MODULE AVERAGING THE SHORT FIBER MEASUREMENT

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Abstract

The effect of module averaging on the HVI short fiber index measurement was evaluated on one hundred and forty eight modules randomly selected from the 2001 U.S. cotton crop. In addition to collecting module data, HVI data on over 115,000 samples, also randomly selected from the 2001 U.S. cotton crop, were used to establish the "normal" relationship of HVI short fiber index to upper half mean length and uniformity index. The normal relationship between the three measurements is strong as evidenced by $R^2 = 0.99$. As a result of this strong relationship, in order to be of value, the short fiber index measurement must be capable of providing accurate information on whether or not a cotton sample exhibits an abnormal amount of short fiber content for its length and uniformity index. Otherwise, the more precise measurements of length and uniformity index are actually more effective in predicting short fiber content.

The normal relationship of short fiber index to length and uniformity index was quantified and used as the basis for normalizing the module averaged short fiber index measurements. Increased precision resulting from module averaging enabled effective normalization. Given a tolerance of 1.0%, short fiber index, reproducibility between HVI's for single bale testing averaged 57% and for module averaging averaged 95%. Of the 148 modules in the study, the detected abnormality of short fiber contents ranged from 15% more short fiber than normal to 15% less short fiber than normal.

Introduction

The Zellweger Uster HVI short fiber index measurement has been under evaluation by the Cotton Program since 1997. Although some improvements have occurred since the initial introduction, measurement variability for single bale testing remains unacceptably high for reliable use in classification (Gibson, 1999), (Knowlton, 2001-1). Given that the HVI short fiber index measurement has been found to be considerably more variable than other HVI measurements, the only foreseeable way to potentially increase its precision to the level required for classification is through module averaging. In addition, given that the HVI short fiber index measurement is strongly related and confounded with the HVI measurements of length and uniformity index (Knowlton, 2001-2), normalization of the short fiber measurement must be performed for a proper assessment. This paper reports on an evaluation that was conducted during the 2001classing season to study the HVI short fiber index measurement with respect to the effectiveness of module averaging and the potential for a normalized short fiber measurement.

Comparing Precision of HVI Measurements

On single bale testing, the HVI short fiber index measurement does not provide the level of precision necessary for classification. Module averaging in lieu of single bale testing improves testing precision of HVI measurements (Boyd, 1995). Therefore, a module averaged HVI short fiber index measurement has the potential of providing acceptable levels of testing accuracy. Before going further into module averaging of the short fiber measurement, it is important to understand and quantify the lack of single bale testing precision in short fiber index measurements.

Within HVI/Within Bale

Overall within HVI / within bale measurement precision was determined for each of several HVI measurement factors. Testing data taken from studies used for setting standard values on calibration cotton bales were utilized for the precision comparison. Approximately 200 bales were selected from value-setting studies that provided a range representative of the U.S. Upland crop for length and strength properties. The analysis was based on multiple replication tests made on each bale using nine Zellweger 900 Automatic HVI systems.

Table 1 summarizes the average within HVI / within bale measurement comparisons for length, uniformity index, short fiber index and strength. Data is summarized in terms of averages, standard deviations (SD) and coefficients of variation (CV). The CV comparisons provide a good perspective on how HVI measurements stack up to one another. The high measurement variability of the short fiber index measurement is apparent relative to the other HVI measurements.

Between HVI/Within Sample

Table 2 data is based upon the Cotton Program's overall average reproducibility results for the 2000 classing season. The given reproducibility results give the overall agreement between HVI's in the twelve classing offices and the Cotton Program's Quality Assurance Branch. The averages are overall measurement averages for all classing offices. Standard deviations of the sample testing biases between classing office and Quality Assurance measurements were calculated using the following relation:

S.D. of Biases = Reproducibility Tolerance X (68.3% / Reproducibility)

The constant of 68.3% is the percentage of data expected to fall within one standard deviation for a normal distribution. The standard deviation of the biases represents the variability of the biases between classing office and Quality Assurance HVI's. Coefficient of variation (CV) was calculated by dividing the standard deviation by the associated average. As in Table 1, quality factors are ranked according to CV. In addition to the quality factors shown in Table 1, Rd and +b were included as additional information in the between-HVI variability comparisons. Although the between-HVI CV's (as expected) are at a higher level than the within-HVI CV's, the CV ranking orders are the same for the quality factors common to both tables. Both the within and between HVI evaluations indicate the variable nature of the HVI short fiber index measurement.

Normalizing Short Fiber Index to Length and Uniformity Index

The data plotted in Figure 1 is based on approximately 229,000 tests performed on ten HVI's in the Quality Assurance Branch. The cottons used in these tests are from the 2001 classing season and represent the full range of expected length properties for the U.S. crop. The data from the tests were sorted by length and uniformity index. The short fiber index measurements making up each combination of length and uniformity were averaged together. Combinations with less than 15 HVI tests were deleted from further use to ensure accurate short fiber averages. The number of combinations with 15 or more HVI tests equaled 189 and are the points plotted in Figure 1. The uniformity index is labeled on each band of points. Interestingly, all points on each of the bands have the same uniformity index.

Figure 1 shows the high correlation between the HVI short fiber index measurement to the upper half mean length and uniformity index. Multiple regression analysis of this data gives an R^2 equal to 0.99. Although not shown, to the left and right of each plotted point exists the point's distribution of individual short fiber index measurements. The plotted points are the averages of these distributions. Standard deviations of these distributions increase considerably moving from the top left toward the bottom right of Figure 1. For example, the standard deviation of the short fiber index measurements making up the 1.18" length and 82% uniformity index is 0.75%. The short fiber index standard deviation for a 1.00" length and 80% uniformity index is 1.93%. It is within these distributions that potential exists for short fiber measurement sensitivity beyond what is predictable with only length and uniformity index. Unfortunately, the variable nature of the short fiber index measurement also exists within these distributions. The best way to determine and deal with these two components of variability is by normalizing the data, increasing precision by means such as module averaging and then performing reproducibility testing to determine how much real short fiber sensitivity exists within a distribution of short fiber index measurements.

Each point plotted on Figure 1 represents the expected or normal amount of short fiber content for each combination of length and uniformity index (UI). Regression analysis was utilized to quantify this relationship into the equation

$$\text{Normal SFI} = a + b\,(\text{Length}) + c\,(\text{UI}) + d\,(\text{Length})^2 + e\,(\text{UI})^2 + f\,(\text{Length})\,(\text{UI}).$$

In 1998, the same data gathering and analysis approach was used to develop a short fiber prediction equation that was used on cottons with known length and uniformity index (Knowlton, 2001-1).

A Normalized Short Fiber Content (NSFC) can be calculated by dividing the HVI short fiber index measurement by the Normal SFI. Multiplying by 100 will put the Normalized SFC in terms of a percentage such that

$$\text{NSFC} = 100\,(\text{SFI} / \text{Normal SFI}).$$

If a cotton sample has a NSFC equal to 100, then the cotton has 100% of its normal expected short fiber content. If a cotton sample has a NSFC of 110, then the cotton has 110% of its normal expected short fiber content. This would indicate that this cotton has 10% more short fiber by weight than normal. In contrast, a cotton sample with a NSFC of 85 will have 85% of its normal expected short fiber content indicating that the cotton has 15% less short fiber by weight than normal.

Module Averaging

In order to accurately assess the value of module averaging on short fiber measurements, samples from 148 modules were randomly collected from all U.S. cotton growing territories and HVI tested twice by the Cotton Program's Quality Assurance Branch. Double testing was performed on different HVI's and provided the opportunity to evaluate between instrument reproducibility of single bale and module averaged short fiber test data. Table 3 gives the reproducibility results for the measurements of short fiber index, normalized short fiber content, length and uniformity index. The module average reproducibility is based on comparing the module average of the first test to the module average of the second test. Likewise, the single bale reproducibility is based on comparing the first and second single bales tests. The high module average reproducibility percentages demonstrate the ability of module averaging to provide very precise fiber quality determinations.

Module Averaging the Normalized SFC

The standard deviation was 5.4% for all 148 module averaged normalized short fiber contents. The average between HVI reproducibility for this data is 77% with a 5.0% tolerance; this equates to a reproducibility standard deviation of 4.3%. Although the range of all measurements within one standard deviation is not much greater than the reproducibility precision of the test, for modules with very high or very low amounts of normalized short fiber contents, the normalized measurement should provide useful sensitivity regarding short fiber content normality. Of the 148 modules in the study, the highest NSFC module measured 114% and 115% for test 1 and 2, respectively. The lowest NSFC module measured 85% and 86% for test 1 and 2, respectively. These results indicate that the detected abnormality of short fiber contents ranged from 15% more short fiber than normal to 15% less short fiber than normal. Confidence of the validity of these results is high given that the measurements were very reproducible from test 1 to test 2.

Handling of Module Average Outliers

As in the module averaging procedure utilized in classification, outlier measurements were removed from module averaging calculations for this study. For length, any single bale test more than 0.06 inches from the module average was kicked out of the measurements being averaged. For Uniformity Index, the tolerance used was 1.0. Since no classification module average tolerance is established for short fiber index, for the purpose of this study a tolerance of 1.0 was used. Out of all 148 modules in the first of the two tests, 19 single bale tests were kicked out for length, 2 were kicked out for uniformity index and 24 for short fiber index. Interestingly, when these outlier bales were tested in the second test, a very high percentage came back within tolerance (Table 4). As a side note, it is important to understand that the percentages in Table 4 are not comparable to the reproducibility data shown in Table 2. Table 2 gives the reproducibility for comparing testing of regular samples between instruments. Table 4 gives the reproducibility of test #1 outlier samples that have been tested a second time and then compared to the module average. Given that these samples were identified as outliers in the first testing, the probability of these samples actually having a measurement level that is away from the module average when retested is greater than for regular samples.

For length, out of the nearly 2,000 total bales making up the 148 modules, only two were actual outliers. For Uniformity Index, there were no actual outliers and for short fiber index only four were actual outliers. This demonstrates the fiber property uniformity in modules and questions whether a single bale measurement should be assigned to an outlier bale in lieu of the module average. For certain, in the case of module averaging short fiber measurements, individual test data that are outliers do not have sufficient precision to stand on their own.

Conclusion

Single bale short fiber index measurement testing lacks the precision required for the cotton classification system. Perhaps equally detrimental, is the confounding nature of the short fiber index measurement with length and uniformity index. However, through normalization and module averaging, the potential is good for a short fiber measurement that has an acceptable level of classification accuracy and offers valuable fiber quality information.

Implementation of a module averaged NSFC into classification is practical. This new quality factor would provide a sound basis for assessing the short fiber content relative to what is expected or normal for U.S. Upland cotton. Given the effects of new cotton varieties and the incentives to reduce short fiber content, the amount of short fiber that is normal today for a given length and uniformity index will hopefully change for the better. Therefore, the normal basis for the NSFC would not be made absolute. Another justification for not establishing an absolute normal relationship is the fact that a reliable and accurate reference method for the short fiber index measurement has yet to be found.

As a means for practical application, the basis for the normalized relationship would be made relative to the previous U.S. cotton crop. At the end of each crop year, a new relationship between short fiber index, length and uniformity index would be quantified in the same way the relationship presented in this report has been done. For each new crop, the relationship determined from the previous crop would be used as the basis for assessing short fiber content normality. This method would provide the cotton production industry with potential premiums to produce cotton with lower levels of short fiber contents relative to the average crop level. In contrast, the production of cottons with higher levels of short fiber contents relative to the average crop level would be penalized.

Additionally, the quantified relationship for determining NSFC would always be made available. Therefore, the relationship could serve as a fiber quality research tool or if desired could be used to back calculate the conventional short fiber index measurement.

References

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Table 1. Within HVI Measurement Precision Comparison.

HVI Measurements	Average	SD	CV
Uniformity (%)	80.6	.53	.66
Length (in.)	1.05	.011	1.05
Micronaire	4.08	.06	1.53
Strength (g/tex)	28.9	.64	2.22
Short Fiber Index (%)	11.7	.64	5.38

Table 2. Between HVI Measurement Precision Comparison.

HVI Measurements	Average	Repro. Toler.	Repro.	SD of Biases	CV of Biases
Rd	76.23	1.0	93	0.73	0.96
Uniformity (%)	80.95	1.0	86	0.79	0.98
Length (in.)	1.061	0.02	79	0.017	1.63
Micronaire	4.30	0.1	80	0.09	1.98
+b	8.57	0.5	94	0.36	4.24
Strength (g/tex)	27.35	1.5	76	1.35	4.93
Short Fiber Index (%)	11.18	1.0	50	1.37	12.21

Table 3. Overall Reproducibility Results: Module Average & Single Bale.

	Short Fiber Index	Normalized SFC	UHM Length	Uniformity Index
Tolerance	1.0 %	5.0%	0.02 inches	1.0 %
Single Bale	57% (CV=13%)	45% (CV=7.4%)	75%	81%
Module Average	95% (CV=6.5%)	77% (CV=4.3%)	100%	99%

Table 4. Second Testing of Test 1 Module Average Outliers. Percentages of Outliers Actually in Tolerance.

	Short Fiber Index			Length			U.I.
Tolerance	1.0%	2.0%	3.0%	0.02 in.	0.04 in.	0.06 in.	1.0%
	54%	71%	83%	74%	90%	90%	100%

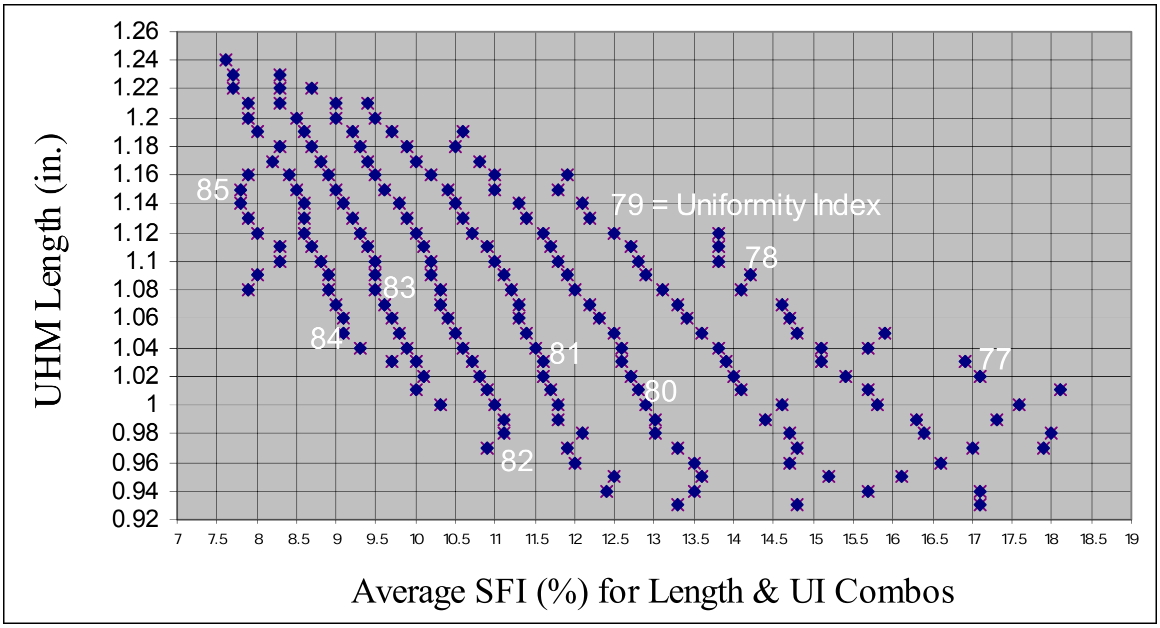

Figure 1. Normal Relationship of SFI versus Length & UI.