ENERGY MONITORING IN GINS

Robert G. Hardin IV
USDA-ARS Cotton Ginning Research Unit
Stoneville, MS
Paul A. Funk
USDA-ARS Southwestern Cotton Ginning Research Laboratory
Mesilla Park, NM

Abstract

Energy costs are the second largest source of variable costs for cotton gins, accounting for 27% of variable costs. Energy use has typically not been a major consideration in gin design and previous studies of energy use have utilized instantaneous readings or aggregated season-long values. In this study, electrical energy use was monitored throughout the entire season for several gins across the cotton belt. Motor loads were recorded for gin stands, fans, cleaning machinery, module feeders, and bale presses. Power consumption and power factor were recorded at motor control center disconnects. Additional variables, such as feed control speeds, were monitored when feasible. The gins monitored in 2010, used less than 40 kWh/bale, slightly less than the annual average values reported in past surveys. Differences in electricity use between monitored gins were likely due to differences in layout and installed equipment. Power factor for most gin equipment varied from 0.75-0.80. Power factor at the bale press motor control center rose from 0.50 between bales to 0.85-0.90 when pressing a bale. Gins may benefit from power factor correction if penalized by their utility for low power factor. The primary factor affecting electricity use per bale at a specific gin was the time required to gin a bale. For maximum energy efficiency, cotton ginners should operate at full capacity as much as possible and avoid idling equipment for periods longer than several minutes.

Introduction

Energy costs- electricity and dryer fuel- account for 27% of a cotton gin's variable costs and are the second largest component of variable costs, after seasonal labor (Valco et al., 2009). A significant opportunity exists to improve gin profitability by reducing energy use. Since 2000, the average electricity costs for US industrial consumers have increased nearly 50%, propane costs nearly 70%, and natural gas prices have been quite volatile (USDOE–EIA, 2010). Furthermore, energy costs are likely to increase due to future scarcity of energy sources and increased demand for energy. Higher energy costs emphasize the importance of increased energy efficiency at gins and increase the economic benefit of implementing conservation measures.

Objectives

The goal of this research was to gain a greater understanding of electrical energy consumption patterns in cotton gins. This knowledge can be used to identify management practices that improve energy efficiency. The objectives of this research were:

- Monitor individual motor loads and total gin electricity consumption throughout a ginning season
- Identify factors significantly affecting electricity use
- Quantify potential energy savings from implementing improved management strategies

Literature Review

Electric power requirements and energy efficiency in gins have been studied by several researchers (table 1). Although ginning capacity and connected power have increased significantly over the past 50 years, the per bale electrical energy requirements have consistently been near 50 kWh/bale. Several of these surveys have demonstrated large variations between individual gins. Electricity use at gins surveyed by Holder and McCaskill (1963) ranged from 28.11 to 71.94 kWh/bale. A more recent survey showed similar variation– 28.51 kWh/bale to 84.51 kWh/bale (TCGA, 2009).

Table 1. Previous surveys of energy use in gins.

Year	Connected Power (hp)	kWh/Bale	Location	Source
1960	344	46.08	AR, MO	Holder and McCaskill, 1963
1961	677	47.68	CA	Wilmot and Alberson, 1964
1961	646	54.31	West TX	Wilmot and Alberson, 1964
1961	392	42.38	NM	Wilmot and Alberson, 1964
1962	772	47.5	MS, LA	Wilmot and Watson, 1966
1964	1098	52.89	CA	Wilmot and Watson, 1966
1964	1125	55.95	West TX	Wilmot and Watson, 1966
1979	–	52	Midsouth	Griffin, 1980
1983	1709	52	Midsouth	Anthony, 1983
1987	–	44.4	Midsouth	Anthony, 1988
2006	–	46.86	TX	TCGA, 2009
2007	–	42.51	TX	TCGA, 2009
2008	–	44.21	TX	TCGA, 2009

Wilmot and Watson (1966) found that 65% of electrical energy was used for materials handling (including fans used to transport seed cotton through dryers), 15% for cleaning, 17% for ginning, and 3% for packaging. Significant energy was consumed while idling– 86% of the operating power was still required when gins were idling, primarily due to increased power consumption by unloaded centrifugal fans. Anthony (1983) performed a similar analysis and determined that 60% of the electricity consumed was used for materials handling, 19% for cleaning, 13% in ginning, and 8% for packaging.

Electricity costs comprise a significant portion of a gin's variable costs and can vary significantly between gins. In a 2007 survey of 144 gins throughout the cotton belt, the average electricity cost was \$3.89/bale, 18% of total variable costs (Valco et al., 2009). Gins producing less than 15,000 bales had an average electricity cost of \$4.46/bale, significantly higher than gins with larger volumes. Western gins had the highest electricity costs, \$5.13/bale, followed by gins in the Southwest, with average costs of \$4.29/bale. Electricity prices are higher in western states, while stripper-harvested cotton in the Southwest requires additional cleaning equipment.

Significant potential exists for energy efficiency improvements in cotton gins, as electricity use per bale has remained constant for many years and large differences in electricity use exist between gins. Comprehensive audits of gin energy use have not been conducted recently and the only current data available is based on seasonal averages reported in ginner surveys. More recent information regarding energy use in gins is needed to assist ginners in operating as efficiently as possible and to focus future research efforts on reducing energy consumption.

Materials and Methods

Electrical energy monitoring systems were installed in four gins in 2010. The layout of gin A is shown in figure 1. Seed cotton cleaning equipment was 3.7 m (12 ft) wide. Gin A used Lummus 170 gin stands and Sentinel lint cleaners (Lummus Corporation, Savannah, Ga.). During monitoring, the stick machine and the second stage lint cleaner were not used. Consequently, this gin used less cleaning machinery than the other monitored gins.

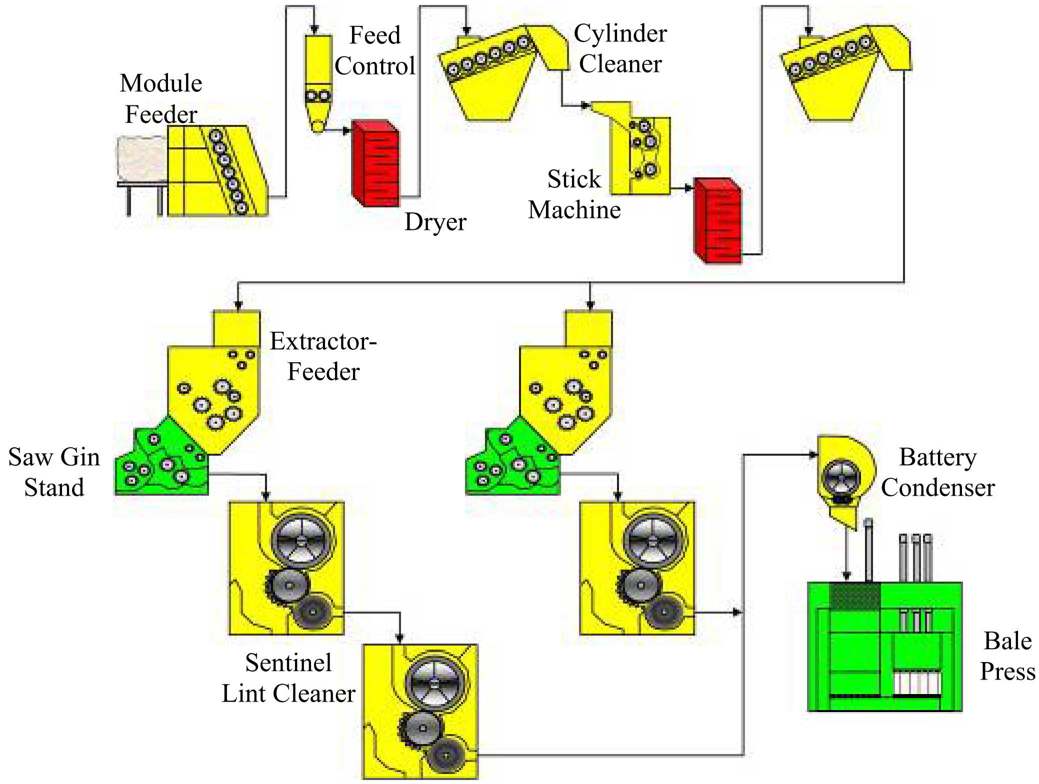

Figure 1. Gin A layout.

Gin B (figure 2) had a Rescuer 5000 stick machine, a third cylinder cleaner and Consolidated 198 gin stands (Lummus Corporation, Savannah, Ga.). Seed cotton cleaning equipment was 3.0 m (10 ft) wide. While there was no second stage dryer, heated air was used to convey cotton from the stick machine to the second stage cylinder cleaner. All trash handling was done using conveyors and this gin had the fewest number of fans for material handling.

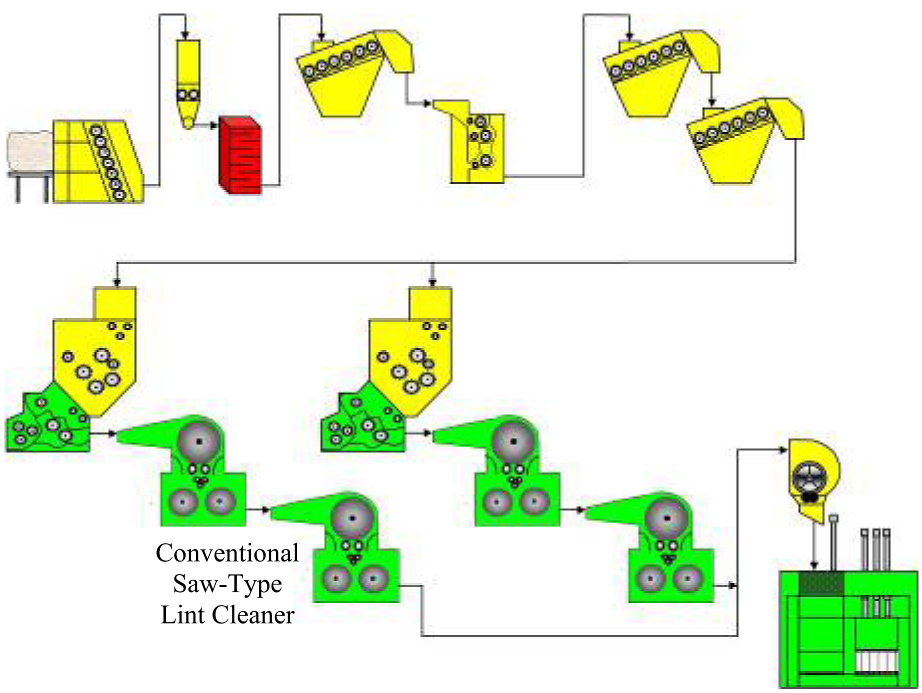

Figure 2. Gin B layout.

The layout of gin C is shown in figure 3. Equipment similar to gin B was used, with a Rescuer 5000 and Consolidated 198 gin stands, although the seed cotton cleaners were 3.0 m (10 ft) wide. This gin had the most cylinder cleaning of all monitored gins, which was not surprising since the gin processed primarily stripper-harvested cotton.

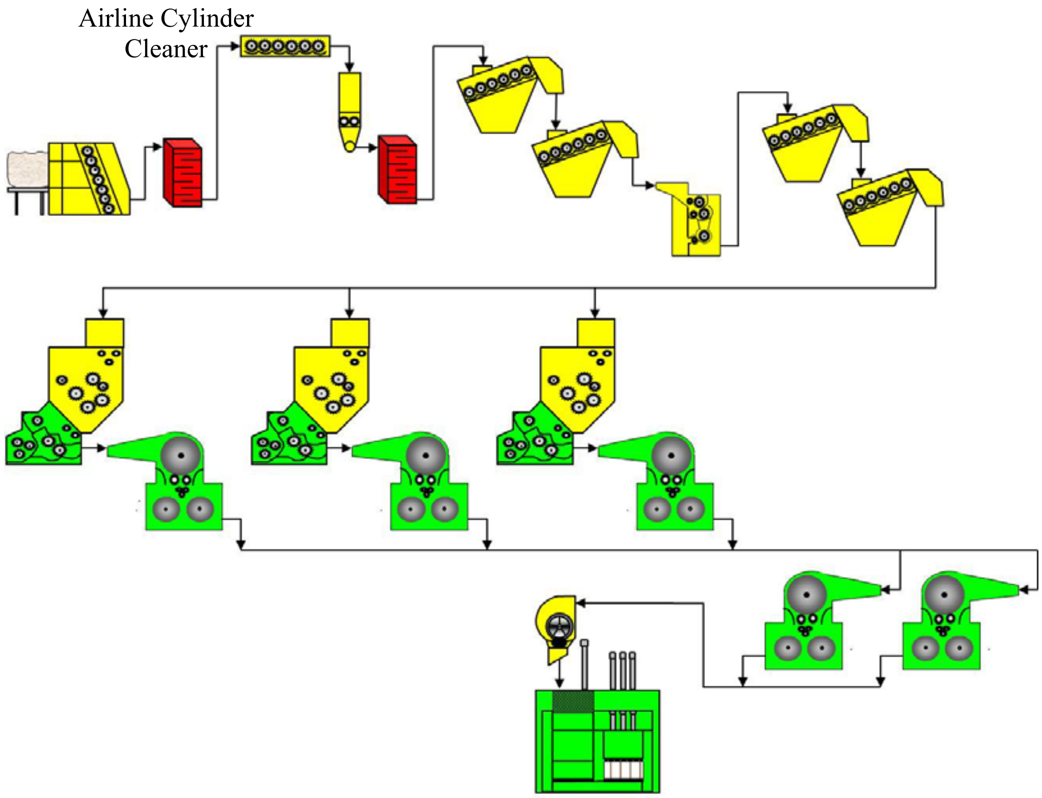

Figure 3. Gin C layout.

Gin D (figure 4) was a combination roller and saw gin plant and the only monitored gin with split-stream seed cotton cleaning. All cotton was processed identically through the final dryer, at which point upland cotton passed through an additional cylinder cleaner before the gin stands. Pima cotton was processed through two additional cylinder cleaners before roller ginning. Several roller gin stands had been converted to high-speed operation and all roller ginned cotton was cleaned by Guardian lint cleaners (Lummus Corporation, Savannah, Ga.).

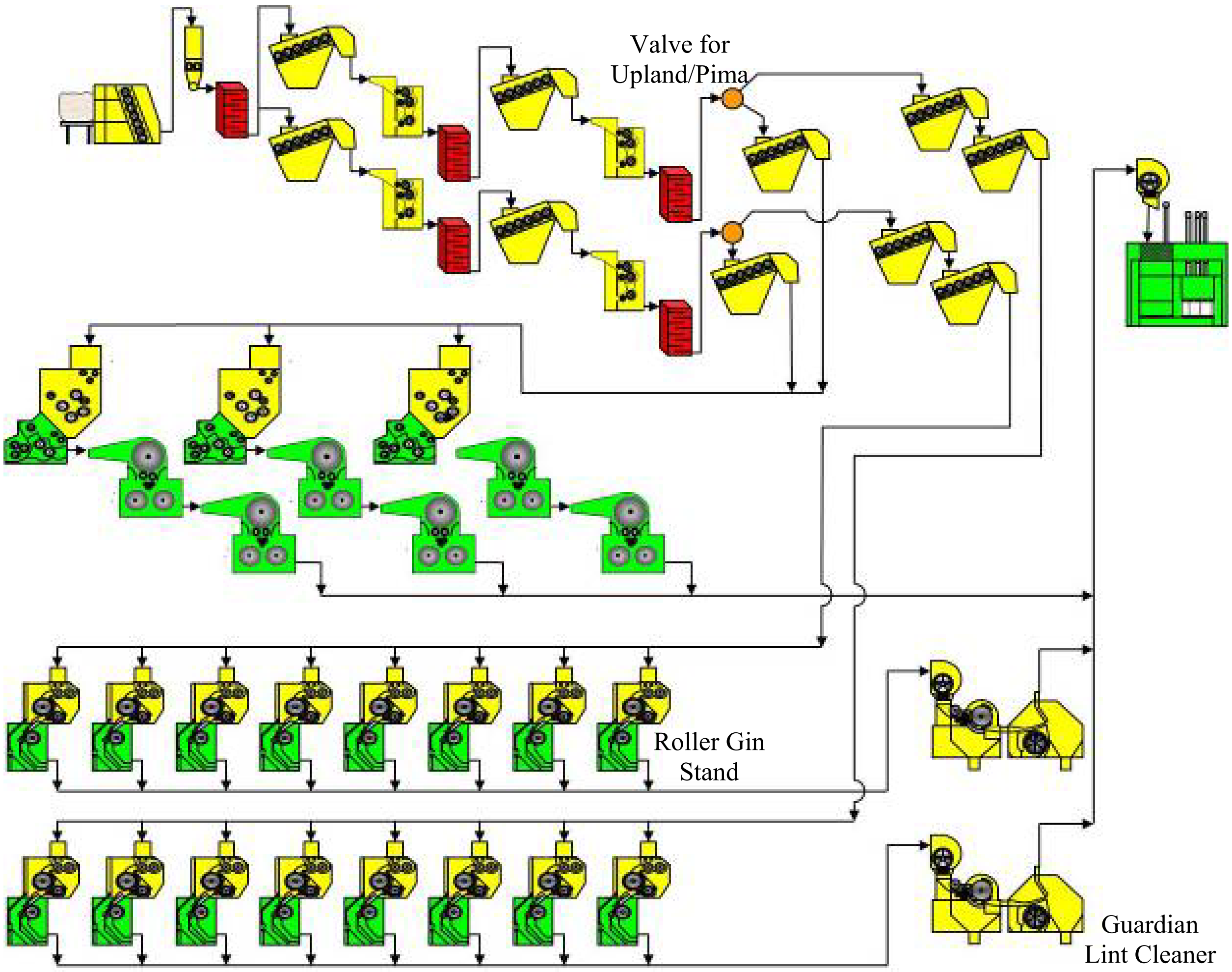

Figure 4. Gin D layout.

Sensors were installed to measure motor loads and total power consumption (table 2). Current transducers were installed at the disconnects on a single phase of all motors 15 hp and larger. All cleaning equipment, gin stands, fans, the bale press pump and tramper motors were instrumented, while motors driving droppers and augers were excluded from this study to reduce instrumentation costs. All transducers were installed on the same phase to reduce the effect of any voltage imbalance on the data analysis. The current transducers were all split-core to facilitate installation and had 4-20 mA outputs to minimize the effects of electrical noise.

Potential transformers were installed on all three phases to record voltage at the gin. The line-neutral voltage was the input voltage for these transformers, except at gin C, where the line-line voltage was measured, since a corner-grounded delta electrical system was used. Flexible split-core current transformers were installed on all phases at each motor control center (MCC) disconnect. Both potential and current transformers had millivolt AC outputs. The sensitivity of the voltage transformers was 1.11 mV/V, while the current transformers had a sensitivity of 0.667 mV/A. The datalogger calculated power and power factor from the potential and current transformer data. When feasible, variable frequency drive reference outputs were connected to the datalogger to monitor variable speed motors in the gin– module bed, steady flow hopper, and feed controls on the gin stand extractor-feeders.

Table 2. Sensors used in energy monitoring system.

Parameter	Input Range	Manufacturer	Model Number
Motor load	0-30, 0-60, 0-120 A	Veris (Portland, Ore.)	H921
	0-100, 0-150, 0-200 A	Honeywell (Minneapolis, Minn.)	CTP-20-200-AVG-001
	0-300 A	Veris	H321
		Veris + Honeywell	H6810-300A-5A + CTP-20-005-AVG-001
VFD motor load (true RMS sensor)	0-100, 0-150, 0-200 A	Honeywell	CTP-20-200-VFD-001
		Automation Direct (Cumming, Ga.)	ACTR200-42L-S
MCC voltage	0-300 V	Magnelab (Longmont, Co.)	SPT-0375-300
MCC current	0-500 A	Magnelab	RCT-1800-500

The datalogger sampled and recorded all data at intervals between 2 and 5 s. The interval chosen was the minimum necessary to sample all inputs and varied between gins. Dataloggers were Ethernet enabled and stored data was regularly emailed to the researchers. Gin managers were able to access recent data through their local networks.

The current and power data was analyzed to provide summary data for each gin and identify factors that significantly affected energy use. A local maximum in the bale press pump motor current data indicated that a bale had been pressed. The total electricity used for each bale was calculated by integrating the instantaneous power demand for each MCC over the length of time required to process the bale. Because all MCC's in a gin were instrumented, the electrical energy per bale calculation includes loads for all motors in the gin, including the smaller motors that were not instrumented with individual current transducers. All bales were used to calculate the average electricity use; consequently, the effect of gin downtime was included in this calculation of electricity use.

The time required to process each bale was used to calculate the average ginning rate. Only bales that were processed in less than 10 minutes were used to calculate the average ginning rate. This condition excluded planned shutdowns for cleaning and significant downtime where equipment was turned off.

Results and Discussion

Data from two of the monitored gins have been analyzed. A summary of these results is shown in table 3. The gin number listed does not correspond to a particular layout, in order to avoid identifying specific gins. The difference in electricity use per bale was likely due to differences in layout and installed equipment between the gins, and both gins were more efficient than past surveys indicated. The gins selected for monitoring were newer and larger than the typical gin in those past surveys.

Table 3. Summary of energy monitoring data.

Gin	# of Bales	Electricity Use (kWh/bale)	Ginning Rate (Bales/hr)
1	16,505	31.6	34.6
2	16,285	39.4	35.3

A plot of electricity use against ginning time for each bale at gin 1 is shown in figure 5. A distinct linear relationship exists, as shown by the regression line and equation on the figure. The regression equation shown in figure 5 indicated that each extra minute to gin a bale required an additional 13 kWh per bale. The ginning time per bale is the primary factor affecting electricity use, as there was little variation in electricity use for bales with the same ginning time. For the most frequent ginning time per bale at this gin, 95 s, the mean energy use was 29.0 kWh/bale and the standard deviation was only 0.56 kWh/bale. The accuracy of the monitoring system in measuring electricity use was estimated to be ±1 kWh/bale and 94% of these bales required between 28-30 kWh/bale.

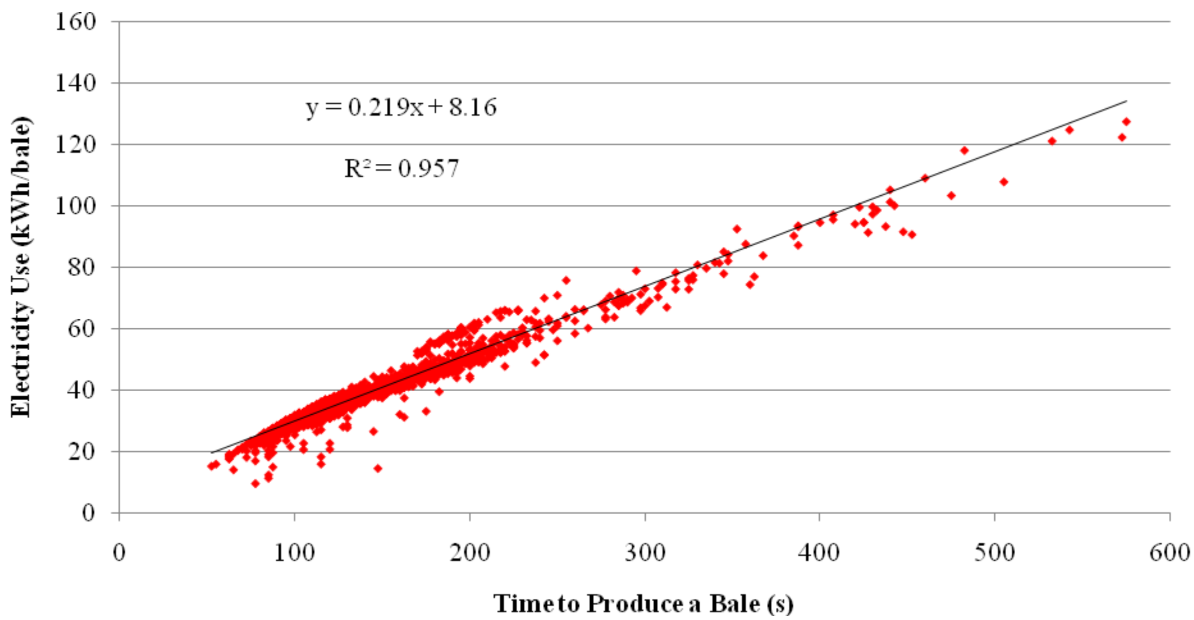

Figure 5. Electricity use and ginning time for bales at gin 1.

Comparing the average power required while ginning a bale to the ginning time provided information about the power required while ginning and idling (figure 6). The average power required to process bales near the minimum time was approximately 1100 kW. As the time to gin a bale approached 600 s, the average power required approached 800 kW. Significant downtime would be experienced for bales requiring this long to gin; consequently, this value of 800 kW can be considered an estimate of the power required while idling. The idling power at gin 1 was nearly 75% of the ginning power, similar to values found by Watson et al. (1964) and Wilmot and Watson (1966). The high idling power was likely due to the increased load on centrifugal fans when unloaded. When not conveying material, the system resistance is lower, air flow increases, and more power is required.

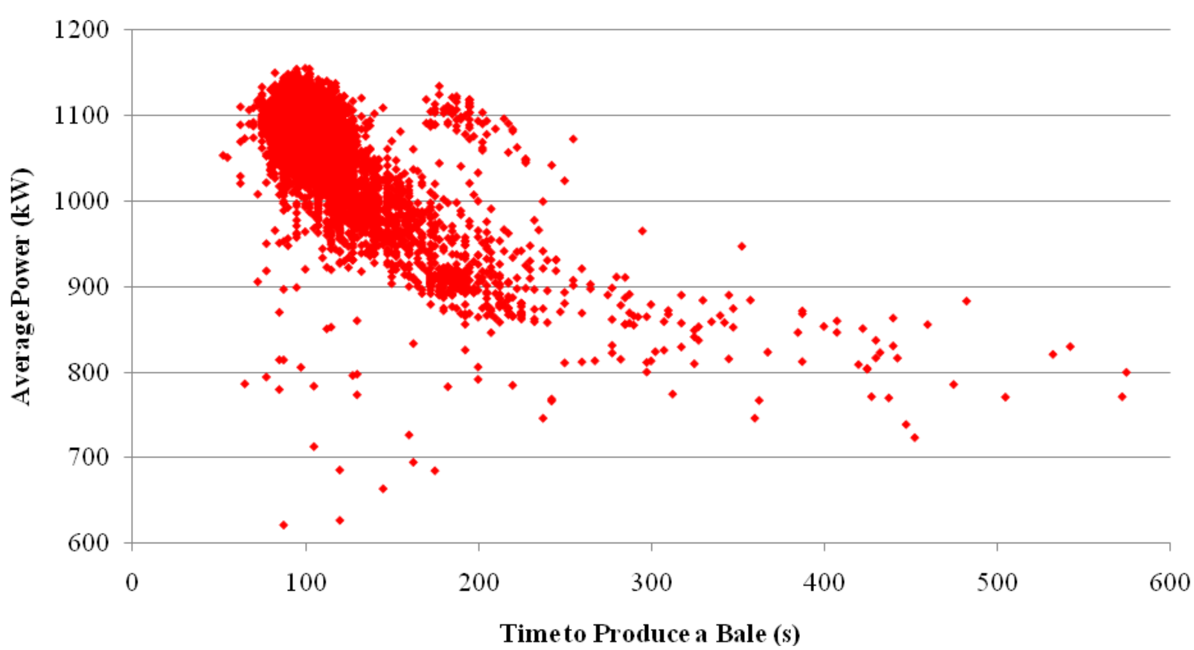

Figure 6. Average power and ginning time for bales at gin 1.

Since nearly as much electricity is used while idling as ginning, long idling periods should be avoided. Factors not investigated in this research, such as dryer warm-up times or the time and effort required stopping and starting machinery, will affect the maximum time a gin should be left idling. Considering electricity use alone, restarting a gin uses the same energy as a short idling period. Watson and Looney (1964) determined that the breakeven idling time was 16.5 s. However, motors should be allowed to cool for a sufficient time before restarting to maximize motor life. The National Electrical Manufacturers Association (NEMA) provides guidelines for these rest times, as shown in table 4. For motors less than 100 hp, recommended rest times are 90 s or less. While these recommendations are for motors cycled on and off repeatedly for intermittent loads, the effect of insufficient rest time on motor life should still be considered. Consequently, using the NEMA rest time recommendation for the largest motor in a gin as the maximum idling time of a gin would be a conservative guideline.

Table 4. Minimum off times for motors (NEMA, 2007).

Motor Size (hp)	Minimum Rest Time (s)
100	110
125	140
150	160
200	300

Because the time required to gin a bale explains most variation in electricity use per bale, understanding the causes of variation in ginning time are important. Figure 7 shows a histogram of ginning times for bales at gin 1. Several peaks are observed in this distribution- 87.5 s, 95 s, between 100 and 102.5 s, and at 107.5 s. The explanation for these multiple maxima has not been identified; however, possible causes are different cultivars, differences in efficiency between day and night shifts, commonly occurring operational conditions that affect ginning time and electricity use, or varying environmental conditions.

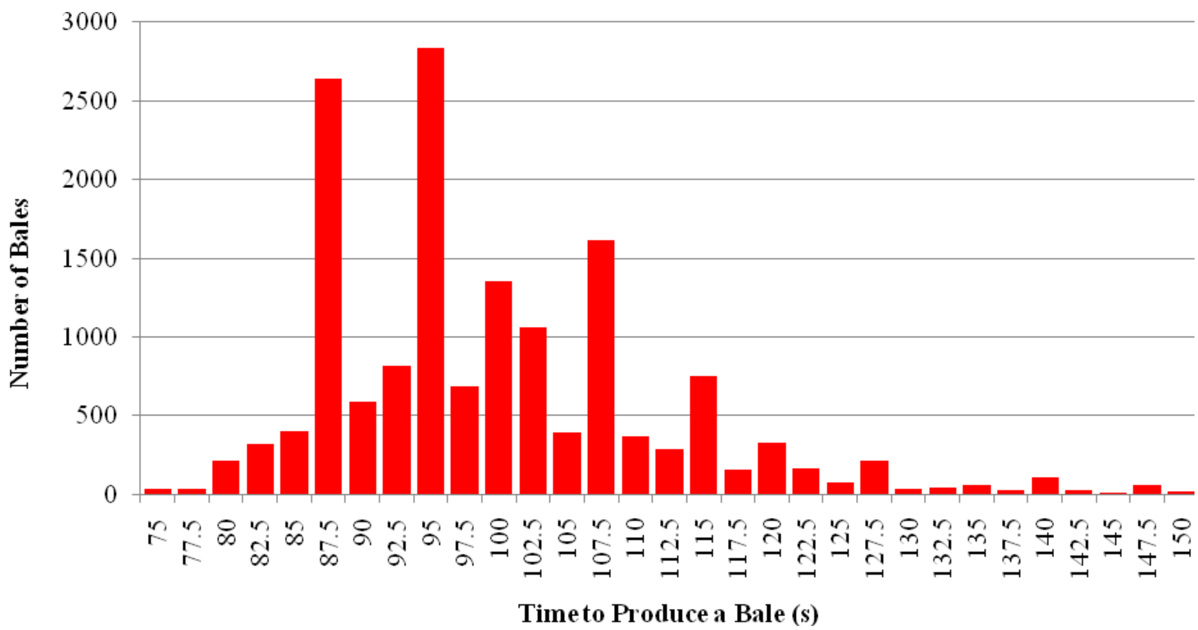

Figure 7. Distribution of ginning times at gin 1.

Similar trends were observed at gin 2, although electricity use per bale was higher. A linear relationship was observed between electricity use and ginning time (figure 8). At this gin, each additional minute required to gin a bale required an extra 16 kWh per bale. The average power required while ginning was 1350 kWh, while the power consumed while idling was approximately 1000 kWh, resulting in a similar ratio to gin 1. Again, there was little variation in electricity use for bales with the same ginning time. The distribution of ginning times also was similar to gin 1, with several ginning times occurring much more frequently than others.

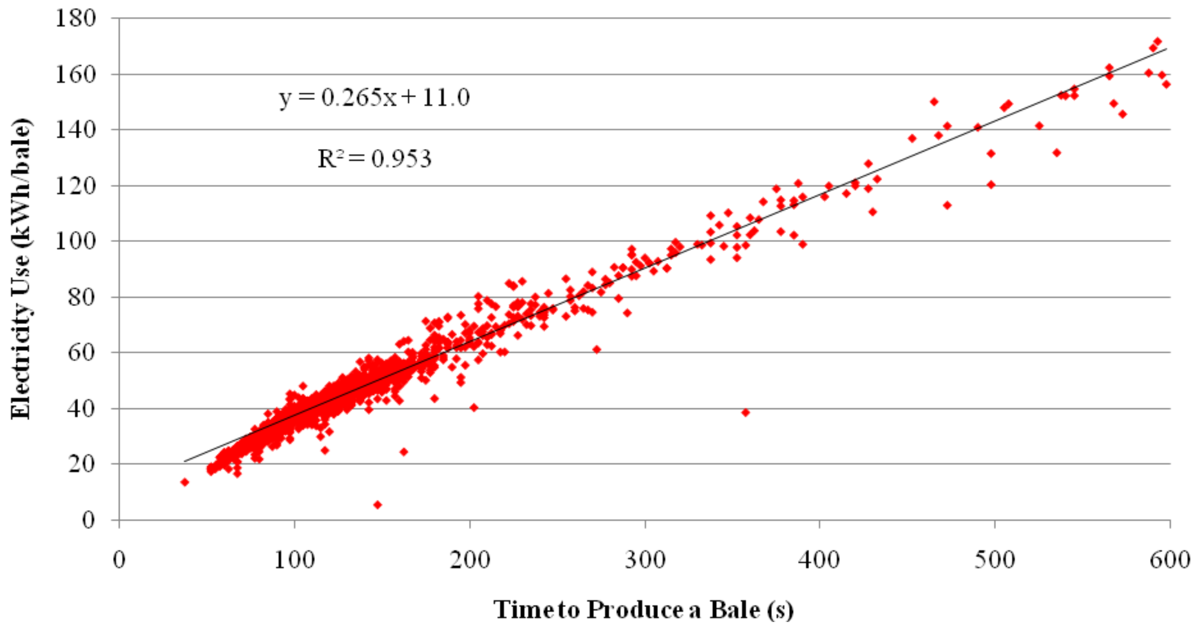

Figure 8. Electricity use and ginning times for gin 2.

Power factor varied from 0.75-0.80 at MCC's for equipment other that the bale press. This result was not surprising, as the power factor for fully loaded motors varies from 0.75-0.85, with larger motors having higher power factor (NEMA, 2007). Additionally, the monitored gins likely had some motors that were oversized, which would decrease power factor. The power factor at the MCC's for bale presses was near 0.50 while the press pump motors idled, although the power factor rose to 0.85-0.90 when pressing bales. If a gin's utility charges a large enough power factor penalty, investing in power factor correction capacitors may be worthwhile, especially at the bale press.

Conclusions

The monitored gins were more energy efficient than gins examined in past surveys, likely because the monitored gins were newer and larger. The primary source of variation in the electricity use per bale was the time required to gin a given bale. The primary implication of this finding for cotton ginners is that gins should be operated at full capacity as much as possible. Additionally, because the power consumed while idling was nearly as large as the power required during ginning, equipment should be turned off if the gin will be idle for several minutes or longer. This time will vary between gins based on warm-up times for dryers, labor requirements for stopping and restarting the gin, and other factors. However, idling times longer than five minutes are likely uneconomical. Low power factor may also be a concern for cotton ginners, if their utility charges a penalty. Some possible factors affecting gin energy use were identified; however, more research and analysis are needed to quantify their effects.

Future Work

Data from the other monitored gins will be analyzed. Cultivar information and classing office data will be obtained from cooperating gins to determine the effects of these parameters on energy use. Data from nearby weather stations will also be used to determine if environmental conditions affect electricity use. Monitored electricity use will be compared to utility bills to verify the accuracy of the monitoring system. Individual motor current data will be examined in greater detail to identify specific situations that decrease energy efficiency. Gins monitored in 2010, will be monitored again in 2011 to determine how energy use varies between years and other gins will also be instrumented. Additional variables, such as ambient temperature and humidity, static pressures in conveying lines, and dryer temperatures, will be measured.

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