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MEASUREMENT OF BALE MOISTURE CONTENT BASED ON BALE COMPRESSION PRESSURE

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Abstract

Proper control of the moisture content (mc) of ginned lint in commercial gins requires accurate moisture sensors. A microprocessor-based system that predicted the mc of lint in the bale based on the bale press geometry and the hydraulic pressure required to form the bale was installed in a new gin in Kansas. Predicted bale moisture values were compared to oven-based moisture values and the uncorrected standard error of the estimate was 0.40. The hydraulic pressure-press geometry method predicted lint moisture content sufficiently accurately for moisture control.

Introduction

The moisture content (mc) of cotton fiber has been manipulated by gins with both drying and moisture restoration employed at many gins (Hughes et al., 1994). Moisture has been intentionally added to lint after ginning for at least 50 years (Griffin and Harrell, 1957). Griffin and Harrell achieved different levels of moisture restoration, but measured the moisture content (mc) by the oven method and thus could not control it while ginning. More recently Anthony and Byler (1997) documented the use of a microwave-based instrument to measure the mc in cotton bales. Anthony and McCaskill (1973 and 1976) examined the relationship between the geometry of the bale press, the amount of fiber in the bale, the pressure required to form the bale and the fiber moisture content. Later, Anthony (1998) described a method to use the bale geometry and force required to form the bale in the press to estimate the fiber mc using either an equation or a special pressure gauge face incorporating the equation.

Interest in restoring moisture to lint after it is ginned has grown over the past few years. Improved humidification equipment capable of adding more moisture coupled with the desire to achieve higher mc levels in the bale have created a situation where moisture control is critical. To accurately control fiber mc a system to quickly and accurately measure the mc of lint in the bale is needed. In current systems the moisture is added either before it reaches the lint slide or on the lint slide, so the mc could possibly be measured as the bale is being formed or soon after it is formed. A reliable and accurate bale mc sensor could be used for feedback to automatically change the control settings of the device that provides the moisture or could be used as an indicator that the ginner would use to optimize the settings.

A resistance-based lint mc sensor developed by the Agricultural Research Service (Byler and Anthony, 1995 and 1996) has been used for several years with the "Intelligin" gin control system marketed by Zellweger Uster, Inc. This sensor has been used successfully to control the drying performed in gins (Byler and Anthony, 1997). One of these sensors was installed in the bale press tramper and was used with an additional sensor in the lint flue to estimate the mc of the lint as the bale was being formed (Byler et al. 2002). Microwave and radio frequency based methods are also used to estimate the mc of cotton bales however; an inexpensive, reliable, and accurate system to estimate bale mc is needed.

Materials and Methods

The equation developed by Anthony (1998) was incorporated with additional software into an independent microprocessor system to estimate the mc of the bale. This equipment was installed in a gin near Moscow KS in November 2002. The readings from the system were compared to the mc of samples taken from the bale and analyzed by the oven method (Shepherd, 1972). All moisture contents were calculated on a wet basis in this study.

Equipment Description

The software was executed by a ADAM-4500 Data Acquisition Module produced by Advantech Co. Ltd. which was designed for industrial automation and control. This module contained an 80188 CPU with 256 KB SRAM and 256 KB Flash ROM. It included ROM-DOS operating system and emulates a standard PC in many ways. Software was written in Borland C and compiled into a DOS executable file. The module included two serial communication ports which could be selected to use either RS-232 or RS-485 standards at up to 115.2 Kbps. A third serial port was used strictly for communication at 57.6 Kbps, with a PC which was used for programming the module and as a terminal device during code development. The controller was contained in a package 2 ¾ inch. wide by 5 in. long and was about 1 in. thick. Advantech Co. Ltd., as well as several other manufacturers, offered a line of communication and I/O modules compatible with this controller for industrial data collection and control. These modules all communicated over a single two wire multi-drop network.

The measurements were based on three inputs; bale weight, bale volume, and measured pressure. First, a switch closed as the bale press ram neared maximum compression. The width and length of the bale press box were known and the depth of the bale at the moment the switch was contacted was known so the volume of the bale was known. Immediately after the switch closure was sensed the pressure was measured with a PX615-5KGI pressure transducer available from Omega Engineering, Inc. This transducer used two wires and was powered by 24 VDC. The output from the transducer was 4-20 mA for the pressure range 0-5000 psig. The switch position and the analog pressure signal were sensed by an ADAM 4012 module. The module had 16-bit A/D resolution plus 2 digital input lines and one digital output line. One of the digital input lines was connected to the signal from the micro switch. The pressure reading was stored until the weight was received from the bale scale through an RS-232 connection. A model RD-4 four digit remote display obtained from Omega Engineering, Inc. was located at the ginners control panel. It received communication on the same RS-485 wire pair as the other equipment. The whole system was powered with a single 24 VDC power supply.

Test Design and Sampling

Samples were taken on Nov. 11, Dec. 4, and Dec. 11-12, 2002. This gin had hoppers above the gin stand for moisture restoration as well as the Lummus moisture restoration system at the battery condenser. These two systems used air from two Samuel Jackson Humidair units as a source of moisture. The controls for the moisture restoration equipment in the gin were set at different levels to produce a range of bale mc. Lint samples were taken from the lint flue and placed in metal cans for the bales included in the test. A sample was taken from each side of the bale and combined in one metal can for each bale. The indicated mc was recorded for each of the test bales. The samples were returned to the U.S. Cotton Ginning Lab. in Stoneville, MS for analysis for mc by the oven method.

Results

The data were examined for outliers and four points were removed resulting in 140 bales with mc determined by the oven method and the mc indicated by the experimental instrument. Two were removed because the mc was too low to predict based on the model development, this occurred when no moisture restoration was being used by the gin. Two more were removed because the mc was considered to be changing too quickly when the bale was being formed to get an accurate measurement. The bale mc ranged from 3.3 to 7.9 percent, wet basis. The mean bale mc was 4.8 with a standard deviation of 1.0. The mc of the samples taken from the lint flue ranged from 3.1 to 6.1 percent with a mean of 4.3 percent. The indicated bale mc ranged from 3.8 to 7.7 percent with a standard deviation of 0.9 percent.

Several models were analyzed with the SAS procedure GLM. The indicated mc as well as the square of the indicated mc, the logarithm of the indicated mc, the lint flue mc, and the sampling set were included in the modeling. The knowledge of the sampling set did not contribute to a better mc prediction. The other factors contributed slightly, but when the root mean square difference between the predicted mc and the measured mc values were examined, Table 1, the additional factors were deemed to not contribute substantially to the prediction. Figure 1 shows the relationship between the predicted and observed mc observed during the test. Based on experience with measuring mc under commercial ginning conditions, the root residual mean square, also called the standard error, of the uncorrected mc predictions of 0.40 was deemed to be good. Factors which contribute to this difference are the basic variation in cotton mc which occurs in all samples, the variation in mc determination by the oven method of at least 0.25 for samples such as these, and the variation in lint mc between the sample and the "true mc" due to the bale lint sampling technique. The conclusion, based on these data, was that the original equation entered into the software was as good at predicting the bale mc as any corrected value based on the models used.

Conclusion

A microprocessor-based system was installed in a commercial gin to predict the mc of lint in the bale. The predicted mc based on the geometry of the bale press and the pressure required to form the bale agreed with the mc determined by the oven method with a root mean square difference of 0.40. Several models were examined to determine if the original equation could be improved but the data did not support any changes. Thus, the hydraulic pressure-bale geometry approach can be used to predict bale mc.

Disclaimer

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

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Table 1. Statistics comparing some different models included in the bale mc prediction.

Model	Mean predicted mc	Root mean square difference
No correction	4.9	0.40
Offset only	4.8	0.37
Slope of indicated mc only	4.8	0.37
Slope of indicated mc plus offset	4.8	0.37
Linear for indicated mc plus lint flue mc	4.8	0.31

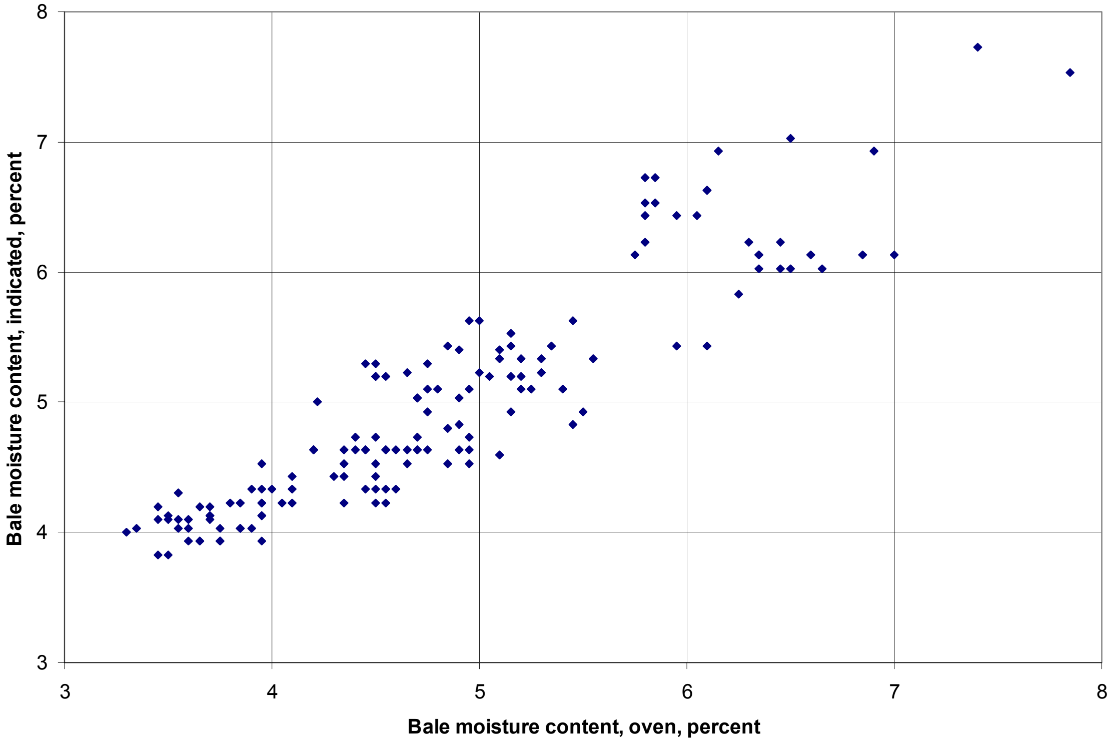

Figure 1. Moisture content predicted by the experimental system compared to the sample moisture content determined by the oven method.