ESTIMATION OF BALE MOISTURE CONTENT WITH A MALCAM MMC-4000

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Abstract

A model MMC-4000, microwave-based technology, bale moisture sensor, manufactured by MALCAM Limited of Tel-Aviv, Israel, was evaluated in two gins in the South in 1996. The MMC-4000 responded directly to differences in moisture content in bales of cotton. At one gin most differences occurred between ±0.4%; at the other gin, the MMC-4000 indicated moisture levels at about 0.5% higher than oven moistures. In addition to moisture, the instrument responded strongly to temperature of the cotton as measured immediately before the tramper and to bale weight. Future research should address the impact of temperature and bale weight on moisture readings by the MMC-4000.

Introduction

Measurement of cotton moisture content probably receives more discussion than any other single topic related to cotton. Moisture is critical at harvesting, storing, ginning, grading, and mill processing. If cotton is harvested at moisture contents above 12% and stored in modules or trailers for extended periods of time, it will deteriorate and become unusable. If cotton is processed at high moisture levels during ginning, cleaning efficiency will be greatly reduced and chokeages primarily at the gin stand, will occur and thus greatly reduce the ginning rate. If moisture content is too low, excessive fiber damage will occur during the lint-seed separation process and subsequent lint cleaning, and mill processability will be reduced. In addition, valuable weight will be lost because cotton will be forced to well below its equilibrium moisture content with the environment. Processing at the textile mill will also be adversely affected if the moisture is too high or too low. What then is too high or too low? There is no concrete answer for too high or too low because it depends upon a compromise in terms of weight loss, fiber degradation, etc. In general, cotton should never be processed below 5% fiber moisture content nor above 9% fiber moisture content. However, the difference between processing cotton at 5% moisture content and 9% moisture content is similar to the difference between daylight and dark. In fact, those moisture levels represent a very wide range of degradation that might occur to the fiber. If fiber length is of utmost importance then moisture content should be in the 7% to 8.5% range. If fiber cleaning is important, moisture content should be in the 5% range. Current market requirements for leaf grade, color grade, and fiber length dictate that cotton should be processed between 5% and 6% moisture content.

Discussion

Numerous methods exist to measure the moisture content of cotton ranging from an old technology using the resistance technique or newer technologies using infrared or microwave technology. In all cases, two aspects of measuring moisture content are critical: 1) cotton fiber must be uniformly compressed to a standard density, and 2) fibers must be free of excess surface moisture. Resistance/capacitance techniques are also sensitive to salts and other chemicals that might be associated with the moisture that is in the fiber. Infrared moisture content is affected by contaminants such as entomological sugars and physiological sugars. Thus, the moisture content of cotton could more accurately be measured after seed cotton cleaning, drying, ginning, and lint cleaning since the influence of some of the contaminants would have been mitigated.

Anthony et al. (1995) successfully measured the moisture content immediately before the battery condenser in several gin installations using resistance technology. MALCAM Limited of Tel-Aviv, Israel, has developed technology to measure the moisture content inside a cotton bale after packaging. A problem with measuring moisture in the bale obviously is that the bale has already been ginned before the moisture content is known. However, gaining useful information from knowledge of the moisture content of the bale is possible. For example, in processing uniform modules of cotton, dryer control can be based on feedback rather than feed-forward systems as it is traditionally done. However, if modules or trailers that are not in equilibrium are used, this method does not work well. Knowledge of the moisture content of the baled cotton can very easily be used to adjust the amount of moisture returned to the bale at the battery condenser and lint slide area immediately before packaging. Moisture return at that stage of the gin process helps bring the bale to the moisture content that it will achieve within a few weeks after bale packaging. It also dramatically reduces the amount of force required to compress a bale of cotton and reduces the resilient forces on the bale ties.

According to company spokesmen, the microwave-based MALCAM technology is not sensitive to chemicals inside the water and the moisture content is measured across the entire depth of the bale rather than on the surface (Greenwald, 1996). The system scans the bale and measures the moisture of more than 1,200 slices of the bale and calculates the moisture inside the bale by a signal

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:1574-1576 (1997)
National Cotton Council, Memphis TN

processing algorithm. However, the temperature of the bale affects the moisture of the bale by 0.08% ± 0.02% per degree Celsius. Since the moisture content is measured after the bale is packaged, steel strapping or steel wire also interferes with the moisture measurement by the microwave method. The MALCAM system provides a method to offset the influence of strapping or wires. Another consideration is that all bales are not the same weight, thus, the density of a bale impacts the moisture estimated by the microwave method in a predictable manner. For bales that typically lie within the 480-520 pound range, the moisture reading will be impacted by about ± 4% of the moisture. In other words, a 500-pound bale at 6% moisture could actually read 5.76 at 480 pounds or 6.24 at 520 pounds. Bale density also differs internally within the bale due to the way the cotton is placed into the battery condenser, however, the MALCAM MMC-4000 averages the internal density within the bale and compensates for changes in internal density.

MALCAM MMC-4000 bale moisture measuring systems were installed at Burdette Gin near Leland, MS, prior to the 1996 ginning season and at Servico Gin near Courtland, AL, during the 1995 ginning season. The MMC-4000 is a microwave based, moisture measuring device for cotton fiber bales that consists of a transmitter, receiver, and a controller with a digital screen.

Burdette

After installation of the MMC-4000 by Mr. Danny Moshe and Dr. Alexander Greenwald of MALCAM Limited in September of 1996 as shown in Figure 1, 10 bales of cotton were ginned at the U.S. Cotton Ginning Laboratory, Stoneville, MS, at moisture levels of 3% to 6% and evaluated by the MMC-4000 at Burdette. Initial analyses indicated that the MMC-4000 was right on target at moisture contents of 4 to 5% but tended to be off about 0.6 percentage points at moistures below 4.0 and above 5.5. Since this variation appeared to be acceptable for the anticipated moistures, no change was made in the calibration of the MMC-4000 as initially established by representatives of MALCAM Limited. Periodically throughout the season, five samples of lint moisture per bale were taken on five bales immediately before the tramper at the end of the lint slide and analyzed with the oven method. Temperature measurements were also made on some moisture samples. The MMC-4000 moisture estimate was also recorded for the bales. Moisture readings were taken on about 200 bales during the ginning season. In the latter part of the season, the bale ties failed on one of the cotton bales and damaged the MALCAM system and further readings were not taken.

Since temperature was known to substantially affect the moisture readings for the MMC-4000, the change in temperature due to bale compression was measured on three bales of cotton and found to be about 6 °F (Thomson, 1996). Change in temperature as a result of compression is important because temperature is difficult to measure across the depth of a bale of cotton. However, it is possible to measure the temperature of the cotton at each tramper stroke using conventional methods. The rise in temperature as a result of compression can then be estimated. The correction factor can then be determined to adjust the moisture reading of the MMC-4000 system.

Data obtained from Burdette Gin is plotted in Figure 2 and covers the range from about 3.0 to 6.0% fiber moisture. The data was analyzed with
regression analyses with MMC-4000 reading as a function of oven moisture as shown in equation 1:

$$\text{MM4-4000 moisture} = 0.044 + 1.005 * \text{oven moisture} \quad (1)$$

Where:

F = 116.4
Probability of greater F = 0.0001
Intercept significance = 0.9244
Slope significance = 0.0001
R-square = 0.68
Root mean square error = 0.46
Coefficient of variability = 9.2%
MM4-4000 mean = 5.0%

This finding supports our initial conclusion that we should not change the offset of the calibration for the MMC-4000. Differences between the oven method and the MMC-4000 readings ranged from -1.28 to +0.78 although the vast majority of the readings were within ± 0.4%. When the limited temperature data was included as an independent variable, the following equation was produced:

$$\text{MM4-4000 moisture} = -16.725 + 1.096 * \text{oven moisture} + 0.192 * \text{temperature} \quad (2)$$

Where:

F = 17.18
Probability greater F = 0.002
Root mean square error = 0.27
Coefficient of variability = 7.4%
R-square = 0.78
Intercept significance = 0.0026
Oven moisture coefficient significance = 0.0089
Temperature coefficient significance = 0.006

Insufficient data was available to properly evaluate the impact of temperatures but the fact that temperature must be considered was substantiated.

Servico

The microwave bale moisture measurement system was installed during the 1995 ginning season and appeared to operate properly. The output from the moisture system was connected to the computer in the gin which recorded the moisture reading for every bale along with much other data such as the moisture content of the cotton at several places in the gin, the color and trash content of the cotton as it moved through the gin, and the drying air temperatures.

At the beginning of the 1996 season the instrument was reinstalled in the gin but did not appear to be operating correctly. It was returned to Israel for repair and reinstalled on November 1. After that date it measured the moisture content of about 14,000 bales.

Only a few samples were taken to check the accuracy of the meter. On November 8, three samples were taken from three different bales, placed in metal cans, sealed, and returned to the U. S. Cotton Ginning Laboratory for moisture analysis by the oven test. Four samples were taken on November 15 from four different bales and treated the same way. Analysis of the data showed that the minimum, maximum and mean of the seven readings was 6.9, 7.8 and 7.2 for the MALCAM instrument and 6.1, 7.1 and 6.7 for the oven test. Regression analysis showed that there was no difference in the slope between the measurements, although the observed range of moisture values was small, a slope difference would be difficult to detect with so few measurements. However, there was a difference in the readings when the measurements were analyzed with a paired t-test, the MALCAM meter reading was 0.5 percent higher than the oven reading. There was less than a 1% chance of obtaining data as different as these two sets of data by chance if they were not actually different. It is not unusual to observe differences of this kind between two measurements of the same thing, and the difference of 0.5 percent is not a serious problem. Perhaps this difference was due to temperature differences as discussed previously.

Data collected between the dates of November 1 and November 15 were examined for a relationship between the moisture content at the lint flue and the bale moisture content. In this gin, moisture restoration equipment was installed at the battery condenser and was in operation most, but not all of the time. Resistance-based moisture data was collected before the battery condenser and thus did not directly include information about the bale moisture. It was theorized that despite the fact that there was no record of the amount of moisture added by the moisture restoration equipment, that there would be a correlation between the moisture measured in the bale and the moisture measured in the lint flue if both instruments were working correctly.

This data set had 8,090 bales (observations) in it. There was a statistically significant positive correlation between the moisture readings at the two locations. This meant that when the moisture content in the lint flue was higher there was a high probability that the moisture content measured in the bale was higher also.

The lower limit which could be measured in the lint flue was 4.8%, wet basis. To reduce the affect of measurements near the lower limit, which may skew the results, all data with moisture contents at the lint flue of below 5.0% were removed which left 1,319 bales. This data had an even higher positive correlation between the bale moisture content and the moisture content measured at the lint flue.

As explained previously, bale weight affects the measured moisture content when using the microwave moisture meter. When the bale weight was used in the analysis, the correlation was improved further with a clearly significant positive coefficient for the bale weight as well as for the moisture content in the lint flue. In this data, the measured moisture content changed 0.019% per pound of change of bale weight. For the 480 to 520 pound bale weight range mentioned earlier, the affect would be plus or minus 0.38 percentage points which is greater than the estimated 0.24% described previously.

Summary

A model MMC-4000, microwave-based technology, bale moisture sensor, manufactured by MALCAM Limited of Tel-Aviv, Israel, was evaluated in two gins in the South in 1996. The evaluations were cursory in nature and sufficient data was not obtained to make concrete conclusions. However, the MMC-4000 appeared to respond directly to differences in moisture content in the bales of cotton. At one gin most differences occurred between ± 0.4%; at the other gin, the MMC-4000 indicated moisture levels at about 0.5% above the oven moistures. The instrument responded strongly to temperature as measured immediately before the tramper and the R-square increased from 0.68 to 0.78 over the limited temperature range of the data. The MMC-4000 also responded directly to bale weight. Future research should include automated measurement of and compensation for the influence of temperature and bale weight.

Disclaimer

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

References

Anthony, W.S., R.K. Byler, L. Deavenport, and D. Scamardo. 1995. Experiences with gin process control in the Midsouth and West. Applied Engineering in Agriculture. 11(3):409-414. American Society of Agricultural Engineers.

Anthony, W. S. 1986. Measurement of cotton moisture with infrared sensors. Trans. of the American Society of Agricultural Engineers. 2(1):25-29.

Byler, R.K., and W.S. Anthony. 1995. Development of a moisture sensor for gin use. Proc. Beltwide Cotton Prod. Res .Conf., pp. 692-693. National Cotton Council, Memphis, TN.

Byler, R. K., and Anthony, W. S. 1991. Initial experiences in computer control of cotton gin drying. Applied Engineering in Agriculture. 8(5):703-709. American Society of Agricultural Engineers.

Greenwald, Alexander. 1996. Personal communication.

Moshe, Danny S. 1996. Personal communication.

Thomson, Steven J. 1996. Personal communication.

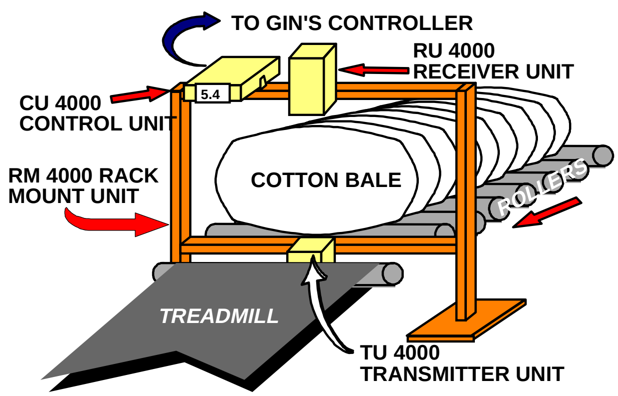

Figure 1. Schematic of a typical MMC-4000 moisture sensing unit measuring the moisture of a bale of cotton.

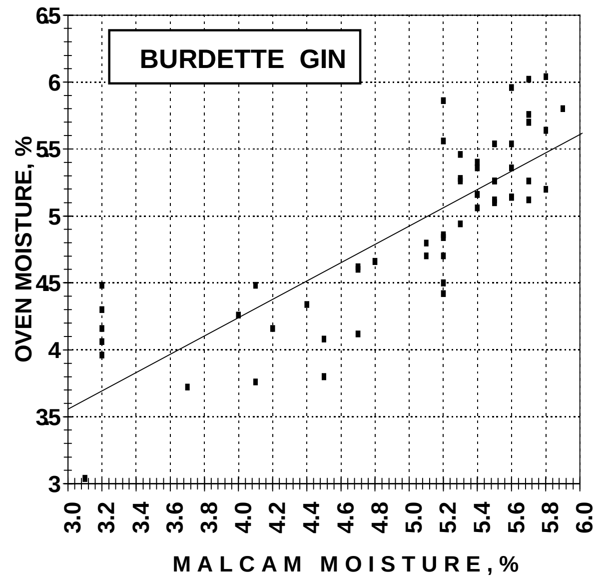

Figure 2. Graphical illustration of the relationship between oven moisture and moisture as measured by the MALCAM sensor at Burdette Gin in 1996.