MEASUREMENT OF MOISTURE CONTENT DURING HARVESTING AND MODULING

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Abstract

Moisture meters were constructed, installed, and tested on a cotton harvester and a module builder in 1996 and 1997. Moisture contents measured during harvesting indicated a greater variation than those during moduling. Data correlated well with reference laboratory measurements with field measurements about 1% higher for the harvester and 0.5% lower for the module builder than reference lab methods. Successful operations in the field clearly indicated the utility of moisture measurements in ensuring that recommended guidelines are followed during harvesting and storage of seed cotton. Knowledge of the moisture content allows the farmer to make risk assessments to protect fiber and cottonseed quality and to ensure adequate profits.

Introduction

Control of moisture during harvesting, storage, and ginning operations is critical to maintaining fiber and cottonseed quality. Resistance-based and infrared moisture sensors have been used in gins recently to provide excellent moisture measurements and subsequent moisture control (Byler and Anthony 1996). Good moisture measurement allows moisture to be removed or added at the gin to enhance cleaning, ginning, and packaging, especially since each requires a different moisture content for optimum operation.

Extension of the resistance-based moisture measurement technology to the harvesting and moduling operations would reduce fiber and cottonseed degradation during storage prior to ginning. When used in conjunction with harvesting, moisture measurements aid the farmer in understanding risk factors in terms of the potential for quality degradation due to harvesting at high moisture contents compared to the potential impact of delayed harvesting. Knowledge of moisture during moduling is useful in guiding continued harvesting as well as informing the farmer as to potential damage during storage due to high moisture. Again, risk assessment can be used to influence the storage time before ginning. The purpose of this study was to provide an inexpensive field method to measure the moisture content of seed cotton during harvesting and module building to alert the operator and farmer to adverse conditions. The moisture content of seed cotton should be estimated with an accuracy of ±0.5% fiber moisture.

Discussion

Harvesting - 1996

A paddle sampler was constructed and integrated with the pneumatic transport system of a spindle harvester and used to capture and compress samples against a specially constructed resistance-based moisture meter. The meter was installed on a two-row John Deere spindle-picker. The rotary actuator was powered by the hydraulic system of the harvester. The sampling mechanism and moisture meter were installed in a substitute conveyance chute so that the original chute remained unchanged. The assembly is shown in Figure 1 with the cover removed to illustrate the meter and the sample collection paddle. The assembled unit mounted on a two-row harvester is shown in Figure 2. Initial operation with cotton of uniform moisture content fed manually into the harvester head verified sample collection techniques and the accuracy of moisture measurements. The meter was correlated with the moisture in the sample based on the oven-dry method. Seed cotton moisture levels ranging from 5% to 12% were tested.

Due to unavailability of computer components to construct the data collection, display, analyses and storage functions, the complete system was not functional in time to test fully during the 1996 season. In 1996, data collection was accomplished with a notebook computer since the standard system was not available. Initial results were encouraging but indicated a need to measure higher moisture levels than those normally found in a cotton gin. Each measurement with the meter, at a given moment, actually consists of eight individual electrode readings which can be sorted and averaged to give one reading. When the individual electrode readings were examined, they were found to be much more variable than was usually seen for cotton in the gin. Table 1 shows four sets of readings with the harvester meter in the field. As described later, the readings in the field with the harvester meter were much more variable with a standard deviation in the range of 1.5, than readings in the gin which usually have a standard deviation no larger than 0.5. A possible explanation was that the cotton samples were not completely and evenly covering the electrode grid during the measurements. An additional factor may have been that the moisture contents actually varied more for the samples which had just been harvested. The seed cotton in this test was not defoliated completely and there were many green leaves in the samples. If only a few electrodes are uncovered or have green leaves on them, it is possible to reject those measurements and average the remaining data. However, in this case it was not possible to determine which data should be kept and which data discarded. Further conclusions were postponed until more data were collected for the following season.

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Harvesting - 1997

The moisture sensors were integrated with data collection, analyses, and storage features. A digital display indicated the actual moisture at each compression. Red, green and amber warning lights were used to provide an additional alert signal to the operator. Mean, mode, standard deviation, minimum moisture, maximum moisture and ginning needs were recorded.

Two tests were conducted, one compared moisture measurements at the harvester to those in the lab, whereas the other monitored the moisture during harvesting without comparing to measurements in the lab. In the first part, five baskets of cotton were harvested and data collected. During the harvest of the first basket, 10 samples were collected manually on the harvester as the cotton entered the basket. For the other four data sets, samples were collected after the basket of cotton had been dumped into the module builder. The samples were placed in metal cans and sealed. They were then returned to the lab where a reference resistance moisture measurement of the lint was made. The seed cotton moisture content was determined by the oven method. The mean of all of the reference readings was compared with the mean of all of the individual resistance moisture readings as shown in Table 2.

Some of this data agreed well, such as the data from the first day and the first set of data from the second day. Other data did not agree well with a moisture difference between the two readings of up to 2.3%. For the data where the readings did not agree, in every case the reference readings were higher than the field readings. The readings with the largest deviation from the reference were also the ones with the highest seed cotton moisture. In addition, the reference readings were lower than what would be expected for lint in equilibrium with seed (Hughs et al.,1994). It is likely that the lint absorbed moisture from the seed while the samples were being stored and transported to the lab where the reference resistance readings were performed before the lint had come into complete equilibrium. The moisture content may have changed during storage. Therefore, the actual lint moisture content in the field probably was lower than it was when the reference readings were taken.

The standard deviations in the meter readings were relatively large, indicating that there was more variation in moisture content in the material being sampled in the harvester than had been seen previously in seed cotton in gins. This is not surprising because some green leaf would be expected in the samples for the harvester. Most of the difference in moisture content between the green material and the cotton would dissipate during storage in the module. Likewise, water which had been added during spindle picking would have dispersed throughout the module before the cotton reached the gin but would be measured by the meter on the harvester. Future research will address the normal variation in moistures during harvesting.

In the second part of the evaluation, moisture measurements were made during routine harvesting for several days. No problems were encountered with the equipment.

Moduling - 1996

Two resistance-based meters to sense moisture were constructed, calibrated, and installed in parallel in the tamper of a module builder. Initially, the sensors were installed on a module builder provided by KBH, and data was collected with a notebook computer. Measurements were made on cotton having uniform moisture content by conditioning in large bags (100 pounds or more) in a controlled environment. The cotton was then used to test the moisture meter under simulated field conditions. Meter readings were correlated with the moisture in the sample based on the oven-dry method. Seed cotton moisture levels ranging from 5% to 12% were tested. Results were analyzed for precision and repeatability.

The meters were then installed (Figure 3) on a new KBH module builder owned by Mississippi State University (Figure 4) and field tested on a limited basis. Data collection was accomplished with a notebook computer since the preferred system was not available. Initial results were encouraging but indicated a need to measure higher moisture levels than those normally found in a cotton gin.

Two tests were performed with the moisture measurement system on the module builder. First, a 6' x 6' x 4' box containing seed cotton was placed under the tamper in a static position. Eight readings were taken of each of the three samples placed in the box. The results are presented in Table 3. The standard deviation was very low because the tamper was not fully retracted between readings so that the same sample was read each of the eight times rather than eight different samples. A higher standard deviation but a better prediction of the average lint moisture content would have resulted if the tamper had been retracted and a different portion of the large sample had been measured each time.

The second test with the module builder moisture meter was done in the field. The tamper was used to compress the module by first spreading the seed cotton and then tamping it periodically as the assembly traveled from one end of the module to the other. Two passes were made while collecting data with the meter. Table 4 presents the results of this data collection. This cotton was harvested on a humid drizzly day after it had dried adequately in the field. Because of this, the difference between the measured lint moisture content and the seed cotton moisture content may have been lower than what would be expected if the lint were in equilibrium at the same conditions as the seed in the seed cotton. Note that the readings predict the lint moisture content not the seed cotton moisture content. The two sets of readings varied little, while the corresponding seed cotton moisture measurements varied more. This would be expected given the conditions of the test.

Table 5 shows two sets of readings with the module builder moisture meter in the field and two sets during the calibration check of the module builder. The module builder field data sets would be considered to be typical of the range of moisture readings often seen with this type of meter. One approach to smooth the data which has been used in the past at gins, is to discard all readings an arbitrary distance from the mean. An acceptable range of 1.4 was chosen and the four readings were reevaluated (Table 4). This approach to analysis of the data looked good with a reasonable number of observations remaining, reasonable standard deviations, and reasonable means. One data set had a low number of observations remaining, but the mean and standard deviation seemed reasonable. Another data set had a very low number of observations remaining and the standard deviation was high. Acceptable results were obtained in three of these four cases (Table 6), but the accuracy of this approach is unknown and needs to be examined in future work.

Moduling - 1997

The moisture sensors were integrated with data collection, analyses, and storage features. A digital display indicated the meter reading at each compression. Red, green and amber warning lights were used to provide an additional alert signal to the operator. Mean, mode, standard deviation, minimum moisture, maximum moisture and ginning needs were recorded.

Data were collected in 1997 both with the tamper operated manually wherein the operator governed the location and number of “tamps” and in the automated mode wherein the location and number of tamps are microprocessor-driven. In Test 1, three baskets of cotton were dumped into the module builder. After each basket dump, the seed cotton was tamped four times and five 50-gram moisture samples were taken in the vicinity of the tamps. Samples were analyzed with a resistance-type laboratory moisture meter manufactured by Zellweger Uster of Knoxville, TN, and by the standard oven method. For Test 2, the seed cotton was automatically tamped and samples were collected in the vicinity of the tamping action. Oven moistures were not measured. In Test 3, the seed cotton was automatically tamped and samples were taken for oven moisture and resistance moisture determination at the U. S. Cotton Ginning Laboratory, Stoneville, MS.

Based on the combined data from the three small field tests, the moisture meter at the module builder indicated a 0.5% lower moisture compared to the reference moisture meter in the lab--7.4% versus 7.9%. Standard deviations ranging from 0.34 to 1.12 for the module meter and averaging 0.67 were found as compared to 0.48 to 0.92 and averaging 0.65 for the lab meter (Table 7). Experiments thus far indicate clearly that measuring the moisture in the module with the resistance-based technology is quite viable. However, additional research will focus on cotton that is substantially out of equilibrium with the climate.

Summary

A sample collection mechanism and a moisture meter were constructed and installed on a two-row, spindle-type cotton harvester in 1996. Initial results were encouraging. Further studies in 1997 which included integrated data collection, analyses, and storage features demonstrated the utility of the system.

Two resistance-based meters to sense moisture were constructed, calibrated, and installed in parallel in the tamper of a module builder. Sensor readings were correlated with the moisture in the sample based on the oven-dry method. In 1996, seed cotton moisture levels ranging from 5% to 12% were tested. Results were analyzed for precision and repeatability. In 1997, the moisture sensors were integrated with data collection, analyses and storage features, and three field tests conducted. When compared to a reference moisture meter, the experimental meter on the module builder indicated about 0.5% lower moisture. The system worked well and clearly indicated the ability to estimate moisture in the module. Additional research will focus on cottonseed moisture.

Disclaimer

References

Anthony, W. S. 1992. U.S. Patent Number 5,087,120. System for capturing, pressing and analyzing entrained solids such as cotton.

Byler, R.K. and Anthony, W.S. 1996. U.S. Patent Number 5,514,973 System for analyzing moisture content of materials such as cotton.

Hughs, S. E., G.J. Mangialardi, Jr., and S. G. Jackson. 1994. Moisture control. Cotton Ginners Handbook. USDA Handbook No. 503. pp. 58-68.

Table 1. Individual electrode readings taken with the resistance moisture meter during harvesting in 1996.

Data set	35430	35432	35433	35435
Electrode 0	below 4.7	6.1	9.9*	7.0
Electrode 1	8.1	6.0	5.7	6.7
Electrode 2	5.6	5.7	6.3	6.2
Electrode 3	5.1	6.0	9.9*	9.9*
Electrode 4	5.6	5.8	8.4	6.3
Electrode 5	6.4	6.7	6.6	6.3
Electrode 6	5.8	9.4	9.4	5.5
Electrode 7	9.9*	5.6	5.8	5.7
Mean	6.6	6.4	7.7	6.7
Standard deviation	1.74	1.27	1.85	1.37

* Sensor maximum

Table 2. Data from the test of the moisture meter mounted on the harvester, 1997.

Day	Picker dump	Mean meter reading	Number of observations in mean	Standard deviation of meter readings	Mean of reference resistance reading	Seed cotton moisture content
1	1	7.3	305	2.0	6.9	-
2	1	8.1	1019	1.7	8.2	11.7
2	2	6.7	1145	1.6	9.0	13.3
3	1	6.9	396	2.0	7.8	10.5
3	2	7.0	649	1.9	9.1	12.4

Table 3. Results of testing the meter on the module builder in the gin yard (1997).

Sample number	1	2	3
No. of readings	8	8	8
Mean lint moisture content, % w.b.	9.0	8.4	8.6
Standard deviation, % w.b.	0.04	0.01	0.05
Minimum observation, % w.b.	8.9	8.3	8.5
Maximum observation, % w.b.	9.0	8.4	8.6
Seed cotton, by oven test, % w.b.	10.5	8.9	10.2

Table 4. Results of testing the module builder meter in the field (1996).

Sample number	1	2
No. of readings	20	18
Mean lint moisture content, % w.b.	9.7	9.6
Standard deviation, % w.b.	0.19	0.19
Minimum observation, % w.b.	9.3	9.3
Maximum observation, % w.b.	9.9	9.9
Seed cotton, by oven test, % w.b.	11.55	10.94

Table 5. Individual electrode readings taken with the module builder moisture meter in 1996.

	Calibration check data		Field data	
Data set	7-2	5-1	11-2	13-4
Electrode 0	8.2	8.8	5.7	5.9
Electrode 1	8.3	8.8	5.6	5.9
Electrode 2	8.3	8.7	5.5	6.8
Electrode 3	8.6	9.0	6.0	6.5
Electrode 4	8.1	9.4	6.7	6.5
Electrode 5	8.0	8.8	5.4	5.7
Electrode 6	8.5	9.2	5.9	5.3
Electrode 7	8.6	9.0	6.0	6.4
Mean	8.3	9.0	5.9	6.1
Standard deviation	0.24	0.22	0.41	0.50

Table 6. Results of discarding observations greater than 1.4 from the mean and recalculating the mean and standard deviation in 1996.

Data set	35430	35432	35433	35435
Number of observations remaining	4	7	2	7
Mean	5.8	6.0	7.5	6.2
Standard deviation	0.36	0.37	1.28	0.50

Table 7. Means and standard deviations for three tests with the module builder moisture meter of 1997.

		Moisture , % wet basis					
Test	Dump	Module[1]	Standard deviation	Lab[1]	Standard deviation	Oven[2]	Standard deviation
1	1	7.3	0.92	8.7	0.48	10.1	0.66
1	2	6.2	0.34	6.6	0.92	8.5	0.63
1	3	6.5	0.47	7.2	0.54	9.3	0.34
2	1	8.2	0.42	9.1	–	–	–
2	2	7.9	1.12	8.1	–	–	–
3	1	7.2	0.66	7.9	–	11.4	–
3	2	8.5	0.74	7.8	–	11.1	--

[1] Lint moisture measured with a Zellweger Uster resistance moisture meter.

[2] Seed cotton moisture based on oven method.

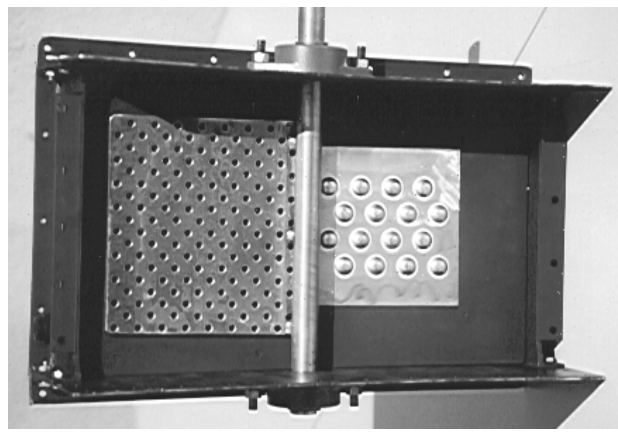

Figure 1. Assembled paddle sampler and moisture sensor.

Figure 2. Assembled unit mounted on a two-row harvester.

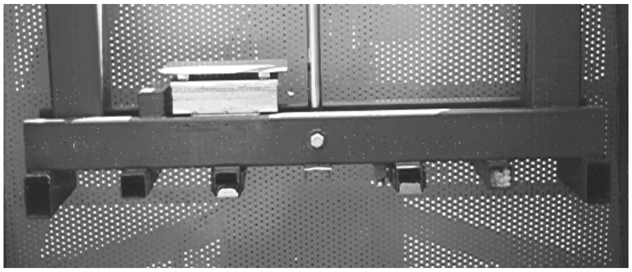

Figure 3. Sensors installed in the tamper of a KBH module builder.

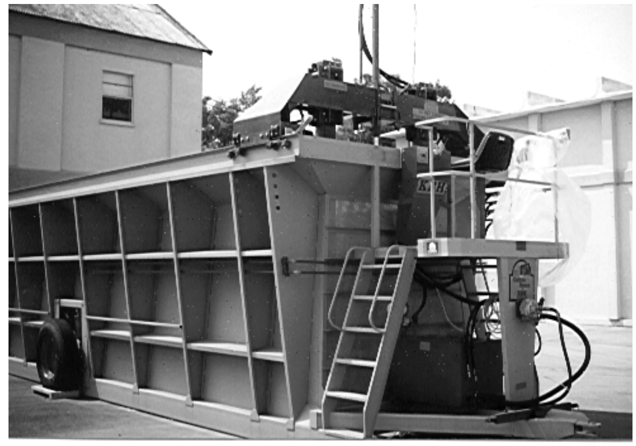

Figure 4. The signal Processor was installed on the operator platform in the area of the plastic bag shown here.