EFFECTS OF FRICTION REDUCTION ON FIBER DAMAGE IN A SAW-TYPE LINT CLEANER

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Abstract

U.S. cotton is at a competitive disadvantage from a fiber-quality standpoint, because lint cleaning is required for mechanically harvested cotton, and lint cleaning causes fiber damage. Lint-cleaning research has focused mainly on modifying saw-type lint cleaners, but the work reported here focuses on the physics of cleaning foreign matter from cotton, specifically the effect of friction reduction on lint-cleaner effects on nep count and short-fiber content (SFC). Two tests were conducted in which a lubricant was added to the fiber prior to lint cleaning, and AFIS nep count and SFC were measured. Preliminary findings are that friction reduction may have a positive effect on neps and a neutral effect on SFC, although one of the lubricant-application levels appeared to produce the lowest levels of neps and SFC.

Introduction

Mechanical harvesting of U.S. cotton requires at least one stage of lint cleaning to reduce its foreign-matter content to a marketable level. Lint cleaning damages fibers by causing fiber breakage and fiber entanglements (neps), such that increases in short-fiber content and nep counts are typically measurable between before-and-after lint-cleaner samples. Mechanical improvements to the traditional saw-cylinder type lint cleaner that might reduce fiber damage are desirable.

Improvements have been made to lint cleaners over the years, but the same cleaning principles that were developed in the 1940s continue to be the state of the art (Baker et al., 1992). Recent research directed at fundamental changes to lint cleaning has approached the problem from two angles: (1) modeling the physics to determine the effects that current saw-type lint cleaners have on cotton fiber (Thomasson et al., 2006 and 2007), and (2) determining the fundamental requirements for removing foreign-matter particles from cotton fiber (Thomasson et al., 2008 and 2009). The modeling work indicated that friction between fibers and machine surfaces was likely a strong contributor to fiber damage. Therefore, the objective of this work was to determine whether reducing fiber-to-machine friction significantly affected fiber damage as measured between before-and-after lint-cleaner samples.

Methods and Materials

Experimental System. Experiments were conducted at the USDA-ARS Cotton Ginning Research Unit, Stoneville, Mississippi. The laboratory's Microgin was used to gin seed cotton with the following machine sequence:

- Dryer
- Cylinder Cleaner
- Stick Machine
- Dryer
- Cylinder Cleaner
- Extractor Feeder
- Gin Stand
- Lint Cleaner

Various lubricant-mixture concentrations were sprayed onto the lint cotton prior to lint cleaning. The lubricant used is sold under the brand name, HIIVol™ (Therdyn Inc., Levelland, TX), and is used in the textile industry and by certain ginning facilities for various purposes such as minimizing processing problems related to static and stickiness. The various lubricant concentrations were realized by mixing the concentrated product with water at differing dilution rates. The gin was set to run at approximately 0.8 bale/hr (0.0504 kg/s), and this setting was not changed throughout testing. A bale mass of 500 lb (227 kg) was assumed for all calculations. Fluid was added to the cotton between the gin stand and lint cleaner at a nominal rate of 1.2 gal/hr by pressurizing the fluid at 10 psi[2] (69 kPa) and spraying with four nozzles (Wm. Steinen Mfg. Co., Parsippany, New Jersey; MistJet® Hollow Cone Misting/Fogging Nozzle, Type AM, Orifice Diameter 0.010 in., 90º spray angle).

Test 1. A first test was conducted on June 17, 2009. Nine treatments were run in the test:

1. No additive (control 1)
2. Water only (control 2)
3. 0.005 lb lubricant/bale (nominal)
4. 0.010 lb lubricant/bale (nominal)
5. 0.020 lb lubricant/bale (nominal)
6. 0.040 lb lubricant/bale (nominal)
7. 0.080 lb lubricant/bale (nominal)
8. 0.160 lb lubricant/bale (nominal)
9. 0.320 lb lubricant/bale (nominal)

Three measurements of ginning rate were made in order to calculate an average ginning-rate: one before the first set of nine treatments, one between the two sets of nine treatments, and one after the second set of nine treatments. Ginning-rate measurements were conducted by collecting and weighing cotton coming off the lint slide for three minutes, and calculating the ginning rate in bales/hr. The cotton was fairly dry coming into the gin, and the temperature on both dryers was set at 200ºF to maximize evaporation of the added moisture and adhesion of the lubricant to the fiber.

Two sets of the nine treatments were run, with the treatments being in random order in each set (Table 1). At the beginning of each treatment run, 1.0 min. was allowed to elapse before samples were taken. Within each treatment run, three lint samples were collected for AFIS (Advanced Fiber Information System) measurements, about 1.0 min. apart, at two locations simultaneously: before the lint cleaner and after the lint cleaner. Also within each treatment run, two lint samples were collected for MCWB (moisture content, wet basis) measurement, and one lint sample was collected for HVI (High-Volume Instrument) measurements. Thus, for fiber damage assessment there were nine treatments with two replications, with three samples each at two locations. In total, 108 samples were collected for AFIS measurements, 36 for MCWB measurement, 18 for HVI measurements, and three for ginning-rate measurement.

Containers of the various mix concentrations were weighed on a scale during each treatment run. Weights were recorded near the beginning and end of each treatment run, and the time between recorded weights was measured. Actual solution-application rate was calculated by converting the weight difference to volume (assuming a constant solution density equivalent to water, 8.33 lb/gal) and dividing by the time between the two weight recordings. Actual lubricant-application rate for a treatment run was calculated by multiplying the actual solution-application rate by the additive concentration and dividing by the average ginning rate.

Test 2. Based on preliminary results from Test 1 that indicated potential benefit from friction reduction, a second test was conducted on December 3, 2009. Eleven treatments were run in the test:

1. through 9. Identical to the treatments in Test 1.
10. 0.640 lb lubricant/bale (nominal)
11. 1.280 lb lubricant/bale (nominal)

The ginning-rate settings were left the same as in Test 1, and so actual ginning rate was assumed to be equal to that of Test 1. Three sets of the 11 treatments were run, with the 33 treatments runs being in random order throughout. At the beginning of each treatment run, 30 s were allowed to elapse before samples were taken. Within each treatment run, five lint samples were collected for AFIS and HVI measurements, about 30 s apart, at two locations simultaneously: before the lint cleaner and after the lint cleaner. Thus, for fiber damage assessment there were 11 treatments with three replications, with five samples each at two locations. At each sampling time one separate sample was collected after the lint cleaner for MCWB measurement. In total, 330 samples were collected for AFIS and HVI measurements and 165 for MCWB measurement.

Results

Test 1. The average ginning rate was 0.871 bale/hr (0.0549 kg/s), and the average actual solution application rate (Table 1) not including control treatments was 1.44 gal/hr (2.54×10^{-3} l/s). The average MCWB of moisture samples collected at the lint slide (Table 1) was 4.04%. For a given treatment, the actual lubricant-application rate (Table 2) for the two replications was fairly consistent and different than that for the other treatments, indicating that the desired rate was achieved and minor deviations were brought on by variations in flow rate of the spray system.

Differences in nep count across the lint cleaner indicated that the lint cleaner added roughly from 40 to 70 neps/g. Considering only the treatment runs in which lubricant was added, the change in nep count across the lint cleaner was significantly correlated with the amount of lubricant added (Figure 1); increasing the level of lubricant tended to reduce the number of neps added by the lint cleaner. Differences in SFC across the lint cleaner indicated that the lint cleaner added roughly from -5 to 10% SFC by weight. Considering only the treatment runs in which lubricant was added, the change in SFC across the lint cleaner was not significantly correlated with the amount of lubricant added (Figure 2); however, increasing the level of lubricant tended to slightly increase the amount of SFC added by the lint cleaner. It is possible that additional data could indicate that the trend for SFC is significant. If this were the case, one might think this to mean that more lubricant yields more broken fiber, opposite from the expected result. However, the number of broken fibers is confounded in the lint, because many broken fibers are removed by the lint cleaner, and one must also measure SFC in the lint-cleaner waste to have an idea of the true effect. Therefore, sampling and measurement of the lint cleaner waste may be desirable in the future.

Test 2. As of this writing, AFIS data have only been recorded for post-lint-cleaner samples from Test 2. Therefore, measurements of the lint cleaner's effect on neps and SFC, and any variation induced by addition of lubricant, have not yet been made. However, some observations are possible based on the post-lint-cleaner samples alone. The lowest post-lint-cleaner levels of neps (Figure 3) and SFC (Figure 4) coincided with one treatment, 0.16 lb lubricant/gal solution. The average actual application rate for this treatment was 637 mg lubricant/kg fiber. The same treatment in Test 1 had an average actual application rate of 484 mg/kg, and while the level of neps tended to be reduced with this treatment in Test 1, the SFC tended to be increased. Thus, while adding lubricant in this range of application rates appears to show some benefit, there is a discrepancy between the two tests with regard to the effect on SFC, and it is possible that variations in the incoming cotton may have produced concomitant variations in the outgoing cotton that were seen in Test 2 data. This possibility appears unlikely since the full complement of treatment runs was ordered at random, but comparing pre-lint-cleaner sample data from Test 2 to post-lint-cleaner sample data from Test 2 will shed additional light on the subject.

Summary and Conclusions

Two tests were conducted in which a water-based lubricant solution was sprayed onto lint cotton between the gin stand and the lint cleaner. Samples were collected before and after the lint cleaner, and fiber quality data were collected. The first test indicated a significant trend towards reduction in nep count with increasing lubricant application rate. The effect on SFC was negligible. The second test appeared to indicate, based on post-lint-cleaner data alone, that a particular application rate on the order of 500 to 600 mg lubricant/kg fiber gave the lowest values of neps and SFC. However, pre-lint-cleaner data are forthcoming and will be compared with post-lint-cleaner data to shed light on the cross-lint-cleaner effect on neps and SFC, and how this effect is altered by addition of lubricant.

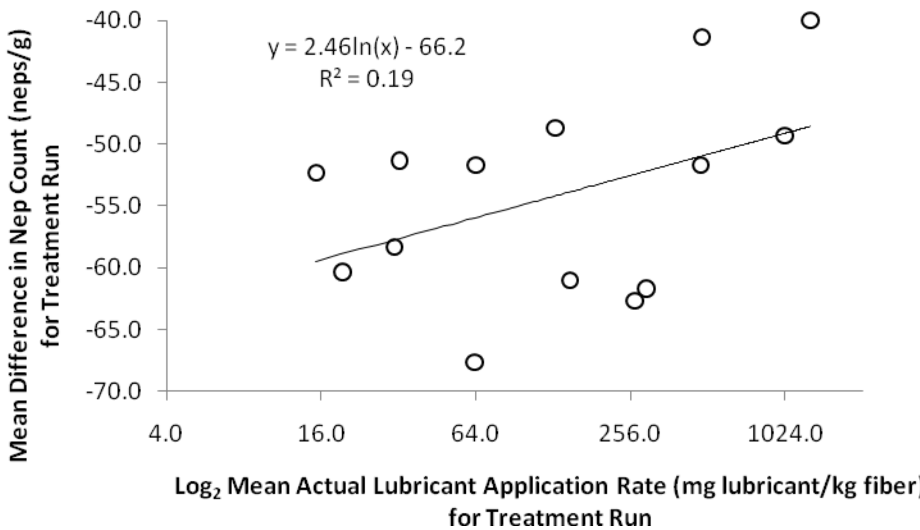

Figure 1. Cross-lint-cleaner (pre-lint-cleaner minus post-lint-cleaner) difference in AFIS nep count in Test 1.

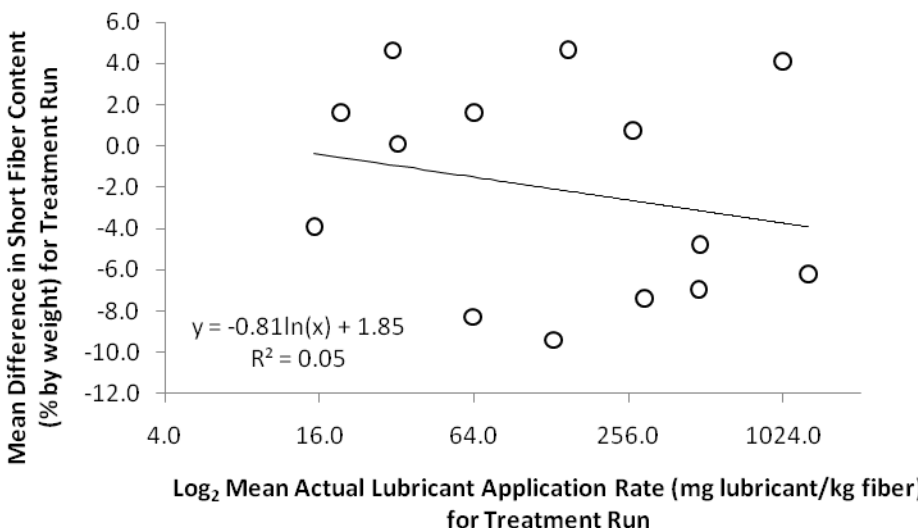

Figure 2. Cross-lint-cleaner (pre-lint-cleaner minus post-lint-cleaner) difference in AFIS short-fiber content in Test 1.

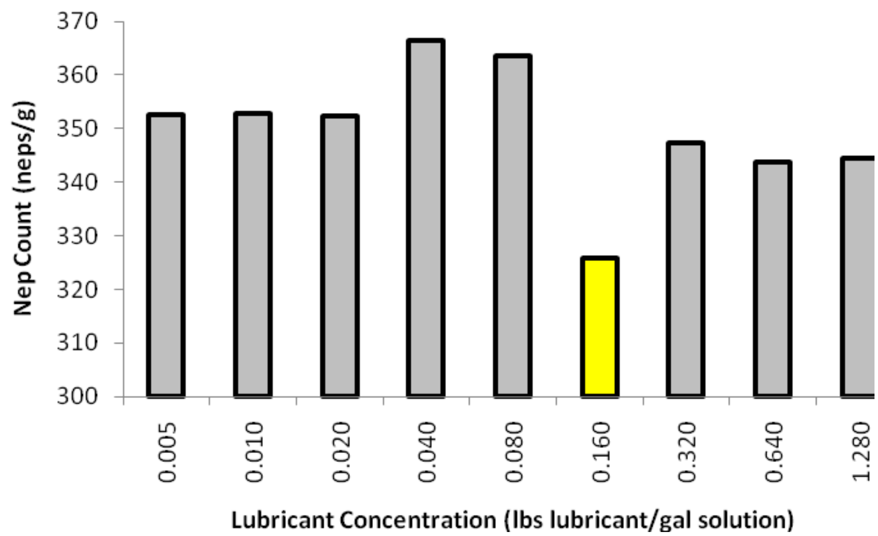

Figure 3. Post-lint-cleaner values of AFIS nep count in Test 2.

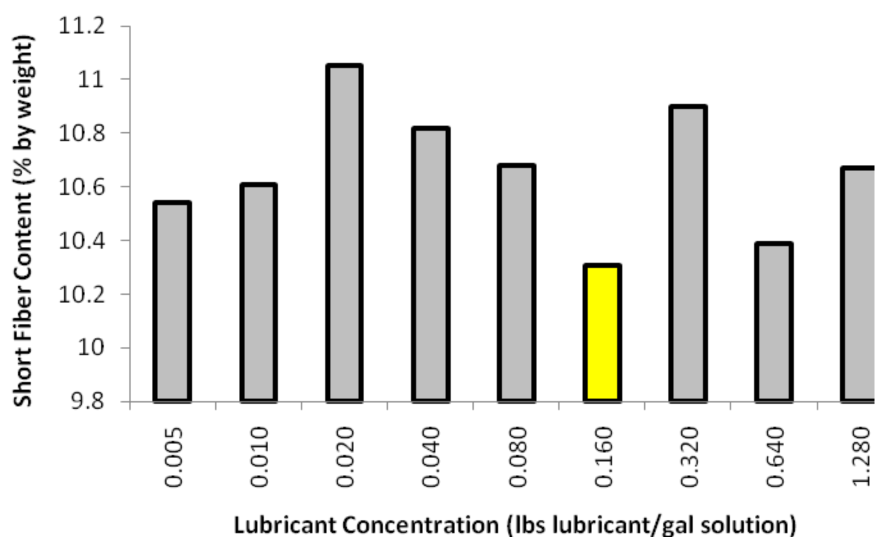

Figure 4. Post-lint-cleaner values of AFIS short-fiber content in Test 2.

Table 1. Actual conditions for Test 1.

Run Order	Treatment	Actual Solution Application Rate (gal/hr)	MCWB (%)
Set 1			
1	No additive (control 1)	0.00	4.38
2	Water only (control 2)	1.61	4.28
7	0.080 lb lubricant/bale (nominal)	1.68	4.22
3	0.005 lb lubricant/bale (nominal)	1.62	4.15
6	0.040 lb lubricant/bale (nominal)	1.31	4.08
8	0.160 lb lubricant/bale (nominal)	1.34	4.28
4	0.010 lb lubricant/bale (nominal)	1.39	4.25
9	0.320 lb lubricant/bale (nominal)	1.37	4.30
5	0.020 lb lubricant/bale (nominal)	1.32	4.30
Set 2			
8	0.160 lb lubricant/bale (nominal)	1.40	4.18
5	0.020 lb lubricant/bale (nominal)	1.42	5.52*
6	0.040 lb lubricant/bale (nominal)	1.33	3.88
3	0.005 lb lubricant/bale (nominal)	1.33	3.55
2	Water only (control 2)	1.45	3.25
7	0.080 lb lubricant/bale (nominal)	1.40	3.45
4	0.010 lb lubricant/bale (nominal)	1.75	3.60
9	0.320 lb lubricant/bale (nominal)	1.37	3.48
1	No additive (control 1)	0.00	3.55

*One of the two moisture samples collected in this treatment run was damp – thus the high average moisture content.

Table 2. Actual lubricant application rates, nep counts, and short fiber content for Test 1.

Actual Lubricant Application Rate	Mean Per Treatment Run					
	Pre-Lint-Cleaner		Post-Lint-Cleaner		Cross-Lint-Cleaner Difference	
(mg lub./kg fiber)	Neps/g	SFC (%, w)	Neps/g	SFC (%, w)	Neps/g	SFC (%, w)
0.0	178.0	15.6	226.3	20.2	-48.3	-4.6
0.0	154.0	14.4	238.3	15.4	-84.3	-1.1
19.3	173.7	18.7	234.0	17.1	-60.3	1.6
30.7	171.3	17.5	229.7	12.9	-58.3	4.6
63.1	178.7	9.7	246.3	18.0	-67.7	-8.3
148.9	170.7	18.9	231.7	14.2	-61.0	4.7
294.7	171.0	10.6	232.7	18.0	-61.7	-7.4
482.0	173.3	12.6	225.0	19.6	-51.7	-7.0
1019.3	180.3	17.9	229.7	13.8	-49.3	4.1
0.0	173.0	9.7	228.3	15.5	-55.3	-5.8
0.0	174.0	15.1	219.3	17.6	-45.3	-2.5
15.2	176.3	13.4	228.7	17.3	-52.3	-3.9
32.2	175.7	14.8	227.0	14.7	-51.3	0.1
64.1	178.3	15.5	230.0	13.8	-51.7	1.6
130.4	178.7	11.0	227.3	20.4	-48.7	-9.4
266.8	169.7	14.5	232.3	13.7	-62.7	0.8
485.2	193.0	13.5	234.3	18.3	-41.3	-4.8
1287.6	188.0	12.1	228.0	18.3	-40.0	-6.2

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