ENERGY MONITORING IN GINS- 2012 PRELIMINARY RESULTS

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Abstract

Energy, comprised of electricity and fuel, is the second largest source of variable costs for cotton gins, after labor. Few studies of gin energy use have been conducted recently and none have monitored energy use continuously throughout the ginning season. More detailed information is needed to identify management strategies and design systems that can reduce energy use. Electricity use was monitored continuously throughout the 2010-2012 ginning seasons at two gins, and fuel use was also calculated from air flow and temperature measurements during the 2011 and 2012 ginning seasons. Electricity use averaged 30.3 kWh bale^{-1} and 26.6 kWh bale^{-1} in 2012, similar to results from 2010 and 2011. LPG use was 1.57 L bale^{-1} (0.41 gal bale^{-1}) and 4.08 L bale^{-1} (1.08 gal bale^{-1}). Greater variation was observed in fuel use, both within a ginning season and between years. Round modules required less fuel per bale than conventional modules because more fuel was used to dry the ends of conventional modules. Higher processing rates reduced electricity and fuel use per bale for all years at both gins. To reduce energy costs, gins should be operated at maximum capacity as often as possible and equipment should not be left idling during significant downtime. Fuel use can be reduced by proper storage of seed cotton, especially with conventional modules.

Introduction

Electricity and fuel account for 25% of a cotton gin's variable costs and are the second largest component of variable costs, after seasonal labor (Valco et al., 2012). A significant opportunity exists to improve gin profitability by reducing energy use. Since 2000, the average nominal electricity costs for U.S. industrial consumers have increased 46%, propane costs 90%, and natural gas prices 21% (USDOE–EIA, 2011). Propane and natural gas costs have been quite volatile recently, with a peak price in 2008, more than twice the cost in 2002. Furthermore, energy costs are likely to increase due to future scarcity of energy sources and increased global demand for energy. Higher energy costs emphasize the importance of increased energy efficiency at gins and increase the economic benefit of implementing conservation measures.

Recent research has shown that the average gin electricity use has decreased from a historical average of near 50 kWh bale^{-1} to 40 kWh bale^{-1} (Funk and Hardin, 2012; Hardin and Funk, 2012a). Fuel use has declined over time as control systems and burner designs have improved (Holder and McCaskill, 1963; Griffin, 1980; Anthony, 1988). A more recent study found that gins used an average of 2.3 m^3 bale^{-1} (81 ft^3 bale^{-1}) of natural gas or 4.0 L bale^{-1} (1.1 gal bale^{-1}) of LPG (Ismail et al., 2011). However, this study was conducted in Australia, which typically experiences drier weather than some cotton producing regions of the U.S. A survey of U.S. gins' costs for the 2010 ginning season found that fuel use averaged 150 MJ bale^{-1} (142 000 Btu bale^{-1}; T.D. Valco, unpublished data). The quantity of fuel corresponding to this energy content is 4.0 m^3 (142 ft^3) natural gas or 5.9 L (1.6 gal) LPG. Fuel use varied widely across regions of the U.S., from 85 MJ bale^{-1} (81 000 Btu bale^{-1}) in the mid-south to 312 MJ bale^{-1} (296 000 Btu bale^{-1}) in the west, due to differences in weather during the ginning season. Hardin and Funk (2012b) determined fuel use for several systems at two gins. First stage drying systems required 1.25 and 1.45 L bale^{-1} (0.33 and 0.38 gal bale^{-1}; the second stage drying system was only used at one gin, requiring 0.32 L bale^{-1} (0.08 gal bale^{-1}); and the burner evaporating the moisture added to lint used 0.89 and 0.38 L bale^{-1} (0.23 and 0.10 gal bale^{-1}). Fuel use by the burner heating air added at the lint slide was not measured.

The goal of this research was to gain a greater understanding of electricity and fuel use in cotton gins. Greater knowledge of energy use patterns should result in improved management strategies and new technologies that improve energy efficiency. This research project was started during the 2010 ginning season, with monitoring of gin electricity consumption and individual motor loads. Measurements of fuel use were also made in 2011. The objectives of this research for the 2012 ginning season were:

- Monitor individual motor loads and total gin electricity consumption, for comparison with previous data
- Measure air flow and burner temperatures to estimate fuel use
- Identify factors significantly affecting electricity and fuel use
- Quantify potential energy savings from implementing improved management strategies

Materials and Methods

Energy monitoring systems were installed in two saw-type gins, located in the Mid-South and Southeast, during the 2010-2012 ginning seasons. Motor loads were monitored for motors larger than 11 kW (15 hp) and power and power factor were measured at each motor control center. Data was recorded at 2.5 s intervals at the Mid-South gin and at 2 s intervals in the Southeast gin. A more complete description of the gins, electrical energy monitoring components, and data acquisition system can be found in Hardin and Funk (2012a).

Fuel (LPG) used by the seed cotton dryers and the burner used to supply heated air to the lint slide in both gins was estimated based on heat transfer to the conveying air. Ambient temperature and humidity, the heated air temperature, and the air flow through the burner were measured to calculate fuel use. Similar measurements were made with the humid air moisture restoration systems at each gin; however, the heated air was assumed to be saturated to determine fuel use. These measurements were taken at the same intervals as the electricity measurements. Additional details of these components and installation are provided in Hardin and Funk (2012b, 2012c).

Sensor data were analyzed to provide summary data for each gin and identify factors that significantly affected energy use. Total power demand and the fuel use by each burner were calculated for each record (2 or 2.5 s interval) in the data. A local maximum in the bale press pump motor current data indicated that a bale had been pressed. The total electricity and fuel used for each bale was calculated by integrating the instantaneous power demand over the length of time required to process the bale. All bales were used to calculate average energy use; consequently, the effect of gin downtime was included in this calculation of energy use. Average gin stand and agitator tube motor currents were calculated for each bale.

Correlations between fuel use, processing rate, power demand, and electricity use were examined (*PROC CORR*, SAS 9.2, SAS Institute, Inc., Cary, NC). Management of the Southeast gin provided cultivar information, USDA–AMS classing data, and bale weights for the monitored bales in 2011. Module type (round or conventional) was determined from a current sensor monitoring the round module handling system and verified with gin records. For the 2011 data at the Southeast gin, an analysis of variance (*PROC MIXED*) was performed on the fuel used by each system in the gin. Independent variables in the model were module type, bale position in the module (the distance a bale was located from the end of the module), and their interaction, while bale weight, ambient temperature, and processing rate were used as covariates.

Results and Discussion

Only part of the 2012 data has been analyzed; consequently, the reported 2012 summary values are preliminary. Electricity use for 2010-2012, is shown in Table 1, along with the number of bales with data for that parameter. Electricity used per bale was similar in both 2010 and 2011, at the Mid-South gin, and decreased slightly in 2012. The average processing rate at the Mid-South gin increased slightly, from 34 bale hr^{-1} in 2011 to 35 bale hr^{-1} in 2012. The Southeast gin reduced electricity consumption by nearly 2 kWh $bale^{-1}$ from 2010 to 2011. Before the 2011 ginning season, the bale press was modified, increasing the average processing rate for the monitored bales from 39 bale hr^{-1} in 2010 to 44 bale hr^{-1} in 2011. Electricity use increased slightly from 2011 to 2012, as the processing rate decreased to 40 bale hr^{-1}. Electricity use was found to be inversely related to processing rate at both gins for all three years.

Table 1. Electricity use for 2010-2012 ginning seasons.

Year	Mid-South Gin		Southeast Gin	
	# Bales[a]	Electricity (kWh bale^{-1})	# Bales	Electricity (kWh bale^{-1})
2010	16774	31.5	5968	27.7
2011	30379	31.4	24591	25.8
2012	11942	30.3	14205	26.6

[a]The "# Bales" column refers to the number of bales with data available, because some instrumentation did not function properly throughout the entire season.

Fuel use for 2011 and 2012, is shown in Table 2. The total fuel use is only calculated for 2012, and only includes bales with data for all systems. Seed cotton dryer fuel use was slightly lower at the Mid-South gin in 2012, than 2011; however, both seasons were generally dry. Less fuel was also used by the moisture restoration system. The ginning season started earlier at the Mid-South gin in 2011, and the average ambient temperature (measured near the 1st stage dryer inlet) while ginning the monitored bales was 9°C (16°F) warmer in 2011. More moisture may have needed to be added to the lint in 2011 than 2012, to produce bales with desirable final moisture contents, requiring increased fuel.

Table 2. Fuel use for 2011-2012 ginning seasons.

System	Mid-South Gin		Southeast Gin	
	2011	2012	2011	2012
	L bale^{-1} (gal bale^{-1})			
1st stage drying	1.25 (0.33)	0.87 (0.23)	1.45 (0.38)	1.67 (0.44)
2nd stage drying	Not used	0.09 (0.02)	0.32 (0.08)	0.26 (0.07)
Moisture restoration	0.89 (0.23)	0.44 (0.12)	0.75 (0.20)	1.70 (0.45)
Heated air at lint slide	Not measured	0.19 (0.05)	Not measured	0.47 (0.12)
Total	-	1.57 (0.41)	-	4.08 (1.08)

Slightly more fuel was used by the Southeast gin for seed cotton drying in 2012; however, significantly more fuel was used for moisture restoration. No weather-related explanations for this difference have been found. This result may be due to the small number of bales (1432) with moisture restoration system fuel use data collected in 2011 not being representative of the entire ginning season. At both gins, a significant proportion of the fuel was used to add moisture to the lint. In 2012, the moisture restoration system burner (for heating the air to evaporate the water) and the burner used to heat air added at the lint slide (to prevent condensation and lint sticking to surfaces) accounted for 40% of fuel used at the Mid-South gin and 53% of fuel used at the Southeast gin.

The relationship between fuel use per bale and processing rate was similar to the electricity-processing rate model (Hardin and Funk, 2012a); however, there was significantly more variation in the fuel use data (Figure 1). Much of the variation in fuel use was likely due to varying weather conditions and seed cotton moisture content.

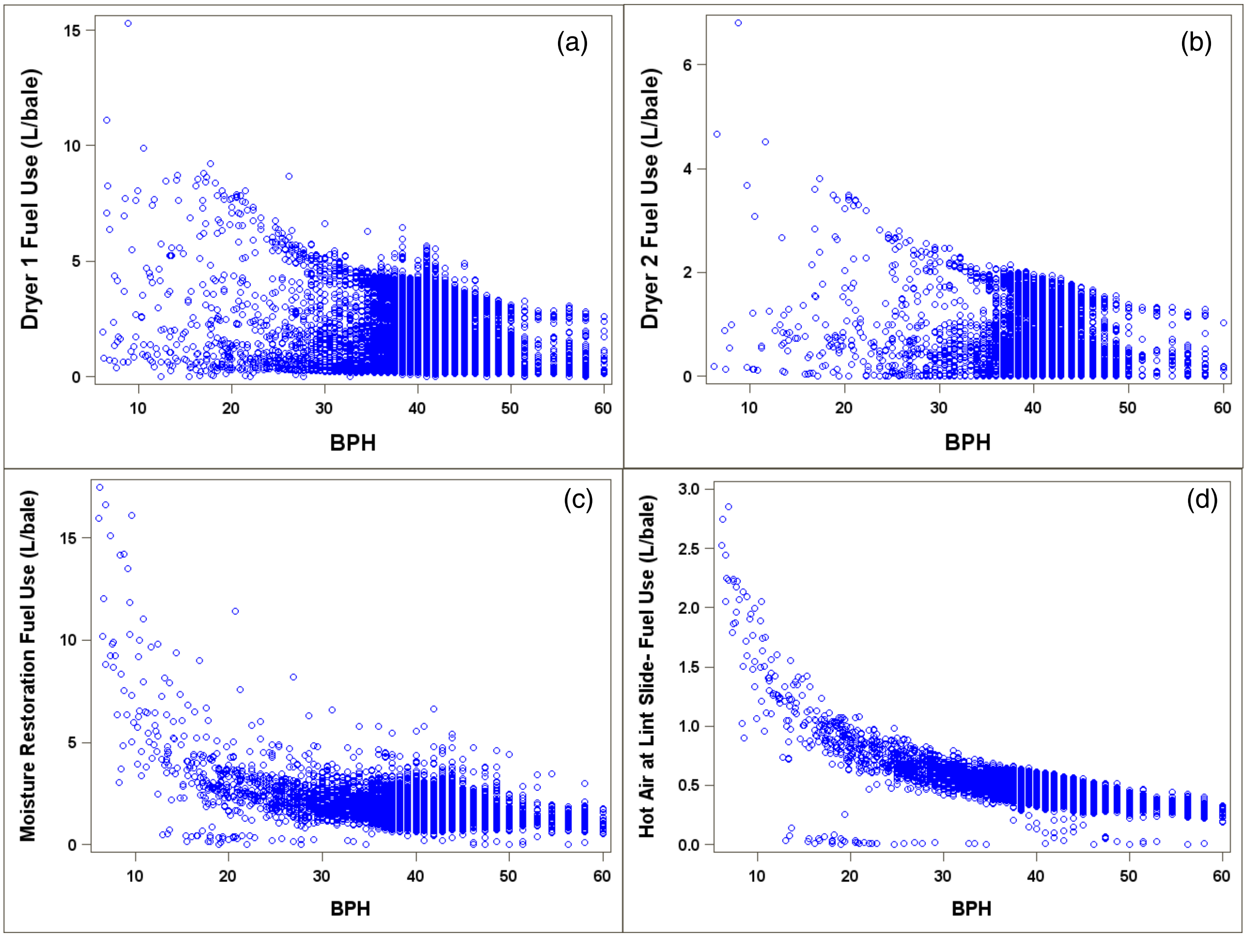

Figure 1. Fuel use by each burner at Southeast gin, 2012.

Fuel use had significant correlation with both processing rate and ambient temperature and results were similar in 2011 and 2012 (Table 3). Higher processing rates resulted in lower fuel use by all systems. Lower temperatures required additional fuel to heat the air for seed cotton drying. Additionally, cooler weather in both regions during the ginning season tends to correspond to wetter weather and incoming seed cotton, which requires more fuel for drying. Similarly, cooler temperatures were associated with decreased fuel for moisture restoration at the Mid-South gin. The incoming seed cotton likely had higher moisture during cooler weather and less moisture was added to the lint to achieve target bale moisture contents. This correlation between moisture restoration system fuel use and temperature was slightly negative at the Southeast gin, possibly indicating that differences in seed cotton moisture content were not observed at cooler temperatures. Therefore, slightly more fuel would be required to heat the cooler air.

Table 3. Correlations between fuel use per bale, processing rate, and temperature.

	Mid-South Gin				Southeast Gin			
System	Processing Rate		Temperature		Processing Rate		Temperature	
	2011	2012	2011	2012	2011	2012	2011	2012
1st stage drying	-0.40	-0.50	-0.61	-0.44	-0.22	-0.21	-0.21	-0.16
2nd stage drying		-0.02		-0.01	-0.18	-0.11	-0.07	-0.07
Moisture restoration	-0.46	-0.20	0.14	0.14	-0.48	-0.48	-0.06	-0.09
Heated air at lint slide		-0.40		-0.37		-0.70		-0.38

Table 4 shows fuel use for each burner system for both conventional and round modules at the Southeast gin in 2011. More fuel was required by all systems when processing conventional modules. While statistically significant differences between the module types are shown here, there may have been differences in weather conditions when harvesting different module types that impacted fuel use. Harvest dates were unknown, so the effect of harvest weather conditions could not be determined. However, round modules tended to require a constant amount of fuel per bale throughout a module. With conventional modules, fuel use would often increase dramatically for a single bale or a few bales, and then return to a lower level. This result indicated that the conventional modules developed wetter regions during storage.

Table 4. Least squares means for fuel use by module type.

Module Type	Fuel Use (L bale^{-1} [gal bale^{-1}])[a]		
	1st Stage Drying	2nd Stage Drying	Moisture Restoration
Conventional	1.54a (0.41)	0.39a (0.10)	0.84a (0.22)
Round	1.09b (0.29)	0.08b (0.02)	0.28b (0.07)

[a]Means in a column followed by the same letter were not significantly different at the 5% level.

These spikes in fuel use often corresponded with the ends of modules (Table 5). The simple main effect of bale position in the module for conventional modules was highly significant for the fuel used by seed cotton dryers. Bale position in the module did not affect fuel use for round modules. The ends of both types of modules are exposed during storage; however, rainfall will drain off the covered sides of round modules and not contact the seed cotton. Furthermore, conventional modules often have low regions in their top surface a short distance from the ends, corresponding to the second or third bale from the end.

Table 5. Least squares means for fuel use by bale position in conventional modules.

Bale Position[b]	Fuel Use (L bale^{-1} [gal bale^{-1}])[a]	
	1st Stage Drying	2nd Stage Drying
1	1.85a (0.49)	0.51a (0.13)
2	1.70b (0.45)	0.45b (0.12)
3	1.55c (0.41)	0.38c (0.10)
4	1.43d (0.38)	0.33d (0.09)
5	1.39de (0.37)	0.33d (0.09)
6+	1.33e (0.35)	0.33d (0.09)

[a]Means in a column followed by the same letter were not significantly different at the 5% level.
[b]Bale position 1 indicates the bale on either end of the module, 2 is the second bale from the end, etc. 6+ refers to all bales more than 5 bales from both ends.

Conclusions

The two monitored gins used 30.3 kWh bale^{-1} and 26.6 kWh bale^{-1} of electricity in 2012, similar to values from 2010 and 2011. At both gins, electricity use per bale decreased with processing rate. Average LPG consumption at the Mid-South gin was 1.57 L bale^{-1} (0.41 gal bale^{-1}) in 2012, with the first stage seed cotton dryer using the largest quantity of fuel, 0.87 L bale^{-1} (0.23 gal bale^{-1}). The Mid-South gin used less fuel in both the first stage seed cotton dryer and the moisture restoration system in 2012 than 2011. The Southeast gin used 4.08 L bale^{-1} (1.08 gal bale^{-1}) of LPG. Similar amounts of fuel were used by the first stage seed cotton dryer, 1.67 L bale^{-1} (0.44 gal bale^{-1}), and the moisture restoration system, 1.70 L bale^{-1} (0.45 gal bale^{-1}). The Southeast gin used more fuel for seed cotton drying and moisture restoration in 2012 than 2011.

Fuel use per bale was inversely related to processing rate; however, there was significant variation in the amount of LPG required at a given processing rate, particularly with the seed cotton dryers. This variation is likely due to differences in seed cotton moisture content and weather conditions. Correlations between fuel use and processing rate or ambient temperature were similar in 2011 and 2012. Ambient temperature was negatively correlated with fuel used by seed cotton dryers and the burner heating the air added at the lint slide. At the Mid-South gin, higher ambient temperatures increased LPG use by the moisture restoration system. Seed cotton ginned early in the season during hot, dry weather likely had low moisture contents. Ambient temperature was negatively correlated with fuel use at the Southeast gin. However, the ginning season started later at this gin and less low moisture seed cotton was processed. Data from the Southeast gin in 2011, indicated that less fuel was used to process round modules. More fuel was used for drying the ends of conventional modules.

Operating all equipment at maximum capacity as often as possible is crucial in reducing both electricity and fuel use at the gin. To maximize processing rate and minimize fuel use, seed cotton must be properly stored so that cotton enters the gin at a suitable moisture content. With conventional modules, the module builder operator and the condition of the module cover are the primary factors affecting the degree of protection of the seed cotton from weather. Producers need to be educated on proper construction of modules. Gins need to regularly inspect their module covers and repair or replace as necessary.

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