg [3.17 lb] vs. 0.33 kg [0.73 lb] per lot of seed-cotton ginned).

Table 3. Average[y] raw fiber properties and white speck counts from initial fiber sample analysis.

Fiber Analysis	Roller Covering Experimental	 Standard	P-value[z]
HVI			
Micronaire	4.0	3.9	ns
Reflectance, Rd	71.1	72.0	<0.01
Yellowness, +b	11.9	11.8	ns
Color Grade, no.	1	1	ns
Leaf Grade, no.	4.6	3.8	0.03
Upper Half Mean Length, mm (in.)	36.1 (1.42)	36.1 (1.42)	ns
Uniformity, %	86.9	86.8	ns
Strength, kN m kg^{-1} (g tex^{-1})	386 (39.3)	380 (38.7)	ns
Elongation, %	8.12	8.11	ns
AFIS			
Length(w), mm (in.)	32.0 (1.26)	32.0 (1.26)	ns
Length(w) CV, %	33.1	33.5	ns
Upper Quartile Length(w), mm (in.)	38.9 (1.53)	39.4 (1.55)	ns
Short Fiber Content(w), %	5.33	5.25	ns
Length(n), mm (in.)	25.4 (1.00)	25.4 (1.00)	ns
Fineness, mTex	151.8	149.8	ns
Immature Fiber Content, %	7.76	8.23	ns
Maturity Ratio	0.93	0.92	ns
Nep size, µm	649.6	621.2	0.03
Neps, cnt g^{-1}	129.5	101.1	ns
Total Trash, cnt g^{-1}	802.8	621.4	0.02
Trash Size, µm	238.7	256.2	ns
Dust, cnt g^{-1}	731.2	557.7	0.02
Trash, cnt g^{-1}	71.7	63.7	ns
Visible Foreign Matter, %	1.66	1.23	0.03
White Specks, cnt per 258 cm^2 or 40 in^2	5.6	5.3	ns

[y] N =6

[z] P-value for significance test of equivalence of properties between roller coverings, ns = not significant at the 5% level.

As the experimental roller wore, fiberglass fibers protruded from the surface of the experimental roller (Fig 2). These 6 to 13-mm (0.25 to 0.5-in.) long fibers could be easily extracted by hand. Because of this, it was expected that the cotton lint samples collected from the experimental roller would contain more contamination than samples from the standard roller. Surprisingly, the initial white speck analyses of the 258 cm^2 (40 in.^{2}) of knitted and dyed fabric from fiber samples taken at the lint slide did not reveal any difference in white speck counts between the two roller coverings, which averaged about 5.4 specks (Table 3); leading to the conclusion that the experimental roller did not contaminate the ginned cotton fiber. These findings prompted a full spinning and dyeing test to be performed on the larger baled lint samples to determine if there was actually no difference in contamination levels or if the stiff fiberglass contaminant may have been removed as waste during the milling process.

Spinning tests revealed few differences between the experimental roller and the standard roller (Tables 4 and 5). For raw, carded, and finisher fiber properties, only Shirley visible foreign matter of the raw fiber from the experimental roller (4.25%) was significantly different from the standard roller (2.23%). Opening and cleaning waste and total card waste was significantly higher for the experimental roller (4.15% vs. 2.07% and 4.72% vs. 4.41%, respectively) . This was likely due to the near double amount of foreign matter in the experimental roller fiber. Yarn elongation and yarn neps were also higher for the experimental roller. White speck counts (1.8 per 258 cm^2 [40 in.^{2}] of dyed fabric) from whole lot sample white speck analyses were not significantly different. Visual inspection of the spinning waste did not reveal any fiberglass contamination.

The experimental roller was installed in one of 16 gin stands at a commercial gin plant during the 2006-07 ginning season. The gin manager reported that the roller "ginned well" at first. However, after only about six hours of continuous ginning the roller

Table 4. Average[y] fiber properties from full spinning analysis.

	Roller Covering		
	Experimental	**Standard**	**P-value[z]**
Raw Fiber			
Shirley Visible Foreign Matter, %	**4.25**	**2.23**	**<0.01**
Upper Quartile Length(w), mm (in.)	**38.6 (1.52)**	**38.4 (1.51)**	**ns**
Short Fiber Content(w), %	**4.87**	**4.93**	**ns**
Maturity Ratio	**0.92**	**0.93**	**ns**
Neps, cnt g^{-1}	**187.8**	**151.7**	**ns**
Visible Foreign Matter, %	**1.40**	**1.13**	**ns**
Carded Fiber			**ns**
Upper Quartile Length(w), mm (in.)	**37.3 (1.47)**	**37.6 (1.48)**	**ns**
Short Fiber Content(w), %	**7.40**	**7.03**	**ns**
Maturity Ratio	**0.91**	**0.92**	**ns**
Neps, cnt g^{-1}	**47.7**	**32.5**	**ns**
Visible Foreign Matter, %	**0.02**	**0.03**	**ns**
Finisher			**ns**
Upper Quartile Length(w), mm (in.)	**38.1 (1.50)**	**37.8 (1.49)**	**ns**
Short Fiber Content(w), %	**5.50**	**5.75**	**ns**
Maturity Ratio	**0.96**	**0.97**	**ns**
Neps, cnt g^{-1}	**41.0**	**41.5**	**ns**
Visible Foreign Matter, %	**0.02**	**0.03**	**ns**

[y] **N =6**

[z] **P-value for significance test of equivalence of properties between roller coverings, ns = not significant at the 5% level.**

covering began to come apart (Fig. 3) and had to be removed. As the roller wore, the center section of the experimental rolled covering material separated at the fabric/rubber interface. It is not certain if the rolled construction (Fig. 1) or if the rubber bonding material was the reason for the failure. Conventional packing is made such that the cotton duck fibers are exposed only to the ends of the duck fibers with the rubber bonding material holding the full remaining length of the duck fibers, but the rolled construction of the experimental covering exposed the fiberglass fabric to broadside contact with the stationary knife such that individual fiberglass fibers could be pulled from their yarns. Also, rolling the fiberglass fabric into a spiraling round and then forcing it into the square cross-section may have resulted in areas of low density, making the bonding of fabric less reliable. It is believed that the rolled construction and/or the properties of the rubber bonding material gave the roller its rough surface texture and aggressive ginning qualities.

Figure 3. Experimental roller damage after six hours of ginning in a commercial gin plant.

Table 5. Average[y] spinning properties from full spinning analysis.

	Roller Covering		
	Experimental	Standard	P-value[z]
Opening and Cleaning Waste, %	4.15	2.07	<0.01
Total Card Waste, %	4.72	4.41	0.01
Actual Ends Down	11.5	26.8	ns
Calculated Ends Down 1000^{-1} spindle-hr^{-1}	29.3	30.5	ns
Lapped Ends, %	18	7.3	ns
Hard Ends, %	28.8	35.5	ns
Yarn			
Size	21.4	21.8	ns
Strength, kN m kg^{-1} (g tex^{-1})	228 (23.3)	232 (23.7)	ns
Elongation, %	7.06	6.98	0.02
Strength CV, %	7.09	6.98	ns
Neps, cnt per 914 m or 1000 yd	17.8	15.7	0.02
Thicks, cnt per 914 m or 1000 yd	104.2	105	ns
Thins, cnt per 914 m or 1000 yd	13.8	12.5	ns
Irregularity CV, %	14.6	14.5	ns
Irregularity CV - Card Sliver, %	3.3	3.4	ns
Irregularity CV - Finish Draw, %	3.2	3.2	ns
Major Faults	3.2	2.2	ns
Minor Faults	55.8	73.2	ns
Long Thicks	12	37.2	ns
Long Thins	162.8	174.5	ns
Appearance	96.7	99	ns
White Specks, cnt per 258 cm^2 or 40 in^2	2.17	1.5	ns

[y] N =6

[z] P-value for significance test of equivalence of properties between roller coverings, ns = not significant at the 5% level.

CONCLUSIONS

The experimental ginning roller covering was much more aggressive than the standard covering: it ginned at twice the rate (2.40 [0.73] vs. 1.02 [0.31] bales h^{-1} m^{-1} [bales h^{-1} ft^{-1}]) at a lower automatic feed-rate controller setting and resulted in less roller heating (32.7 vs. 67.2 °C [91 vs. 153 °F] average). There was more trash in the lint from the experimental covering based on HVI and AFIS measurements, but this was likely due to differences in the amount of trash removed by different extractor feeders feeding the two gin stands. However, there were no significant differences in other raw fiber measurements and few differences in the spinning test measurements between the experimental and standard roller coverings. Analysis showed that the fiberglass fibers in the experimental roller did not contaminate knitted cloth made from the lint ginned with the roller.

Roughness of the covering and its tendency to remain rough seems a likely cause of the greater ginning rate of the experimental covering. Future work focusing on this property may provide a better understanding of the relationships between covering construction, roller life, ginning rate, and fiber properties.

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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