SAW THICKNESS IMPACT ON GINNING ENERGY

Paul A. Funk
USDA-ARS
Las Cruces, NM
Joe W. Thomas
USDA-ARS
Stoneville, MS
Kathleen M. Yeater
USDA-ARS
Fort Collins, CO
Carlos B. Armijo
USDA-ARS
Las Cruces, NM
Derek P. Whitelock
USDA-ARS
Las Cruces, NM
John D. Wanjura
USDA-ARS
Lubbock, TX
Christopher D. Delhom
USDA-ARS
New Orleans, LA

Abstract

Cotton gin saws have long been available in three thicknesses: 0.036, 0.037, and 0.045 inches. Yet no published experiments present the effect of saw thickness on the economically important performance measures gin processing rate and energy consumption. A pair of cylinders with 16-inch diameter saws of 0.036 and 0.045 inch thickness were tested on a reduced-width (46-saw) Continental Double Eagle gin stand with constant rib spacing at the USDA-ARS Southwestern Cotton Ginning Research Laboratory in Las Cruces, New Mexico. Energy consumption was recorded for target processing rates 0.0108 and 0.0134 pounds per saw per second using pre-cleaned seed cotton grown in New Mexico, Texas, and Mississippi in a randomized complete block experiment with five replicates. On this equipment we found that the thicker saws averaged 90% (0.0103 pounds per saw per second) the processing rate of the thinner saws (0.0115 pounds per saw per second). Net ginning energy of the 0.045-inch gin saws was 12.0 W-h per pound compared to 8.9 W-h per pound for the 0.036-inch saws, or about 35% more energy. Fiber and seed value were not significantly different between treatments. Results were consistent for cottons from all three regions. Thicker saws are less likely to break under harsh conditions at the ends of the gin stand and are still recommend for use there, but there appears to be no advantage with regard to processing rate or energy use to installing thicker saws across the full width of the gin stand if rib spacing remains unchanged.

Introduction

Debate regarding the impact of cotton gin saw thickness on energy consumption and processing rate has been based on untested, conflicting theories. To the best of our knowledge, no published work has looked at energy use as a function of gin saw thickness. This suggested a controlled experiment was needed to quantify the difference in processing rate and energy consumed per unit of lint processed for different saw thicknesses.

One test (Boykin, 2007) measured the energy required to gin 65 Mississippi cultivars using the Continental 93 (reduced to 20 saws) research gin stand at the USDA-ARS Ginning Laboratory in Stoneville, MS. He found it took an average of 9.16 Watt-hours per pound of lint ginned, increasing with fiber attachment force, neps, and trash content. Another test (Hardin IV & Funk, 2012) found ginning energy calculated from monitoring data from commercial gins in all four US cotton regions (Southeast, Mid-south, Southwest and West). Ginning energy averaged 9.34 Watt-hours per pound on commercial gins, similar to Boykin's results using a research gin.

This study looked at the impact of having thicker gin saws across the entire width of the gin stand using a 46-saw research gin. We measured processing rate (lint basis), and power and energy consumption, both at idle and under load, of the saw cylinder motor, which also turned the huller front, seed roll seed tube, and doffing brush.

Materials and Methods

We used our Continental Double Eagle with 16-inch diameter saws (Continental Gin Company, Prattville, Alabama) modified for research to a width of 46 saws, or 30.75 inches. The rated ginning capacity for the Continental Double Eagle 96-saw gin stand originally was 6 to 8 lint bales per hour (Mangialardi Jr & Anthony, 2005). On a per-saw basis, the maximum ginning rate as-built was 0.011 pounds per saw per second. Modified to 46 saws it was expected to process approximately 4 bales per hour. Our target processing rates were 3.71 and 4.63 bales per hour.

An old rule of thumb was that the gap between ribs is three times the saw thickness, so the space for fiber to pass through on each side is equal to the saw thickness. However, other factors, such as seed size, are more important in determining the optimum gap. Many commercial operators have changed saw thickness but we're not aware that any attempted to modify rib spacing at the same time. For this reason, we did not replace the ribs to account for the thicker saws, so the gap where fiber could pass through was 0.036 inches for the thin saws, and 0.0315 inches on each side for the thicker ones, or 87.5% of the clearance compared to the thin saws. For reference, when the thicker saws were installed, our laboratory gin had 80% of the clearance of that designed for a commercial gin stand sold with 0.045-inch saws (Consolidated Cotton Gin Co, Inc., Lubbock, TX).

We used two saw cylinders that were professionally stacked (Precision Gin Works, Lubbock, TX), one with OEM thickness (0.036 inch) and the other with thicker (0.045 inch) saws (Phoenix Gin Saws, Hartsville, South Carolina) using spacers of a thickness that would keep saw center-to-center distance the same.

We used three growths (cultivar, production practices, and harvest method): a spindle-harvested upland cotton (STV 4848, BASF, Ludwigshafen, Germany) from Stoneville, Mississippi (MS); a spindle-harvested upland cotton (NexGen 4545 B2XF, Americot, Lubbock, TX) from Las Cruces, New Mexico (NM); and a stripper-harvested upland cotton (Deltapine 1549 B2XF, Bayer, Leverkusen, Germany), harvested using a stripper equipped with a field cleaner, from Lubbock, Texas (TX).

Seed cotton growths from MS, NM, and TX were pre-cleaned separately in advance of the test to reduce contamination between growths and stored in trailers. The two spindle-harvested growths were pre-cleaned using an inclined cylinder cleaner, a stick machine, and a second inclined cylinder cleaner. The stripper-harvested growth (TX) was pre-cleaned using an inclined cylinder cleaner, two stick machines, and a second inclined cylinder cleaner. These pre-cleaning sequences are considered common practice for each harvest method (Anthony & Mayfield, 1994). The moisture content of each seed cotton growth, from 5.6 to 8.0% dry basis, was low enough to not require drying. Pre-cleaning machinery was thoroughly cleaned between each growth to minimize cross-contamination.

We ran 200 to 225 pounds of seed cotton to our overflow hopper before each test. The overflow feeder automatically supplied seed cotton at the required rate. We packed the seed roll, ran two tests for that growth at the two target processing rates, cleaned the overhead, and ran the next two growths (four lots) before changing the cylinder.

Run time, voltage, current, and power factor were recorded. The lint produced by each run was kept separate and later weighed on our bale scale. One pound of seed and two one-ounce fiber samples before lint cleaning and two one-ounce fiber samples after lint cleaning were collected during each run. Louisiana Department of Agriculture and Forestry State Seed Testing Laboratory (Baton Rouge, LA) estimated seed quality by germination following official rules (AOSA, 2016). Cotton Incorporated kindly provided high-volume instrument (HVI, Uster Technologies AG, Uster, Switzerland) fiber quality data for the lint samples. Fiber quality data were converted to market price using FSA national average loan rates (FSA, 2021a) and premium and discount tables (FSA, 2021b).

Results and Discussion

There was a distinct separation between the two target processing rates ("maximum" was 20% greater than "normal"). Processing rate varied with growth. NM was 8% faster than MS and TX (Table 1).

Table 1. Processing rate by growth for normal and maximum ginning rate.

Growth	Processing Rate (lbs./saw/sec) Normal Rate	Maximum Rate	Average
MS	0.0099	0.0114	0.0106
NM	0.0103	0.0127	0.0115
TX	0.0097	0.0116	0.0106
Average	0.0099	0.0119	

Ginning energy was a function of growth, processing rate, and saw thickness. Comparing experiment means, the thicker saws used 15% more energy. However, the processing rate was slower with thicker saws. To normalize for processing rate and account for covariates and interactions an analysis of covariance model was constructed by backwards regression. Comparing model least squares means, the thicker saws used 35% more energy (Table 2).

Table 2. Ginning energy experiment means and model least squares means by growth for 0.036 and 0.045 thick gin saws.

	Net Ginning Energy (Watt-hours/pound)					
	Experiment Means			Model Least Squares Means		
	Saw Thickness			Saw Thickness		
Growth	0.036 in	0.045 in	Average	0.036 in	0.045 in	Average
MS	9.46	10.46	9.96	9.17	11.37	10.27
NM	8.79	10.3	9.54	7.33	10.84	9.09
TX	10.87	12.78	11.83	10.25	13.83	12.03
Average	9.7	11.18		8.91	12.01	

Seed and fiber value were analyzed to compare the effect saw thickness might have on these variables. There were no measurable differences in seed damage. To normalize for processing rate and account for covariates and interactions an analysis of covariance model was constructed by backwards regression (as for energy, above). Comparing model least squares means, there was not a statistically significant difference in fiber value due to saw thickness. The P-Value was 0.06713 in the full model that included all variables and all interactions, and 0.0641 in the reduced model that only had saw thickness, and the significant factors growth, processing rate, and their interaction.

Table 3. Experimental and model least squares means and P-Value for fiber value in dollars per pound.

		Experiment Mean	Model L.S. Mean	P-Value
Growth	MS	0.522	0.511	<0.0001
	NM	0.562	0.518	
	TX	0.410	0.453	
Thickness	0.036	0.495	0.485	0.0641 (n.s.)
	0.045	0.500	0.503	

Summary

The cylinder with thicker saws averaged about 90 percent of the processing rate of the cylinder with thinner saws, 0.01034 vs. 0.01149 lint pounds per saw per second, respectively. Net ginning energy of the thicker gin saws was 35% higher than net energy of the thinner saws. These results were consistent for all three growths (cultivars/ production practices/ harvest methods). About 18.5% of electrical energy used by a gin facility is used for ginning

(Funk, et al., 2013) and electricity costs per bale recently averaged $4.18 beltwide (Holt, et al., 2021). Therefore, replacing 0.036 thick saws with 0.045 saws could add roughly $0.27 per bale to ginning energy costs, a modest amount. The consequence of a reduced processing rate would have a greater economic impact. Part of the observed result may be ascribed to the test being conducted with the same gin ribs for both saw thicknesses – hence a slightly narrower rib-to-saw clearance with the thicker saws. It would be interesting to repeat this experiment with a gin stand that was capable of different rib-to-saw clearances.

Acknowledgements

The authors acknowledge the contribution of lab personnel Kirk Zivkovich, Cassy Salvatti, Branyan Sanxter, Tye Lightfoot, Ernest Herrera, Juan Gomez, Arnold Gomez, Russel Gardner, and Paul Delgado; they stayed healthy and accomplished much under pandemic guidelines.

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