EVALUATION OF MASS FLOW RATE SENSORS FOR STRIPPER HARVESTED COTTON

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Abstract

Mass flow sensors are needed at various locations in the cotton gin if process control is to reach its full potential. Several devices, including belt scales, light array bars and a microwave flow meter were evaluated for their suitability in detecting the flow of cotton and the mass flow rates of stripper harvested cotton. The readout from the truck scales was used to provide the lot weight for the study. Although equipment problems prevented us from testing the accuracy of the scale units under varying rate conditions, these units should provide the most accurate method of measuring mass flow. The mechanical nature of the scale units, however, limit their usefulness in commercial gins which use primarily pneumatic systems to convey the cotton. The microwave based sensor was unsuitable for measuring mass flow but did provide an excellent indication of the presence of flow in the pneumatic pipes. The signal from the light bar array correlated very well with the mass flow rate of the cotton through the pipes (R^2 = 0.98) and requires only minor modifications in the conveyance system. All devices need estimates of moisture and trash content to improve accuracy.

Introduction

The current economic climate makes it imperative that we reduce the cost of producing cotton. Process control has the potential of eliminating labor requirements and thus reducing costs when utilized in the processing industry, Anthony (1996). In addition, orderly shut down of processing equipment would reduce both machine damage and down time. One of the requirements of good process control is the accurate measurement of material flow during the processing phases. With this in mind, a project was initiated to identify potential devices for their applicability to accurately measure the mass flow of cotton and its component parts in various places in the gin. There is also a need for measuring the mass flow rate of seed cotton during harvesting for use in determining yield in precision farming applications, Khalilian et al., 1999.

Thomasson, et al. (1997) successfully used two devices for measuring mass flow in cotton pickers and in two locations in the gin. They reported that the light bar device produced acceptable results in both the picker ducts and the gin. Wilkerson, et al. (1994) reported that the output from their sensor was highly correlated with the mass of cotton conveyed through the chute. Searcy and Roades (1998) evaluated a commercial cotton yield system which uses light arrays to sense the mass of cotton flowing in picker ducts. They determined that the system still needs improvement to reach the accuracy level of grain yield monitors.

Belt scales have been utilized in many commercial facilities to measure mass flow. Pelletier and Upadhyaya (1999) reported on methods for eliminating the noise in load/yield monitors. They concluded that filtering, to remove impulse noise from irregularities in the field, improved the results from typical belt scales.

The objective of this study was to compare the suitability of four different types of mass flow sensors for measuring the flow rate of stripper harvested cotton during the initial phases of ginning and/or harvesting. Both regular and field cleaned cotton was used with rates varying from 62 to 425 lbs/min.

Equipment and Procedure

The equipment chosen for this test included a commercial belt scale, a commercial light array, truck (trailer) scales with load cell, and a microwave based commercial mass flow sensor. The single idler belt scale, which used two actively summed load cells in compression mode, was purchased from Milltronics® and installed in a belt conveyor dryer, Laird, et al. (1995). The system includes electronic readout and accompanying digital speed sensor, which was coupled to the tail pulley with a stub shaft. Three flat idler rollers, 1.9 inches in diameter and 24 inches long, were used in the system. The center roller was mechanically attached to the load cells, while the other two idlers were spaced 18 inches on either side of the weighing roller.

The microwave based commercial mass flow sensor, Fig. 1, was obtained from Monitor® Manufacturing, Inc. This unit emits radiation in the 24.125 GHz range with energy levels less than 1 mW/cm^2 and essentially uses the same techniques as RADAR to measure the presence of and mass of moving material. The flow sensor was mounted at approximately 21° angle to the pipe so that it was looking downstream. This prevented trash or other material buildup around the sensor.

A 12 inch light bar Beam-Array® system was purchased from Banner Engineering Corporation, Fig. 1. These units typically come in 12 inch increments and are used for parts measurement and profiling, hole detection, parts ejection verification and counting. This unit has 0.20 inch diameter infrared (880nm) LED light beams on 0.25 inch centers and utilizes both an emitter and a receiver unit. The emitter and receiver units were mounted perpendicular to the material

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flow on a specially constructed square transition with glass sides.

A 450 pound capacity load cell was placed in the linkage between the truck (trailer) platform scale and the dial indicator read-out. A strain-gage bridge amplifier was attached which provided a 4-20 ma signal. The load cell was in tension and produced a 2 mV/V output. All four devices were then connected to a data acquisition system and appropriate amplifiers. The devices were scanned at 20 Hz (0.05 sec).

The study was designed as a split plot design utilizing standard stripped cotton containing approximately 35 percent trash and field cleaned cotton containing 15 percent trash. The study utilized five flow rates (from slow to fast) and three replications within each type of cotton. The lot weight was approximately 800 pounds. The suction operator was assigned the task of operating the suction at different rates so that different flow rates would be applied to both the belt scale and the truck scale. After leaving the belt scale, the entire lot of cotton accumulated in a hopper above the steady flow device. The steady flow device was then used to control the flow rate through the section of pipe containing the light array and the microwave flow sensor. The control knob, which controlled speed of the steady flow paddles, was set to five different settings, depending upon the treatment.

Results

Truck and Belt Scales

Modifications and improvements to the unloading system in the Laboratory gin resulted in increased capacity which exceeded that of the belt dryer, in which the belt scales were mounted. Belt slippage and choke-ups were encountered at the point where the separator dropped the cotton onto the belt, resulting in loss of data from the belt scales. After the first portion of the study was complete (standard stripped cotton), the dryer was modified by replacing the drive rollers with positive drive sprockets. However, the flow rate on these two devices could not be varied in the desired manner. Thus, the results shown in this paper for the truck and the belt scales was limited to field cleaned cotton and a direct comparison of the two devices.

The data from the belt scale was integrated and compared with that from the truck scale to determine accuracy and the amount of time shift which was necessary for correlation of the two scales. The data for the truck and belt scales contained excessive noise from both electronic and mechanical sources. The noise in the data was removed by treating all of the data with a discrete Finite Impulse Response filter to perform low pass filtering on the signals, Porat (1997). The low pass filter selected was a maximally flat Butterworth filter with a damping value of 0.7, which reduced the high frequency noise that was observed in the signals (cut off frequency of 10 Hz). The data acquisition system was set to a 0.05 second sampling interval or 20Hz sampling rate.

A discrete correlation between the integrated belt scale data and the weight removed from the truck scale was performed to determine the conveying time lag between the two scales. The noise in the data combined with a very short time interval from the suction pipe to the belt scales, however produced a time lag of zero, when analyzed using the discrete correlation function. The two integrated values for the two data sets agreed very well, Fig. 2.

Light Array and Mass Flow Units

The microwave based mass flow sensor produced a definite signal when cotton was present in the duct, Fig. 3. However, it produced the same voltage reading regardless of the flow rate. The manufacturer indicated that the unit does not work well on materials with a low dielectric constant. Also, the unit works on the same principal as radar and is measuring the presence of flowing material instead of mass. The output of the microwave based mass flow sensor (located in a close proximity to the light bar array) was used to determine the true residence time for the cotton passing through the light array.

The light bar array performed very well for flow rates between 62 and 425 lbs/min, Fig. 4. Little or no difference was detected between the cotton stripped with a field cleaner and that stripped with the same standard brush stripper without a field cleaner. Lot weights were determined, to the nearest 5 pounds ± 2.5 pounds from the dial indicator on the truck scales. Linear regression was used to determine the relationship between the integrated value of the signal from the light bar array and the actual flow rate. The processing time for each lot was determined from the microwave based mass flow sensor. The prediction equation has an R^2 value of 0.98 when the data from both types of cotton are included. Increasing the sampling rate should increase the prediction accuracy for this type of device.

Conclusions

Four devices were evaluated for their ability to measure stripper harvested seed cotton flow rates in a cotton gin. The devices tested included a commercial belt scale, a load cell placed in the linkage of the truck scales, a commercial light bar array, and a commercial microwave based mass flow sensor. The light bar array and the microwave based sensor were mounted on a specially constructed transition in the duct work immediately after the steady flow unit in the USDA Laboratory Gin. The commercial belt scale was mounted in a belt dryer which was immediately downstream from the suction pipe.

Two types of cotton, standard stripped cotton (35% trash) and field cleaned stripped cotton (15% trash) were used in the study. The steady flow device provided a wide range of flow rates from 62 to 425 lb/min. The microwave based (radar) mass flow sensor produced a very good indication of material velocity and thus indicated the presence of flowing material, however, the signal could not be correlated with mass flow. The signal from the light bar array correlated very well with the mass flow of stripper harvested seed cotton over the range tested when the residence time from the microwave mass flow sensor was used to determine the flow rate.

Mechanical problems prevented the actual measurement of mass flow rates with the two scale units and also prevented tests with the standard stripped cotton. However, the extremely good correlation between the two units indicates that these devices should work very well. Additional work needs to be done to eliminate the noise from the signals produced by the two scale units.

Disclaimer

Mention of a trade name, proprietary product or specific equipment does not constitute a guarantee or warranty by the USDA and does not imply approval of the product to the exclusion of others that may be available.

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A

B **B**

Figure 1. Mass flow sensor (A) from Monitor® Manufacturing, Inc. and Light bar array (B) from Banner Engineering Corporation® used in the study.

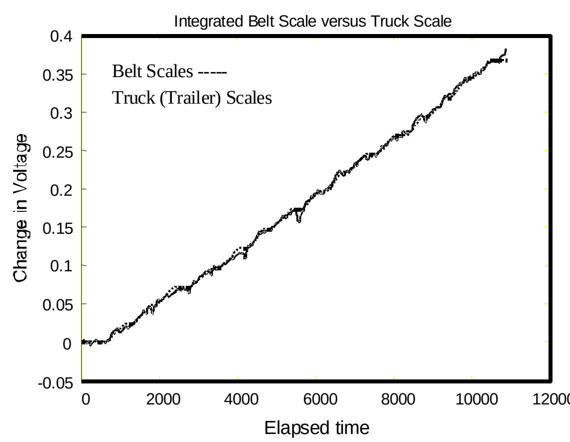

Figure 2. Comparison of the integrated signal output of the belt scale with that of the integrated truck scale.

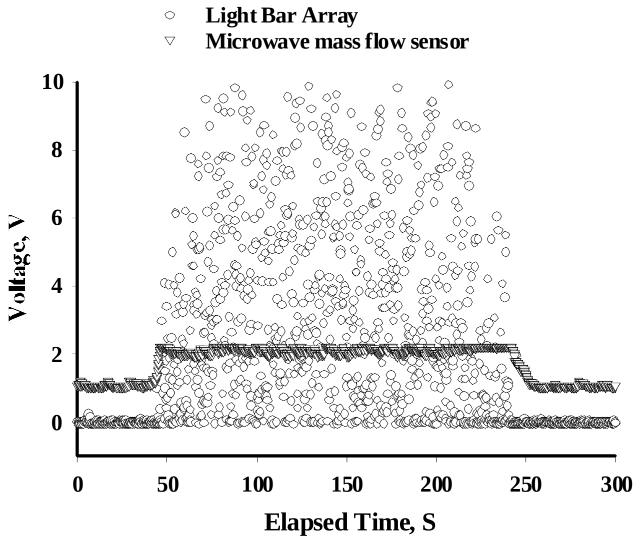

Figure 3. Plot of data signals from the light bar array and the microwave based flow sensor for one treatment and replication. Only every 4th data point is shown for clarity.

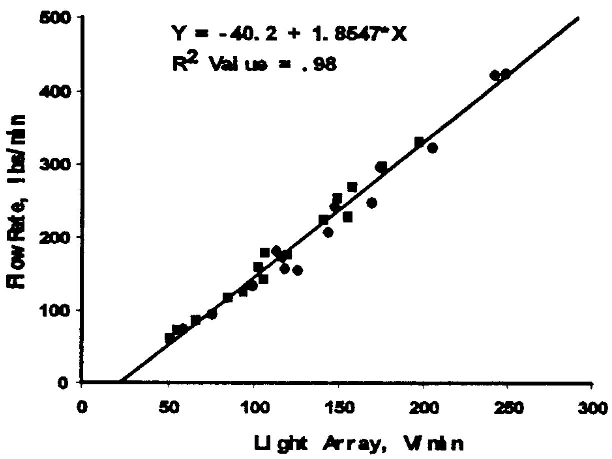

Figure 4. Plot of the observed flow rate against the integrated voltage signal from the light bar array. The circles indicate stripper harvested cotton with a field cleaner and the squares indicate standard stripper harvested cotton.