MICROWAVE BALE MOISTURE SENSING: FIELD TRIAL

M G. Pelletier
Agricultural Engineer
USDA, ARS
Cotton Production and Processing Research Unit
Lubbock, TX

Abstract

A microwave moisture measurement technique was developed for moisture sensing of cotton bales after the bale press. The technique measures the propagation delay of a microwave signal that is transmitted through the cotton bale. This research conducted a field trial to test the sensor in a commercial cotton gin that is utilizing moisture restoration systems. The field-trial test's cross-validation accuracy was found to be 0.25% with a repeatability of 0.15% moisture content. These results indicate the sensor has the potential to provide a low cost reliable non-contact measurement of the moisture content of cotton bales.

Introduction

The final stage in the cotton processing stream is the cotton bale packaging system. Recent innovations have shown that the use of cotton moisture restoration systems both reduce stress on the pale packaging system as well as add additional weight to the bales. As cotton is sold on a wet basis there is a perceived market incentive for the utilization of these systems. As such, these systems are beginning to proliferate through the ginning industry. In utilization of these systems, it is necessary to be able to determine the moisture content of the cotton bales in order to avoid adding excess moisture which has been shown to lead to later quality degradation. Currently there are few sensors in use that can be utilized for this type of monitoring. The current industry main-stay is a hand-held resistive meter, however resistive sensors are marginally effective when utilized in these types of systems as the surface moisture these systems add to the cotton alter the calibration of these sensors in an uncontrolled manner. The only other types of sensors that can be utilized are very expensive microwave bale moisture sensors that are typically utilizing very high frequency microwave technology that is prohibitively expensive to manufacture. Given this fact there are a large number of cotton gins that are using moisture restoration systems without any type of feed back control sensor to maintain the correct moisture in the cotton bales. It is well documented that process control can improve both the economic return as well as improve quality of the final product (Anthony, 1990)(Byler and Anthony, 1995) (Byler and Anthony, 1997) and provides a sound basis for the need for a low cost accurate sensor that can provide control for these systems.

Cotton bales are provided an official grade that is based upon samples obtained immediately after the baling of the cotton. These samples are then shipped to a USDA-AMS classing office where both the color and trash content are measured, typically within one to two weeks. This grade is then used to set the value of that particular bale of cotton. Unfortunately, when moisture is added to the bale in an excessive amount, this grade has been shown to change as the moisture degrades the cotton. This has led to hundreds of bales being returned back to the gins and has caused a great deal of concern in the industry over the potential damage to the USDA-AMS classing grade. Given this situation, the development of a low cost moisture measurement system that will determine the moisture content of the cotton bales would provide the industry with a valuable tool. This low cost, accurate system could then be deployed at an affordable price to all gins that are using moisture restoration which would help to ensure and maximize the quality and value of their cotton as well as preserve and protect the reputation of US cotton and USDA-AMS cotton grades both domestically as well as abroad. This paper presents the test results of a field trial of a proto-type microwave moisture sensor in a commercial environment.

Procedure

A proto-type microwave moisture sensor that has been under development at the USDA-ARS Cotton Ginning Laboratory was deployed for a field trial in a commercial cotton gin. The gin had two moisture restoration systems setup in series that could be run independently to apply moisture to the lint at the lint slide. The first moisture restoration system was a humid-air system and the second was a spray type moisture restoration system. The test was performed in two parts; in part one, only the humid air system was utilized. The amount of water added to the bales by the humid air system was varied by adjusting the water temperature of the system. In the second test, the humid air system was set to the lowest water temperature (least amount of water) and remained fixed throughout the second test, while the spray system was adjusted to provide a wide variation in the amount of added water to the bales throughout the second test.

In this manner, cotton bales that had a wide range of moisture contents, with humid-air only as well as humid-air plus spray-on, were obtained for this study by manipulating the moisture restoration systems. The bales ranged from 7-9% percent moisture content. All bales were weighed during the test by the gins bale scales. Before the lint entered the press-box and after both moisture restoration systems, ten lint samples were obtained from each bale for moisture content determination by standard gravimetric analysis.

After the bales exited from the bale press box, the bales where conveyed between two microwave horn antennas in order to obtain a propagation delay measurement by the proto-type microwave sensor. This propagation delay value was then attached to the obtained lint samples along with the bale weight for later analysis.

Results and Summary

The results from the study indicate that the moisture restoration systems modified the bale moisture in a non-uniform manner. The in-bale moisture variation of the humid air system was found to provide a bale-moisture non-uniformity of +/-0.4% with the spray system providing a bale-moisture non-uniformity of +/-1.2% (95% confidence). This wide range of in-bale moisture variation is cause for concern when viewed in conjunction with bale degradation due to moisture contents in excess of industries recommended 7.5% level. One of the problems with these large variations, is that if a ginner obtained a single sample from a bale in the interest of tuning his moisture restoration system to avoid moisture damaged bales, that this large in-bale moisture variation, in conjunction with a typically poor accuracy resistance sensor, could mislead the ginner into believing his cotton is running at 6% when in fact it could be running as high as 8.0% or even 9% which could likely lead to bales that may be returned due to quality degradation. To illustrate the magnitude of this issue, figure 1 details the wide variation in bale moisture that a set of ten samples produced. Given this degree of measurement inaccuracy associated with large in bale moisture variations due to moisture restoration systems, it is the recommendation of this research for ginners to obtain a minimum of five samples per bale and take the average of these five readings before making an assessment about the current setting of their bale moisture restoration systems. Ideally these readings would be performed with higher accuracy systems than resistance meters. Suitable measurement techniques would be either gravimetric oven tests or microwave moisture sensors. The technology that appears to provide the best solution for a rapid field test is to utilize a microwave moisture sensor that performs a scan of moisture contents across the length of the bale. In this manner the system will gather hundreds of samples and could output both the average bale moisture as well as quantify the range of moisture variation within the bale. This information would then provide the ginner with a sound basis for any decision regarding moisture restoration system management. The other problem with large in bale moisture variations, is that is lowers the target moisture content in order for the ginner to avoid having portions of his bale becoming subject to excess moisture and subsequent quality degradation.

In the interest of preserving quality and maximizing economic return to the cotton gins, these moisture systems need an accurate and low cost sensor that can work with these systems to optimize the amount of water added to the bales while maintaining the quality of the cotton. This is important both in the short-term economic interest of the producers and cotton ginners, but also in the long term goal of preserving both the cotton gin's reputation as well as US cotton's international reputation. In working toward solving this problem; this research has focused on the development and deployment of a proto-type low-cost microwave bale moisture sensor that is the result of a multi-year development effort. This sensor was deployed into a commercial cotton gin, in the interest of quantifying it's suitability and accuracy for use in a commercial environment. The results of this field trial indicate that for these tests, the system provided a cross-validation accuracy of 0.25% moisture content with a 95% confidence (figure 2). The repeatability of the sensor was found to be within 0.15% moisture content again with a 95% confidence. With this level of accuracy in conjunction with the sensor's ability to provide a scanning measurement of the in-bale moisture variation, as indicated by these tests, this system has the potential to provide these key quality control measurements for use in moisture restoration system's control.

References

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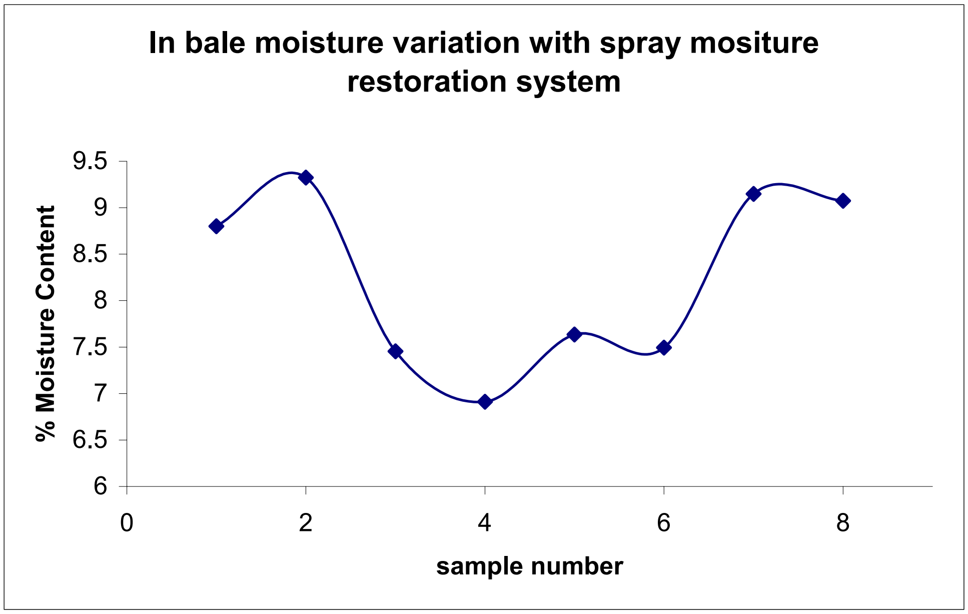

Figure 1: A set of eight samples taken from a single bale shows significant variation of the moisture content of this bale due primarily to the non-uniform application of applied water from the spray type moisture restoration system.

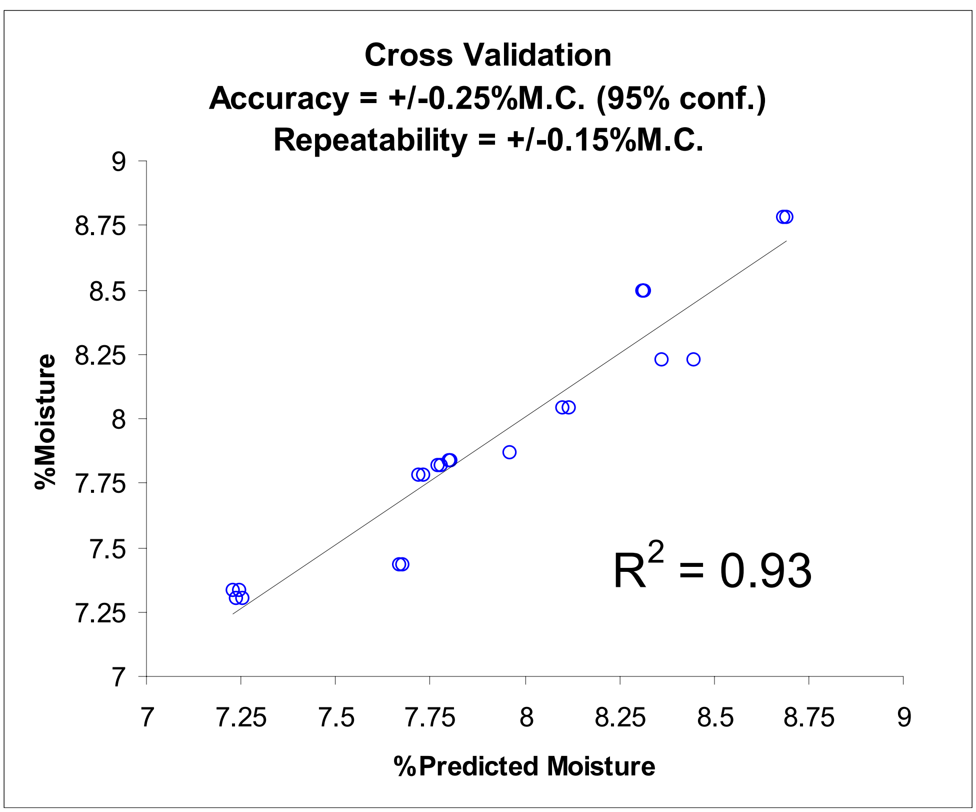

Figure 2: Preliminary accuracy test results of a commercial field trial for the microwave moisture sensing system.