A HARVESTER BASED CALIBRATION SYSTEM FOR COTTON YIELD MONITORS

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Abstract

The objective of this work was to develop a system for measuring seed cotton weight on a cotton harvester to facilitate on-farm research efforts and provide information for use in semi-real-time calibration of yield monitors. The system tested in 2014 was improved from the original design developed in 2013 in regard to ease of operation and weight measurement accuracy. A simplified model was developed to measure seed cotton weight as a function of basket lift cylinder hydraulic pressure measured at a single consistent basket position. Automated basket positioning via a proportionally controlled hydraulic valve and limit switches allowed for consistent basket positioning. The resulting weight measurement accuracy observed in 2014 was RMSE of 21.8 lb and mean absolute error of 2.75% of reading or 0.44% of span.

Introduction

The objective of this work is to develop a system used onboard a cotton harvester for obtaining seed cotton weight data. This system can be used to measure seed cotton weight on a load by load basis, thereby enhancing the ability for a producer to conduct on-farm research to evaluate the yield influence of various treatments applied on a small-plot basis (e.g. variety, tillage, irrigation, chemical, etc.) Further, seed cotton weight data can be used to calibrate yield monitor systems on a semi-continuous basis as crop conditions or varieties change throughout a field. Work began in 2013 on the development of this system and continued in 2014. This report details the research conducted in 2014.

Materials and Methods

The weight measurement system tested in 2014 was modified from that tested in 2013 to improve weight measurement accuracy and simplify operation. The basic concept of relating basket lift cylinder hydraulic pressure to cotton load weight was maintained but was simplified to take weight measurements at only one predefined basket position in the dump cycle. In 2014, newly developed software was used to control the position of the basket and record data from improved data acquisition hardware and sensors. The following describes the operation and design of the system tested in 2014.

A touch screen PC mounted in the cab of a John Deere 7460 cotton stripper was used with custom written software to control the weight measurement system and record system data from custom built data acquisition (DAQ) boards implemented on the harvester chassis (figure 6) and basket (figure 7). The DAQ boards communicate with the PC via serial communication. The harvester operator initiates the PC software from inside the cab and begins configuring the system for data collection from the main screen (figure 1). The operator sets the file name, field/project name, and initial plot and load numbers by tapping the blue boxes below each label. The operator can then configure system parameters in the coefficients page by tapping the “Get Coefs” button. The coefficients page (figure 2) is used to input slope and intercept coefficients for the equations used to convert sensor voltage signals to engineering units. The operator can also adjust parameters for hydraulic pressure stability (used for error checking) and PWM valve timing and duty cycles. Once all parameters are adjusted, the user taps accept/save to exit the coefficients page and return to the main screen.

Once back on the main page (figure 1), the operator is ready to begin using the system. Just before the operator begins harvesting the first plot or area of the field from which they want to measure cotton weight, the user taps the “Mark Start” button on the main page (figure 1). The software logs the GPS location and time where the “Mark Start” button was pushed and the machine begins harvesting in the field. Once the operator finishes harvesting the basket load or plot, they push the “Mark Stop” button (figure 3) that appears after “Mark Start” is pushed. The

"Mark Stop" button push logs the ending GPS position and time of the harvested area and activates the "Next Position/Get Reading" button (figure 4). With the harvester on level ground, the operator pushes the "Next Position/Get Reading" button and initiates the basket auto-positioning cycle. The auto-positioning cycle moves the basket to a pre-determined point at which the hydraulic pressure data is collected and used to calculate the weight of cotton in the basket. A microcontroller on the chassis mounted DAQ board sends a PWM current signal to a proportional directional control hydraulic valve (figure 8) that sends pressurized fluid to the lift cylinder circuit. The microcontroller monitors the state of two limit switches (figure 9) mounted on the rear of the machine which sense the presence/position of the basket. The two switches are offset such that when switch one actuates, the microcontroller reduces the duty cycle of the PWM signal to the proportional control valve, effectively slowing the basket movement. When switch 2 actuates, the microcontroller stops the PWM signal and basket movement. When the basket stops after switch 2 actuates, the system begins reading the voltage signals from the hydraulic pressure transducer, linear transducer mounted on the rear lift cylinder (figure 10), DAQ board mounted angle transducers, and the string potentiometers mounted on the basket compactor vane hydraulic cylinders. The sensors are read for a preset period that is specified on the coefficients page. A filtering scheme is used to reduce weight error caused by hydraulic "noise" induced by stopping the basket, wind, and other sources. The filtering scheme disregards the first third of the data read from the sensors over the reading duration and calculates and records the average of the last third of the data as long as the difference in hydraulic pressure between the average of the middle third and last third of collected data is not greater than the hydraulic pressure threshold set in the coefficients page (figure 2). A reading period of 8 to 10 seconds was used in 2014 with a hydraulic stability threshold of 5 psi.

Once the sensor reading period ends, the operator has the option to repeat the reading period by selecting the radio button next to the "Repeat Reading" label (top right corner, Figure 5) or press the "Finish/Log Data" button to record the data and auto increment the load number for the next plot.

Hydraulic pressure was measured using a pressure transducer with 0 – 2500 psi pressure range from Omega Engineering (PX409-2.5KG5V-EH, error specification +/- 0.05% FS = +/- 1.25 psi) which was improved over the original 1% error transducer used in 2013. The extension length of the rear hydraulic lift cylinder was measured using a magnetostrictive linear position sensor from MTS sensors (MHC1400MN10E3V11, error specification +/- 0.04% FS = 0.56 mm, repeatability +/-0.005% FS = 0.07 mm) to evaluate the repeatability in basket stopping position using limit switch control. Over all basket loads harvested in 2014, the mean lift cylinder extension length was 160.53 mm (6.32 in) with standard deviation of 0.898 mm (0.035 in). Angle transducers were mounted on the DAQ boards on the chassis and basket to evaluate the ability to use a low cost accelerometer based inclinometer in controlling basket position. The data recorded from the angle transducers was quite noisy and was deemed of no use at this time – more work will investigate their potential further. String potentiometers were attached to the basket compactor vane hydraulic cylinders to gauge vane position in the basket. Over the season, it was determined that the vanes should be positioned fully to the left side of the basket to produce the most accurate weight measurements. It is anticipated that several of the sensors used in the development of this system will not be needed on the final system design (e.g. linear position transducer and string potentiometers).

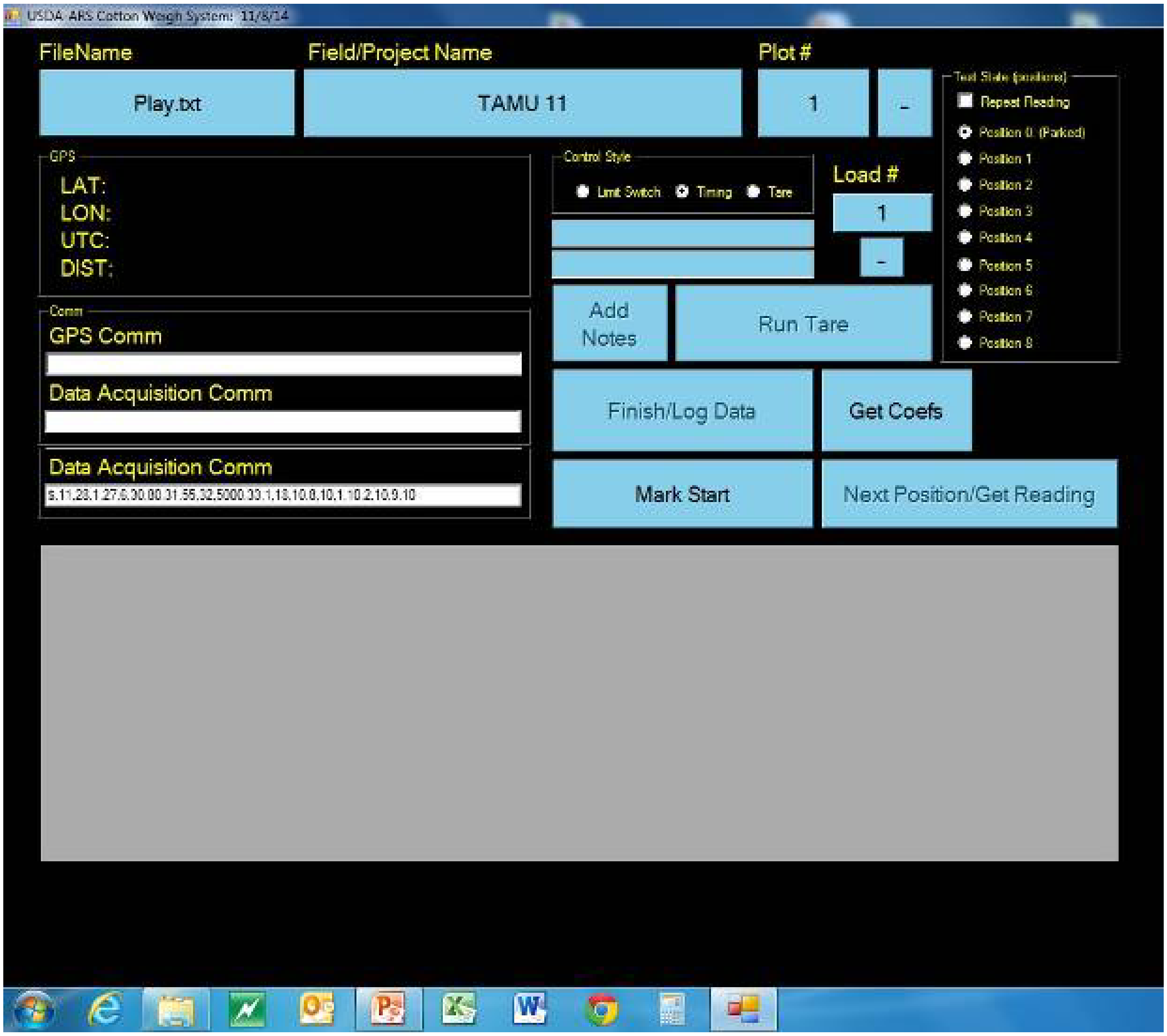

Figure 1. Software main screen displayed after the software is initiated and the file name field/project name, and plot/load number are specified.

Figure 2. Coefficients page used to configure engineering unit conversion equations for the angle transducers, lift cylinder extension length transducer, hydraulic pressure transducer, as well as hydraulic stability parameters for error checking, and PWM valve timing and duty cycle inputs.

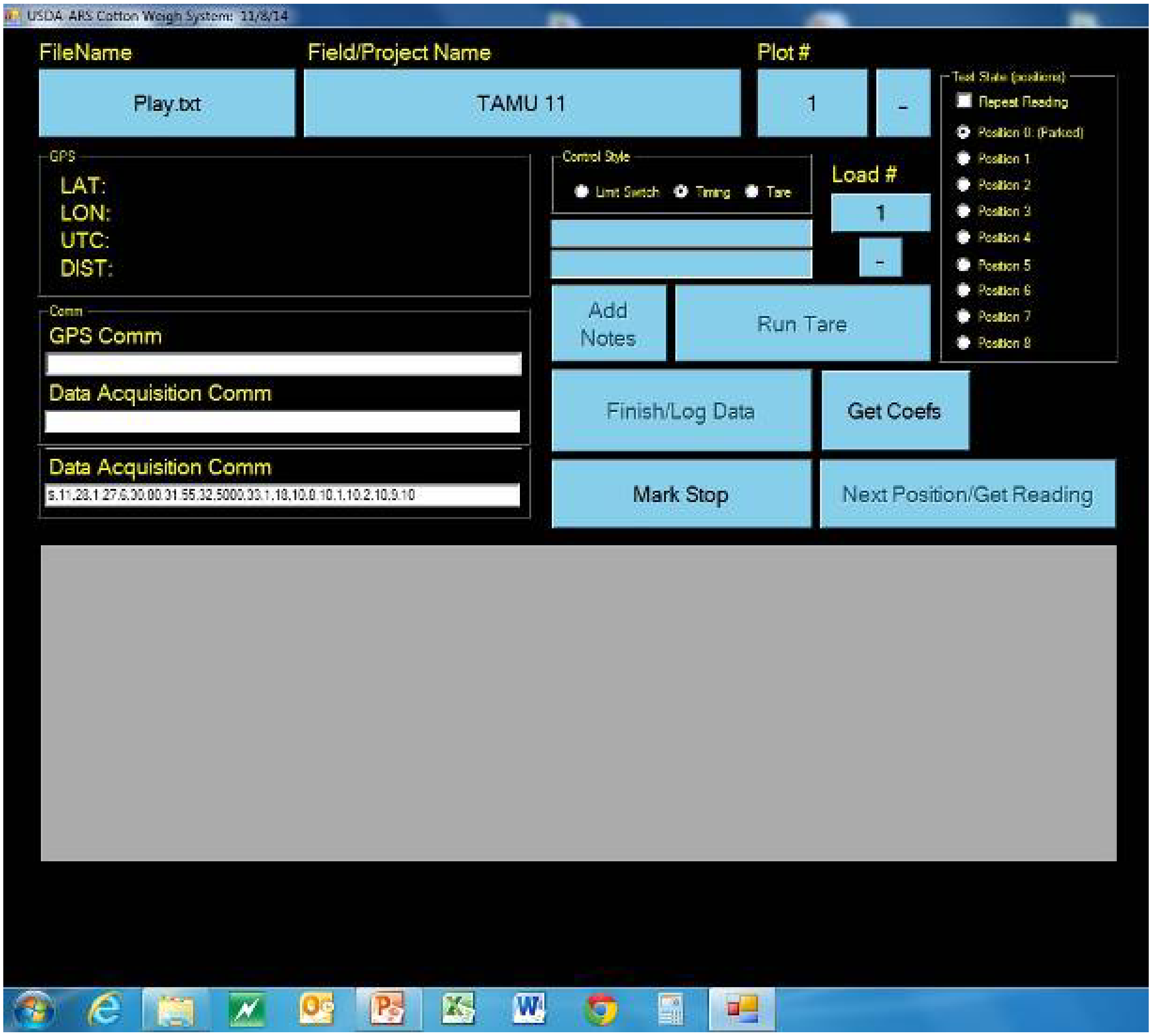

Figure 3. Main screen displaying “Mark Stop” after the “Mark Start” button is pressed.

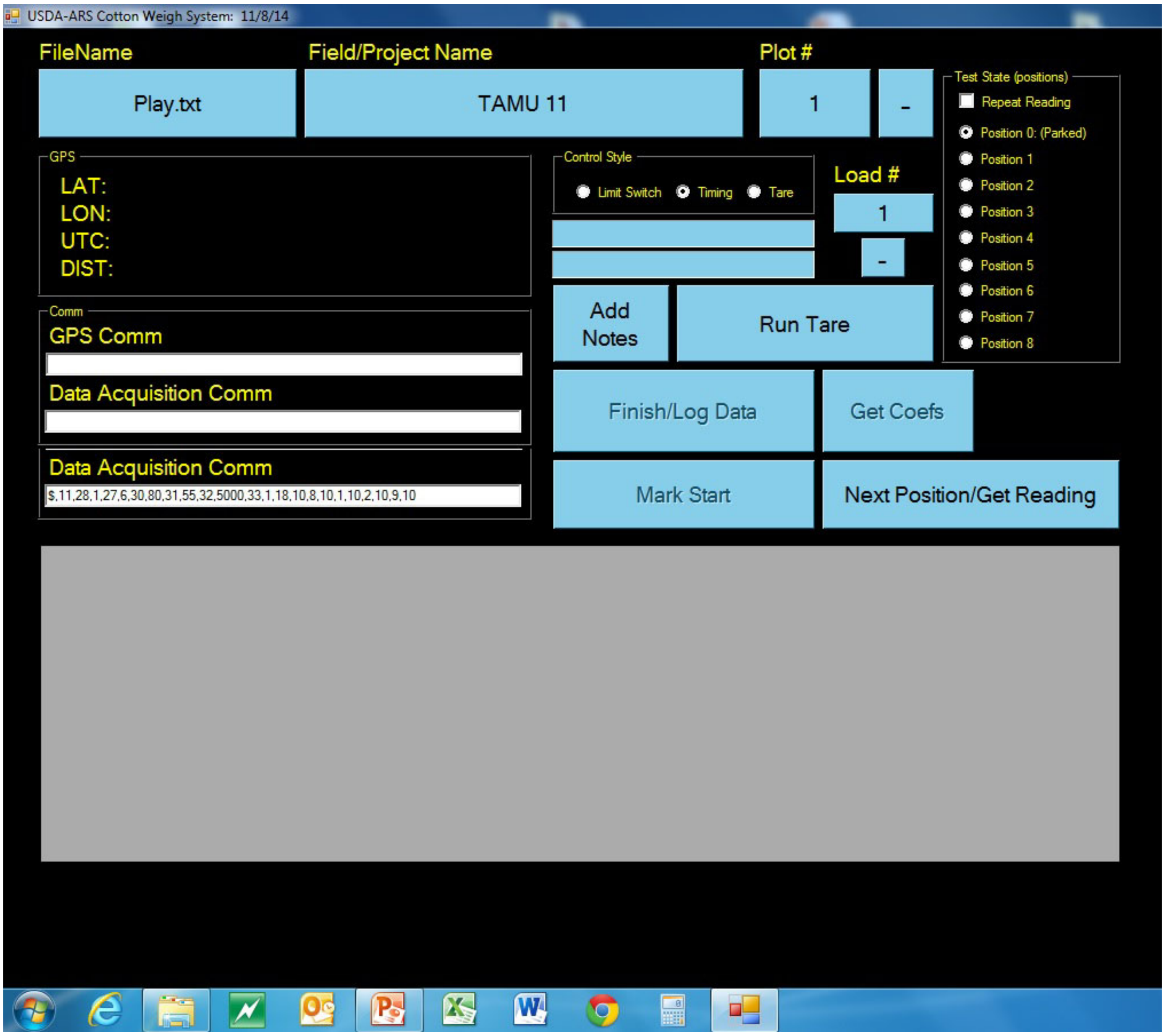

Figure 4. Main screen with "Next Position/Get Reading" button active. With this screen, the system is ready to automatically position the basket and collect weight data.

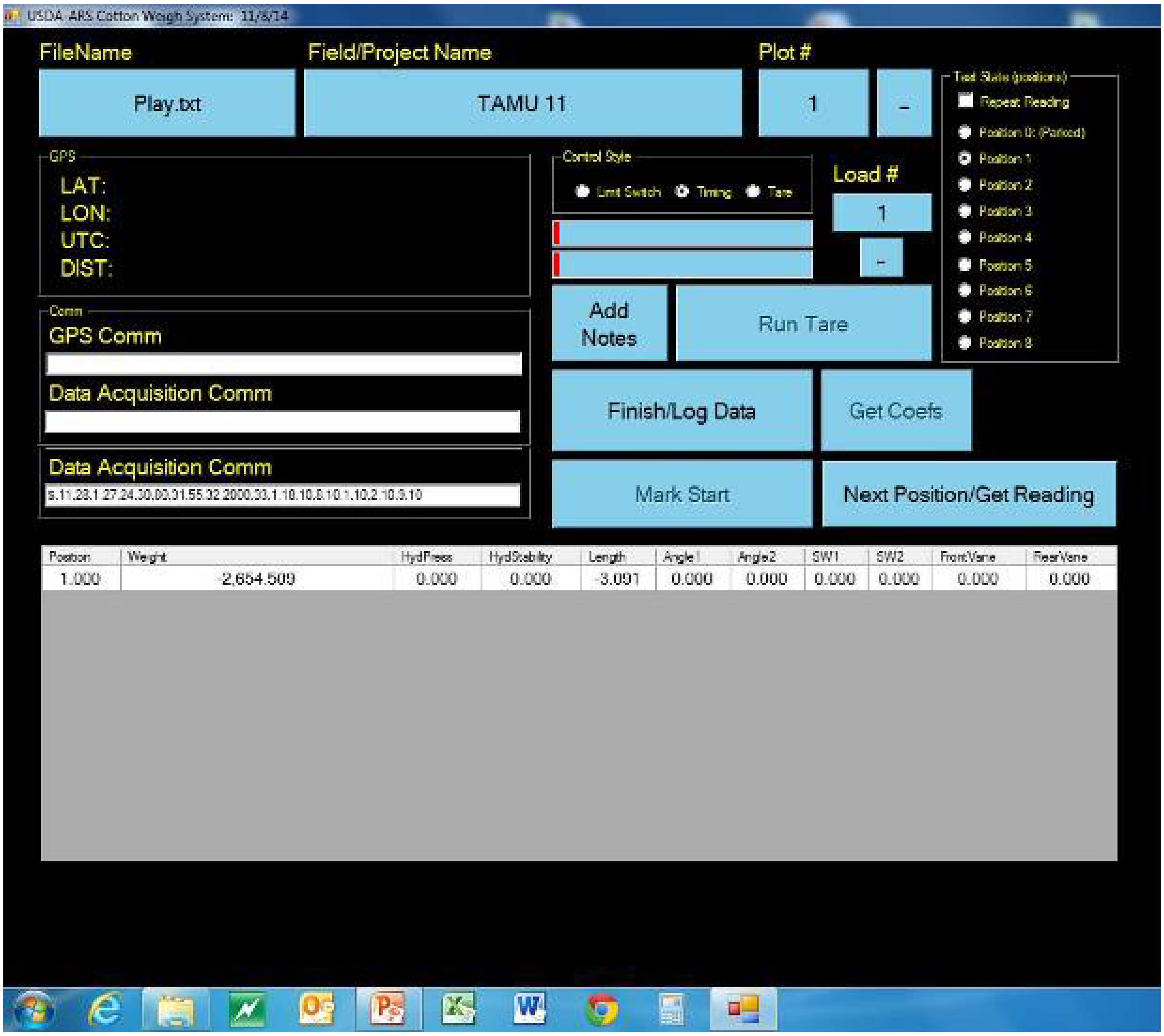

Figure 5. Main screen after data collection period displaying basket weight and sensor readings.

Figure 6. Chassis mounted DAQ board.

Figure 7. Basket mounted DAQ board.

Figure 8. Hydraulic PWM valve (top) used to raise the basket and pressure transducer (bottom) used to measure lift cylinder circuit hydraulic pressure.

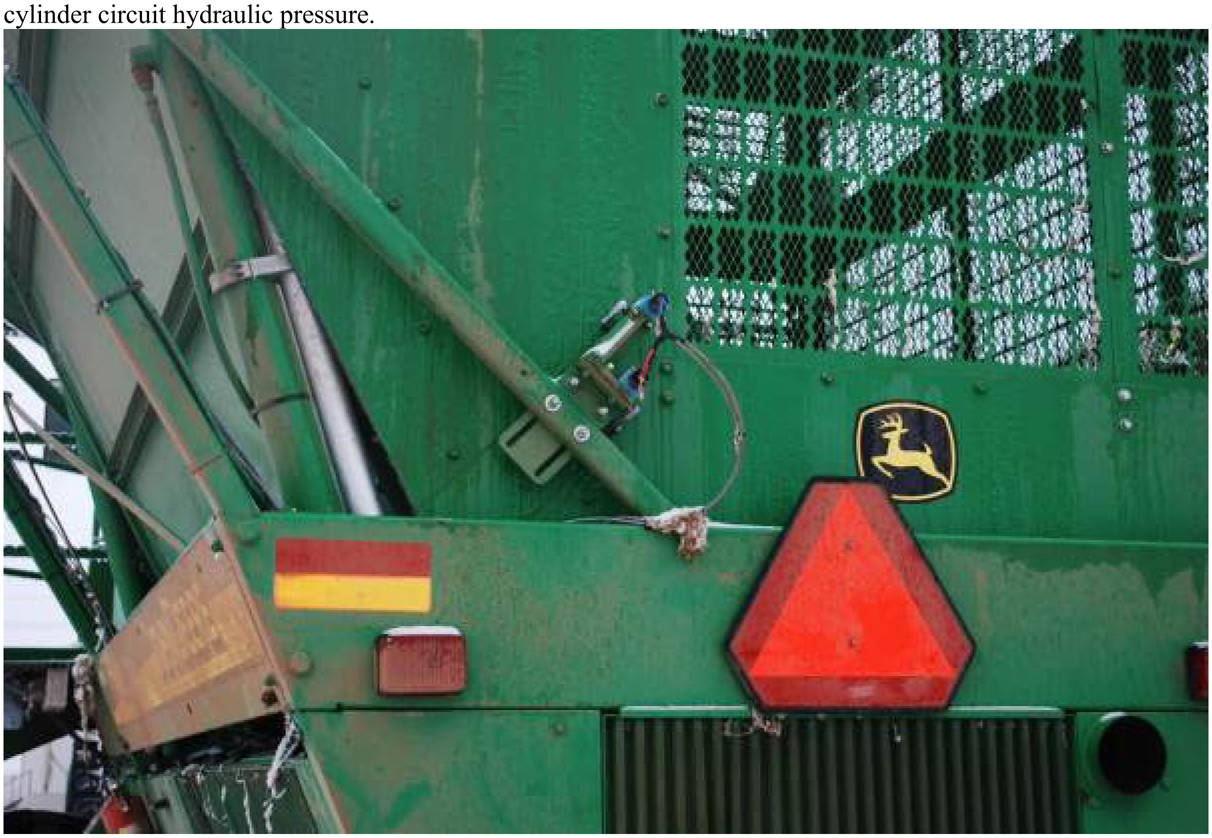

Figure 9. Limit switches mounted at the rear of the basket used to slow and stop the movement of the basket.

Figure 10. Image of the linear position transducer follower assembly housing mounted to the rear basket lift cylinder.

Calculating Seed Cotton Load Weight

Work in 2013 indicated that lift cylinder pressure is linearly related to the weight of the cotton in the basket (measured by the reference scale) when pressure readings are taken with the basket located in a single consistent location. Thus, limit switches were implemented to stop the basket at a pre-defined location in 2014. Approximately 165 basket loads were harvested with the JD 7460 stripper and used to develop the weight model shown in figure 11. Reference weight for each load harvested was measured using a custom made seed cotton scale/sampling trailer which utilizes a load cell system with +/- 0.25% error specification. Calibration of the reference scale system was checked using certified test weights several times throughout the season.

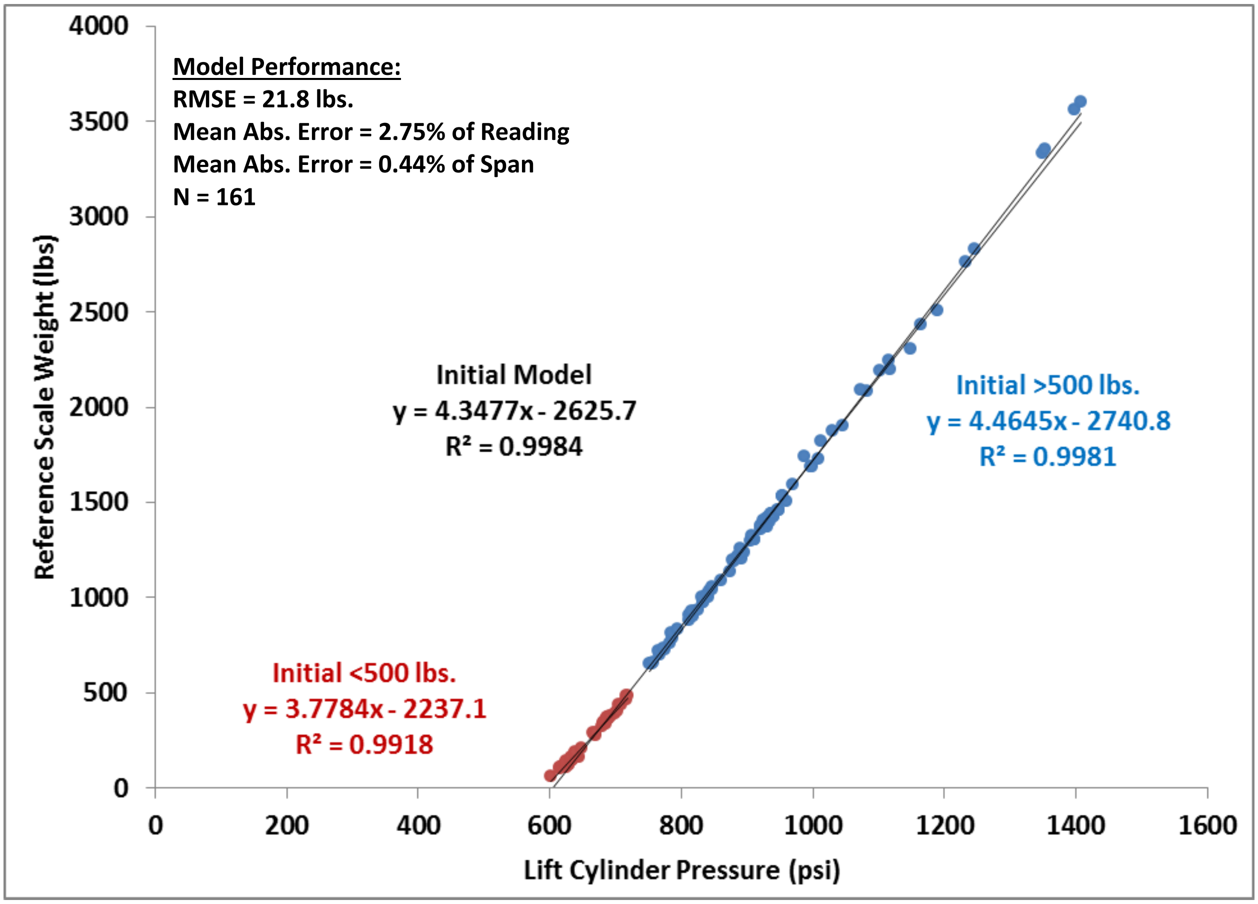

Figure 11. Two part model relating cotton load weight as a function of lift cylinder hydraulic pressure.

As noted from the work conducted in 2013, slight variations in the relationship between lift cylinder pressure and cotton weight are introduced with basket loads of different weight. This is due to the changing moment arm length to the cotton center of gravity as the geometry of the cotton in the basket changes with weight. Thus, the model developed in 2014 is a two part model that uses different relationships for basket weights above and below 500 lbs. Two steps are required to measure final cotton weight once the lift cylinder pressure is determined. First, the system calculates the initial weight using the "initial model" shown in figure 11 (initial weight = 4.33477*(PSI) – 2625.7) and then calculates the final weight using the relationships for initial weight less than 500 lbs (Final Weight < 500 lb = 3.7784*(PSI) - 2237.1) or greater than 500 lb (Final Weight > 500 lb = 4.4645*(PSI) - 2740.8). The RMSE of the two part model is 21.8 lb with mean absolute error of 2.75% of reading or 0.44% of span (span = 3600 lbs).

The impact of the weight measurement system is demonstrated in the results of the cultivar test illustrated in figure 12. The cultivar test was conducted on a cooperating producer's sub-surface drip irrigated field near Acuff, TX. Eleven cultivars were planted in a randomized complete block design and harvested with the JD 7460 cotton stripper equipped with a microwave sensor based yield monitor and the weight measurement system. Only ten of the cultivars tested are displayed in figure 12 due to reference scale issues with two loads of Stoneville 4946 GLB2. The seed cotton yields calculated from the weights from the stripper based weight measurement system closely match those calculated from the reference scale weights. Considerable variation in the yield monitor yields is present (relative to the reference scale). Tukey's HSD test was used to separate the cultivar means into statistically similar groups and the results are presented in table 1. Similar statistical grouping of the means was observed between the yields calculated from the reference scale weights and the stripper based weight measurement system. The mean yield groups from the yield monitor data were not similar to the reference scale or weight measurement system and would lead a producer to draw erroneous conclusions from this on-farm test concerning cultivar performance.

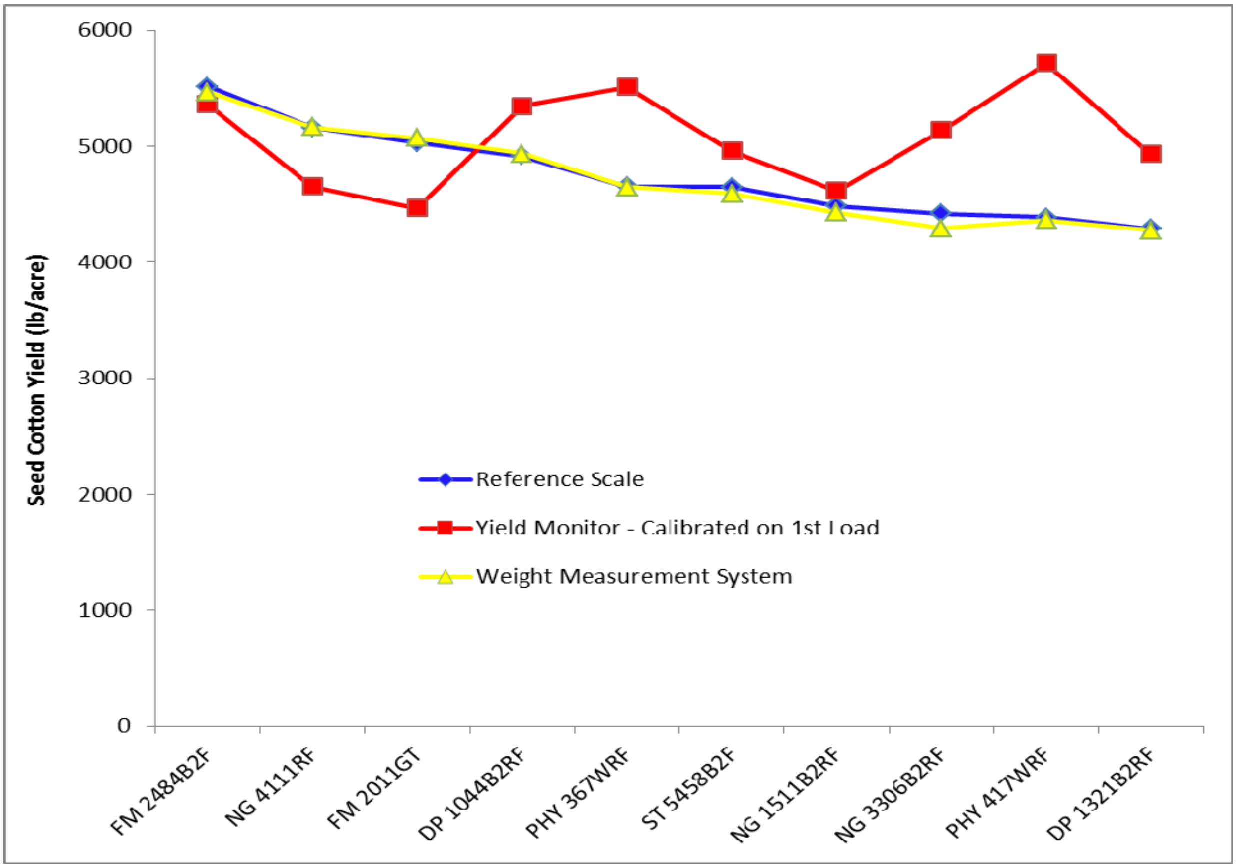

Figure 12. Seed cotton yield for 10 cultivars averaged over three replications based on weight data collected from the reference scale, stripper based weight measurement system, and microwave sensor based yield monitor.

Table 1. Results of Tukey's HSD means separation test (α = 0.05) on cultivar mean seed cotton yields as measured by the reference scale, stripper based weight measurement system, and microwave sensor based yield monitor.

Weight System Yield (MSD = 628.7 lb/acre)			Reference Scale Yield (MSD = 538.3 lb/acre)			Yield Monitor Yield (MSD = 505.9 lb/acre)		
FM 2484B2F	5466	a	FM 2484B2F	5516	a	PHY 417WRF	5713	a
NG 4111RF	5163	ab	NG 4111RF	5163	ab	PHY 367WRF	5512	ab
FM 2011GT	5072	ab	FM 2011GT	5032	ab	FM 2484B2F	5360	abc
DP 1044B2RF	4938	abc	DP 1044B2RF	4914	bc	DP 1044B2RF	5345	abc
PHY 367WRF	4646	bcd	PHY 367WRF	4653	bcd	NG 3306B2RF	5139	bcd
ST 5458B2F	4590	bcd	ST 5458B2F	4648	bcd	ST 5458B2F	4958	cde
NG 1511B2RF	4430	cd	NG 1511B2RF	4483	cd	DP 1321B2RF	4933	cde
PHY 417WRF	4362	cd	NG 3306B2RF	4418	cd	NG 4111RF	4654	de
NG 3306B2RF	4292	d	PHY 417WRF	4386	cd	NG 1511B2RF	4617	e
DP 1321B2RF	4273	d	DP 1321B2RF	4289	d	FM 2011GT	4468	e

Summary

The weight measurement system design was improved in 2014 to provide higher weight measurement accuracy and ease of operation. Improved data acquisition system design and new sensors with improved accuracy specifications were implemented. A simplified model was developed to measure seed cotton weight as a function of basket lift cylinder hydraulic pressure measured at a single consistent basket position. Automated basket positioning via a PWM hydraulic valve and limit switches allowed for consistent basket positioning. The resulting weight measurement accuracy specifications are RMSE = 21.8 lb and mean absolute error = 2.75% of reading and 0.44% of span.

Future plans include reliability testing of the weight measurement system installed on several producer owned and operated cotton strippers. Considerable interest in this system has been expressed by producers in the Southern High Plains region as well as state extension agents in Texas and Oklahoma. Plans to work with these interested individuals are being developed for the 2015 cotton harvest season.

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