SAVING ENERGY IN COTTON GINS

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Abstract

Cotton ginning energy costs average 25% of total variable cost. Studies were conducted to find industry energy use best practices to reduce the economic and environmental cost of cotton ginning energy. This paper summarizes key findings and recommendations. Both electrical and fuel energy can be saved by operating at full capacity, minimizing down time, and shutting systems off if idle time will exceed 12 minutes. More than half of electrical energy is used for materials handling, primarily pneumatic conveying, so reducing air system losses is important, as is replacing pneumatic conveying with mechanical conveying where possible. Motor replacement is only recommended when motors are improperly sized or at the end of their useful life. Fuel energy savings can be realized by shortening the distance from the burner to the material pickup point, and insulating this duct. Fuel energy can be saved by encouraging growers to only pick cotton after it is dry, and by storing modules so the cotton remains dry.

Introduction

Energy costs have averaged 25% of the total variable cost of ginning since 2001, with electricity cost ranging from $1.71 to $10.19 and dryer fuel costs between $0.05 and $6.55 per bale in 2016 (Valco, et al., 2018). These large disparities indicate opportunities for energy cost savings. Two major energy studies were conducted cooperatively with USDA-ARS gin labs, National and regional Cotton Ginners Associations, Cotton Inc., and over thirty commercial cotton gins. Electricity use audits commenced in 2009, and fuel use audits concluded in 2017. These studies sought to find industry best practices in the area of energy use, to share with the entire U.S. cotton ginning industry and thus help reduce the economic and environmental cost of post-harvest processing energy use.

Materials and Methods

Electricity use was quantified using both audits and monitoring studies. An electricity audit typically involved two visits, one during the dormant season and one during the ginning season. The dormant season visit allowed scientists to make a process flow diagram, list each motor, determine its rated horse power, and assign it to a category. During the ginning season the current in at least one leg of each motor was measured using clamp-on ammeters. This value, the voltage at the motor control center, and the power factor, were used to calculate the true power each motor was using at the time with: $P = V*I* 3*PF$. Power was then divided by the gin processing rate at the time of the measurement to estimate the energy per bale for each motor, category, and gin (Funk & Hardin IV, 2012).

Electricity monitoring involved installing current transmitters in motor control centers and connecting them to data loggers to record amperage draws by each motor throughout the ginning season. This set of studies provided scientists with insight into how energy consumption per bale changed with changes in other variables such as cultivar and processing rate (Hardin IV & Funk, Electricity use patterns in cotton gins, 2012).

Fuel use efficiency was estimated by dividing the power used to dry cotton by the power added to the drying air by the burners (Funk, Terrazas, & Hardin IV, 2018). Measure fuel consumption with flow meters would have been cost-prohibitive, so burner fuel use was estimated from air flow measurements (Pitot-tubes and pressure transmitters) and temperature sensors (thermocouples). The sensors transmitted a 4-20 mA current signals to synchronized miniature data loggers. Calibration curves allowed scientists to calculate the velocity pressure and temperature values after data retrieval. Burner power consumed was found using the equation:

$$P_{in} = \left(\rho \pi r^2 0.92 \sqrt{\frac{2p_v}{\rho}} \right) C_p \, \Delta T \, \eta^{-1}$$

Where: P_{in} = burner power consumed; Á= air density; À= pi; r = duct radius; 0.92 = Pitot-tube centerline to average correction; p_v = velocity pressure, c_p = specific heat capacity of air; ” T = temperature increase through burner; and estimated burner efficiency = · . Burner efficiency measured with a fuel meter was determined to be 0.92.

Seed cotton moisture content was measured by collecting 30 samples of seed cotton before and after each drying system (typically one sample was taken for each bale processed, or once every two minutes). The moisture content was determined by oven drying (Funk, et al., 2018). The change in seed cotton moisture content multiplied by bale weight and processing rate and divided by turnout provided the rate of water evaporation. The power used to dry cotton was calculated by multiplying the evaporation rate by the enthalpy of vaporization. Multivariate statistical methods were used to look for correlations between fuel use efficiency and numerous controlled and uncontrolled variables (Funk, Terrazas, & Hardin IV, 2018).

Results

Electricity

Compared to 50 years ago, more processing is required for modern cotton ginning because gins today are receiving cotton that is 100% machine harvested and shipping cotton that is packaged in UD bales. There is considerably more automation in gins today, with mechanization replacing labor in many parts of the process. Additionally, more stringent air quality regulations have increased the energy burden by adding abatement devices on every fan exhaust. Despite these challenges, U.S. cotton gins are using 25% less electricity per bale compared to 50 or even 30 years ago (Funk, Hardin IV, Hughs, & Boykin, 2013).

Figure 1 presents the U.S. average electrical energy consumption per bale processed for five categories from three national studies: 1962 (Holder & McCaskill, 1963); 1982 (Anthony, 1983); and 2009 (Funk & Hardin IV, 2012). The percent of the total for each category is from the most recent study. Note that materials handling was 59% of electrical energy used. The following recommendations are intended to reduce the materials handling burden (Funk & Hardin IV, 2017); in order of increasing investment cost:

- Operate at maximum capacity; centrifugal fans used for conveying draw more power when unloaded
- Use the minimum recommended air velocity for pneumatic conveying of materials
- Repair ducts where there are air leaks
- Seal covers and access doors on machinery that is under positive or negative pressure
- Maintain vacuum dropper and separator main and end flashings
- Add evasés to cyclones where permitted (Funk, 2015)
- Upgrade fan wheels in clean air flows with high-efficiency backwards-inclined-fin-type fan wheels
- Replace sharp elbows at the fan inlet with long radius elbows and straight duct sections
- Replace long, complicated ducts with short runs having few elbows
- Replace blast gates with variable frequency motor drives*
- Stack machinery to use gravity instead of pneumatic conveying*
- Replace pneumatic conveying systems with mechanical conveyors, especially on trash lines*

*The last three recommendations require careful engineering analyses specific to each system to determine the return on investment.

Few cotton gins pay additional charges for low power factor, so it’s not often monitored. However, measuring the power factor of a gin provides insight into average motor loading. The power factor of a motor operating under full load is 85% to 90%, depending on size. It decreases to 75% when the motor is operating at 50% of full load. The average power factor measured in a representative sample of U.S. gins was 79%, indicating that a significant number of motors were not fully loaded. Motors need to be oversized on flows that fluctuate to avoid choke-ups, but motors on systems that do not experience load fluctuations can be selected to better match their respective loads. Measure the current under normal operating conditions, calculate the power (P = V*I* 3*PF), convert W to HP, and compare the result to the motors rating. If the motor is not the appropriate size for the actual load, replace it with one that is the correct size. Implementing this recommendation requires balanced judgement. New motors have higher efficiencies than legacy ones, but replacing all motors is not cost effective. Because gins run approximately 2,000 hours per year, ROI can be 5 to 9 years, so motor replacement is only recommended when motors are improperly sized or already at the end of their useful life (Funk & Hardin IV, 2012).

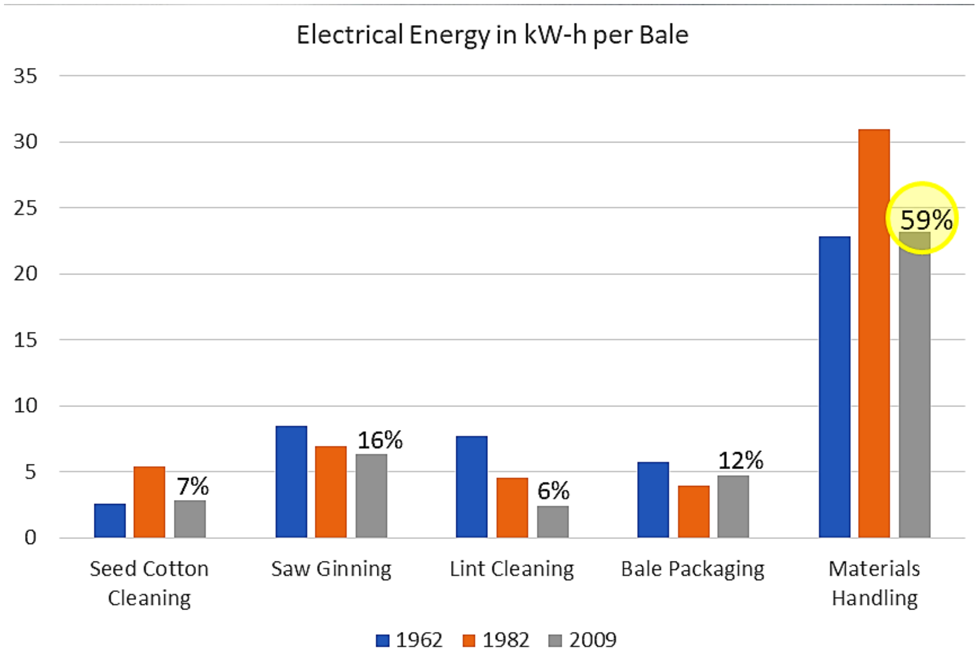

Figure 1. Average electrical energy consumption per bale processed from three national studies: 1962; 1982; and 2009. The percent of the total for each category is from the most recent study; materials handling was 59%.

Monitoring studies results showed that gin stands were running at 92% of full capacity, up from 84% in 1964 (Watson & Holder, 1964). Gains are ascribed to automated module feeders and electronic feed control systems. In each gin, the last stand operated at a lower capacity, showing the importance of a steady flow hopper and overflow system to keep gin stands supplied with sufficient seed cotton.

Monitoring results showed that gins require 71% of full power electrical energy when at idle. This loss can be mitigated by minimizing down time. It pays to shut the gin down when the gin will be stopped for cleaning or repairs if the down time will be more than eight to sixteen minutes (with an average of twelve minutes). Operating the gin at lower processing rates took almost as much electricity as operating it at full capacity, so the energy per bale cost is minimized when the gin is operated at full capacity. Recommendations based on the electrical energy monitoring studies (Hardin IV & Funk, Electricity use patterns in cotton gins, 2012) include:

- Install a feed control hopper if the gin does not have one
- Keep every system operating at full capacity by properly matching equipment sizes
- Implement a comprehensive maintenance program to avoid unscheduled downtime (Funk & Hardin IV, 2018)
- If it is necessary to stop for more than 12 minutes, shut everything off

Fuel

Fuel use efficiency audits found that more fuel energy was lost to the surroundings than went to drying cotton. Also, fuel consumption depended on weather as much as on system design. The moisture content of incoming cotton was the best predictor of fuel consumption, so the gin has an incentive to encourage its growers to deliver seed cotton at the lowest possible moisture content by waiting for the lint to dry before harvesting and keeping stored seed cotton dry. Fuel use efficiency increased as the distance between the burner and the mix point decreased. Gin management can manipulate this variable and the relationship makes sense: thermal losses will decrease when the length of pipe in which high temperature air is conveyed is reduced. Insulating this duct saves more energy than insulating the duct after the mix point, because the duct before the mix point is hotter and so it loses more heat per unit length.

Several process variables can be controlled to reduce drying fuel use as well. As with electricity (and everything else) maintaining process flow rate at the maximum level makes the best use of fuel energy. A lower volume of air used for seed cotton conveying and drying requires less fuel for heating. Higher volumes than needed for conveying have not been shown to improve drying (Hardin IV, Funk, & Pelletier, 2018). Drying cotton more than necessary not only wastes fuel, but will decrease fiber quality. With saw ginning, the target lint moisture content should be 6-7% w.b. (Hardin IV, Barnes, Valco, Martin, & Clapp, 2018). To maintain gin efficiency and achieve leaf grades that optimize bale value, a compromise lint moisture content of 5-6% may be needed. Lower moisture contents increase fiber damage, resulting in decreased fiber length, more short fiber, increased neps, and reduced strength. Fuel use efficiency audits resulted in these recommendations (Funk, Terrazas, & Hardin IV, 2018):

- Avoid unnecessary drying
- Use the minimum amount of air needed for satisfactory conveying
- Insulate the duct from the burner to the material pick-up point
- Minimize the distance from the burner to the material pick-up point
- Don't pick wet cotton
- Store modules on high, dry ground under sound covers or wraps

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