ADVANCED OPTICAL
COTTON YIELD MONITOR

J. Alex Thomasson and Ruixiu Sui
Department of Agricultural and Biological Engineering
Mississippi State University
Starkville, MS

Abstract

An advanced optical cotton-flow sensor was designed, fabricated, and field-tested as a yield monitor. Results showed that sensor output was very strongly correlated with the weight of seedcotton flowing through the sensor. The sensor was also capable of measuring trash content in seedcotton, and was immune to the effects of dirt and dust buildup, a problem that has yet been difficult to overcome. Some test results are presented in this paper.

Introduction

Precision-agriculture technologies provide a way to adjust production inputs based on the needs of individual areas within fields. These adjustments can be managed to optimize profit and minimize environmental impact. Optimizing profit requires knowledge of the amount of crop yield at a given point in a field. Thus, cotton yield monitors are very important for the future of precision agriculture in cotton. Accurate, tough, and inexpensive cotton yield monitors are badly needed by cotton producers.

Wilkerson et al. (1994) developed a sensor to measure real-time cotton flow. Their work included a light-source array that projected light across a cotton-picker discharge chute. On the opposite side of the chute was a photo-detector array that measured the amount of light crossing the chute. Measuring light attenuation caused by passing particles allowed calculations of the amount of cotton passing the sensor cross-section in a given time. The original field test of the device in a cotton picker was unsuccessful, primarily because of problems with stray light. However, laboratory tests resulted in a high correlation ($R^2 = 0.93$) between the mass of cotton passing the device and the device's output. Cotton feed rate was reported to affect sensor performance, and airflow rate was a significant factor affecting sensor output.

Thomasson et al. (1999) reported the design and fabrication of two experimental devices (device A and device B) for measuring the flow of pneumatically conveyed cotton. Both devices worked on the principle of optical attenuation and consisted of a light-sensing bar and a light source in Device A, and an LED array and light-sensors in Device B. In limited tests on a cotton picker in 1989, device A recorded data that were highly correlated with yield, with $R^2 = 0.89$ one day, and $R^2 = 0.98$ the next. Differences are likely attributable to using sunlight as the light source in those early experiments. When both devices were mounted in a gin-unloading duct, data from device B and actual flow rates were highly correlated, with an R^2 value of 0.90. When the devices were mounted in a lint-cleaner-waste duct, data from device A and flow rates were highly correlated, with an R^2 value of 0.92.

Zycom Corporation and Micro-Trak Systems, Inc. commercialized optical cotton yield monitors in 1997. Both Micro-Trak and Zycom cotton yield monitors were evaluated (Gvili, 1998; Durrence et. al. 1998). These yield monitors have provided some useful data, but they have had some problems. One of the primary problems with optical yield monitors to date is that they are greatly affected by the buildup of dirt and dust on sensor surfaces; i.e., dirt and trash often introduce significant errors in the form of a drifting baseline. Khalilian et al. (1999) developed an air-box, pressurized by the picker fan, to help keep the sensors clean. The air-box completely encloses the sensor, effectively sealing it from environmental contamination. This method was able to keep the sensor clean over several harvested loads. In general, test results have shown that the commercial cotton yield monitors performed well when their sensor windows were clean and the systems were properly calibrated on a regular basis. These conditions are very difficult to maintain in a commercial production situation.

Objectives

The goal of this study was to develop an advanced optical cotton flow sensor that could satisfy the following objectives:

1. Higher fundamental accuracy in mass-flow measurements than current systems;
2. Basic insensitivity to buildup of dirt, dust, etc. on sensor surfaces;
3. Ability to measure trash content in the cotton at the same time mass flow is being measured.

Procedures

An optical cotton flow sensor was designed and fabricated. The sensor was two-dimensional, with five detection channels each in the horizontal and vertical directions. Channels 0 through 4 were in the vertical direction, while channels 5 through 9 were in the horizontal direction. LEDs were used as light sources, and silicon photodiodes were used as detectors, as reported by Sui et al. (1998). Two different detection techniques were tested. Channels 0, 1, 5, and 6 represent a new detection technique, while channels 2, 3, 4, 7, 8, an d 9 represent the conventional technique.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:408-410 (2000)
National Cotton Council, Memphis TN

The sensor was field-tested at Mississippi State University's North Farm with a John Deere two-row cotton picker during the 1999 cotton-harvesting season (Figure 1). In order to evaluate the sensor's insensitivity to dirt and its ability to measure trash content, non-defoliated cotton fields were selected for testing the sensor. Harvested cotton flowed through the sensor while the sensor collected data, and the cotton was captured with a mesh bag. The bagged cotton was weighed, and the trash content is currently being evaluated with fractionation analyses on the seedcotton.

The signal relating to cotton mass flow was computed by using the baseline (sensor output without cotton flowing through the sensor) and the sensor output with cotton flowing through the sensor. The relationship between the cotton mass-flow signal and the cotton weight was analyzed. Trash content index was calculated with sensor output data, and it was compared to visual assessments of trash content. The baseline data were analyzed to evaluate the sensor's insensitivity to buildup of dirt, dust, etc.

Because of patent considerations, information about the sensor and analysis will be given in more detail in a later manuscript.

Results

Figure 2 shows the relationship between the cotton mass-flow signal and seedcotton weight, which is a very strong linear correlation (R^2=0.967). The correlation between the cotton mass-flow signal and the cotton weight for all detection channels and several channel combinations is presented in Table 1. Channel 0 exhibited the strongest correlation, for any one channel, between the cotton mass-flow signal and weight (R^2=0.950). All the correlations obtained from channels 0, 1, 5, and 6 are quite strong (R^2>0.91) and greater than those from channels 2, 3, 4, 7, 8, and 9 (R^2<0.90). The combination of channels 0, 1, 5, and 6 showed the best performance (R^2=0.967). Therefore, it appears that the new detection technique is superior to the conventional technique. In general, channel combinations performed better than any individual channel, but the difference was not great. The R^2 value for channel combinations in the vertical direction was 0.924, while that for the horizontal direction was 0.917. The R^2 for channel combinations in two directions was 0.933, which is not significantly different from that obtained in either the vertical or horizontal direction.

Table 2 shows the results of trash content measurement. A trash-content index was calculated with the output data from the sensor. The index varied from 0.868 to 1.281 with an average of 1.049. It was subjectively determined that the trash-content index was a good indicator of visible differences in trash content. Samples are currently being evaluated for trash content via fractionation analysis. The relationship between trash-content index and gravimetric trash content will be examined in the near future.

Figure 3 shows the baseline variation related to dirt and dust buildup over time, along with the sensor's insensitivity to long-term effects. Taking channel 3 as an example, at the beginning of harvesting (point 1) the baseline was 2.21 volts. After harvesting for a period, the baseline dropped 26.7%, to 1.62 volts (point 2). The technique employed in the sensor that affords it its insensitivity to dirt and dust buildup caused the baseline to return to 2.10 volts at point 3. If the output at point 1 is used as a reference, 95% of the effect of dirt and dust on the window was eliminated at point 3, and later 99.1% of the effect was eliminated at point 5.

Conclusions

Based on the results obtained, the following conclusions can be made:

- While all sensor channels exhibited a strong correlation with cotton mass flow, sensor channels designed with the new measurement technique performed better than channels designed with the conventional measurement technique.
- Increasing the number of detection channels did not significantly increase measurement accuracy.
- Two-dimensional measurement performed slightly better than the one-dimensional.
- The sensor was able to detect visible differences in cotton trash content.
- The sensor exhibited greatly reduced sensitivity to dirt and dust buildup.

The results obtained in this study were quite promising. Further study will be conducted, and more field-testing is needed.

Acknowledgement

Authors would like to extent their special thanks to Mr. Daniel Chesser for his assistance in this project.

References

Durrence, J. S., C. D. Perry, G. Vellidis, D. L. Thomas, and C. K. Kvien. 1998. Evaluation of commercially available cotton yield monitors in Georgia field conditions. ASAE Paper No. 98-3106. St. Joseph, Mich.: ASAE.

Gvili, M. 1998. Cotton yield sensor produces yield maps. In *Proc. Beltwide Cotton Conf.*, D. A. Richter, ed., pp. 1655-1657. Memphis, Tenn.: National Cotton Council of Am.

Khalilian, A., F. J. Wolak, R. B. Dodd, Y. J. Han. 1999. Improved sensor mounting technology for cotton yield monitors. ASAE Paper No. 991052. St. Joseph, Mich.: ASAE.

Sui, R. X., J. B. Wilkerson, W. E. Hart, and D. D. Howard. 1998. Integration of neural network with a spectral reflectance sensor to detect nitrogen deficiency in cotton. ASAE Paper No. 983104. St. Joseph, Mich.: ASAE.

Thomasson, J. A., D. A. Pennington, H. C. Pringle, E. P. Columbus, S. J. Thomson, and R. K. Byler. 1999. Cotton mass flow measurement: experiments with two optical devices. *Applied Engineering in Agriculture* 15(1):11-17.

Wilkerson, J. B., J. S. Kirby, W. E. Hart, and A. R. Womac. 1994. Real-time cotton flow sensor. ASAE Paper No. 94-1054. St. Joseph, Mich.: ASAE.

Figure 1. The sensor was tested in a non-defoliated cotton field.

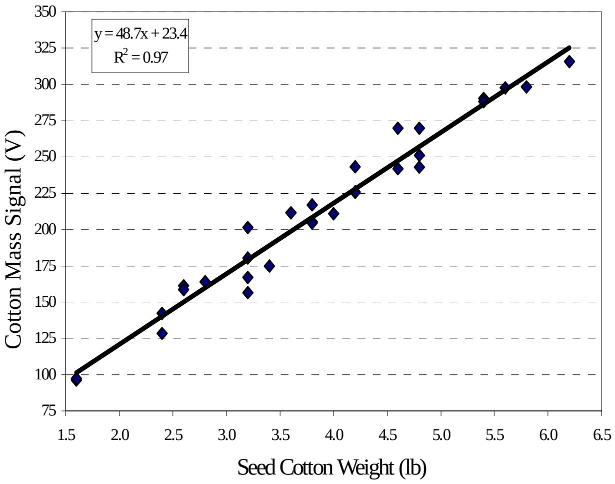

Figure 2. Cotton Mass Signal versus Seedcotton Weight.

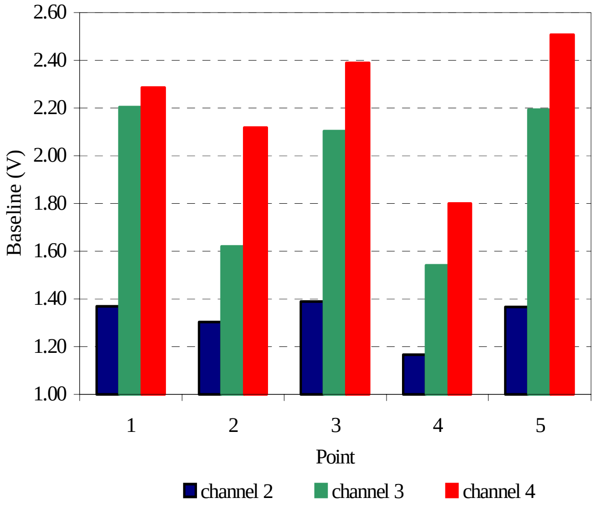

Figure 3. Sensor baseline reduction and restoration.

Table 1. Correlation between seedcotton weight and output from each detection channel and channel combinations.

Channel	R^2	Channel combination	R^2
0	.9502	0&1	.9586
1	.9316	2&3&4	.9111
2	.8967	0&1&2&3&4	.9244
3	.8970	5&6	.9425
4	.7223	7&8&9	.8902
5	.9240	5&6&7&8&9	.9186
6	.9121	0&1&5&6	.9668
7	.6093	2&3&4&7&8&9	.9174
8	.8686	0&1&2&3&4&5&6&7&8	.9331
9	.8211	&9	

Table 2. Trash Content Index.

Sample number	Trash index	Sample number	Trash index
an	0.868	bc	1.207
ao	1.170	bd	1.106
ap	1.001	be	1.035
aq	1.031	bf	1.159
ar	1.017	bg	1.064
as	0.988	bh	1.032
at	0.989	bi	1.098
au	1.192	bj	0.978
av	1.081	bk	0.959
aw	1.229	bl	0.972
ax	1.039	bm	0.893
ay	0.974	bn	1.198
az	1.120	bo	0.962
ba	1.281	bp	0.908
bb	0.932	bq	0.974