1789 Measuring the short fiber content of cotton

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ABSTRACT

Twenty-nine bales of cotton with short fiber content ranging from about five to twenty-five percent were selected for the purpose of comparing the effectiveness and relationships between current test methods for fiber length. These various instruments/methods used to measure short fiber included: HVI, AFIS, and Suter-Webb array. Comparisons between the four methods indicate that they all correlate well with each other. The Suter-Webb array technique gives higher estimates of short fiber content than those of HVI and AFIS, and show greater discrimination among the samples. Highly significant regression models were developed to predict short fiber content from long fiber data (length and strength), and micronaire.

INTRODUCTION

The presence of excess amounts of short fibers can cause significant problems for the spinner. These include excess waste, loss of yarn strength, and increases in ends-down, and yarn defects.(Backe, 1986) There are several approaches to measuring the short fiber content (defined as percent by weight of fibers of 0.5 inches or less) of cotton, and all of them essentially require some type of measurement of the distribution of total length. The most fundamental, direct, (and tedious) measure of fiber length is the Suter-Webb array method in which a comb-sorting technique is used to segregate the fibers into length groups each of which are weighed on an analytical balance.(ASTM D1440) The AFIS instrument is also a direct measurement of fiber lengths, as it utilizes a mechanical opener to inject individual fibers into a rapid air stream where their length may be measured by a high speed electro/optic system.(Bragg, et al., 1993) There is some legitimate concern that the AFIS mechanical opener can cause some fiber breakage which would bias its length measurement.(Cui et al., 1997)

In the late 90's, Zellweger-Uster (now Uster Technologies) modified its HVI program to allow for calculation of the short fiber content of a sample of cotton based upon an algorithm that calculates a "Short Fiber Index (SFI)" based upon the other conventional HVI measures of length, strength, and micronaire.(Gipson, 1999) Subsequently, the USDA AMS Cotton Program developed an improved short fiber prediction equation based upon HVI length and Uniformity Index.(Knowlton, 2001) This improved prediction (PredSFI) has shown to be slightly more repeatable than the HVI SFI but the general conclusion of the AMS experience has been that the only way to achieve short fiber measurements on par with other HVI measurements is by increasing the number of test specimens per sample.

Cui, et al (2003) reported a study to evaluate the differences between the various measures of short fiber content including Suter-Webb, AFIS, and HVI. Included in this study were thirty-six upland cottons grown on experimental plots in Mississippi. These cottons had a range of short fiber contents 6.5-13.9%. Studies of the inter-relationships between Suter-Webb, AFIS, and HVI yielded correlation (R) values between about 0.6 and 0.7. Some of the

conclusions reached here were that real differences existed between the three methods and that a significant contributor to these differences was the general non-uniformity of the samples.

At the 2004 Beltwide Cotton Conference, James Knowlton reported on a collaborative effort "to evaluate available short fiber measurements relative to each other and relative to textile processing performance."(Knowlton, 2004) The study encompassed several different laboratories conducting a wide range of tests on several different instruments. Twenty-nine commercial bales were chosen for the study having a wide range of fiber properties. The results Knowlton presented were preliminary, but they indicated good correlations between the various test methods, although different methods were on different levels of short fiber contents. The present study deals with specific data from the same set of cottons. Here we concentrated on HVI measurements from the AMS Memphis Classing Office, from three separate AFIS instruments, and from Suter-Webb array analysis. Our emphasis is to study the relationships between the various short fiber measurements, their relationships to other fiber properties, and couple these with the determination of their relative utility as predictors of process quality. It should be emphasized that the number of replicated measurements of the various properties would be far greater than those followed in practice, but these results will at least confirm that we are moving in the correct direction.

MATERIALS AND METHODS

The cottons chosen for this study represent a wide range of fiber properties as shown in Table I. Fiber lengths are between 0.92 and 1.21 inches with a wide range of uniformity index between 77.8 and 84.4 %. Fiber strength varies between about 24 and 34 g/tex while micronaire varies between about 2.9 and 5.5. The HVI short fiber index varies between 6.86 and 17.13 %.

As mentioned above, HVI measurements reported here on these bales were conducted at the Memphis Classing Office of the USDA AMS Cotton Program. The values used in this analysis are averages of approximately 150 individual measurements on each of the bales.

The AFIS measures were obtained on three different instruments located at: a) the Southern Regional Research Center (SRRC) in New Orleans, Louisiana; b) Cotton Incorporated (CI) in Cary, North Carolina; and c) the Cotton Quality Research Station (CQRS) in Clemson, South Carolina. Ten replicate samples from each of the twenty-nine cottons were run at each of the locations. Each of the AFIS measurements represented characterizing at least 15,000 fibers per rep.

Suter-Webb array analyses were conducted at the CQRS, Clemson according to ASTM D-1444. Determinations were based upon averaging three separate samples run by three different operators.

RESULTS AND DISCUSSION

Relationships among Short Fiber Variables

Definitions of the six short fiber measures discussed in this study are given in Table II. Two of these are from the HVI – the HVI SFI and the PredSFI. The AFIS short fiber content (SFC) measurements are from Southern Regional Research Center, New Orleans, LA [SRRC];

Cotton Incorporated, Cary, NC [CI]; and the Cotton Quality Research Station, Clemson, SC [CQRS]. SW denotes the Suter-Webb array analyses performed at the CQRS.

In Figure 1 we compare the short fiber measurements for the three methods (instruments) in this study: a) the HVI (SFI); b) the SRRC AFIS (SFCw1); and c) the Suter-Webb (SW) array method. Each set of data was sorted from the smallest to largest values. The SW data has the largest range of values and HVI (SFI) the smallest range. The AFIS data tend to track SW better, especially in the area of the lower short fiber contents. The HVI (SFI) measure shows the least sensitivity (is flattest) in the range of short fiber contents for the sample numbers between about 5 and 15.

A compilation of the significant statistical parameters of the six short fiber measurements is given in Table III. These include: MEAN (the average weight % of total fiber lengths less than 0.5 in; standard deviation (SD); coeff. of variation (C.V.=100 * SD/MEAN); and the minimum (MIN), median (MED), and maximum (MAX) values. The mean values for short fiber content for each measurement for all samples range between 9.72 and 13.17 %. The PredSFI is the least discriminating having the smallest SD (2.63) and the narrowest range of values (7.10-15.95 %). The Suter-Webb array method (SW) is the most sensitive with the largest SD (5.19) and the greatest range of values (6.4 – 26.6 %).

The correlation matrix (Pearson's R-values) shown in Table IV indicates the relationships between each of the six measures of short fiber. The inter-correlations between all six variables are quite high (close to or greater than 0.90). It is not surprising that the highest R-value (0.978) is between HVI SFI and PredSFI. Even though SW has a significantly larger mean and range of values than HVI SFI, it correlates quite well with HVI SFI (R=0.945). It is also noteworthy that the interrelations between all three AFIS's are all greater than (R=0.96Definitions of fiber properties (other than short fiber) as measured by HVI, AFIS, and Suter Webb are given in Table V. Data from HVI includes: length, length uniformity, strength, and micronaire. Values for all three AFIS lengths and the Suter Webb upper quartile lengths (UQL) are also included. The correlation matrix (Pearson's R-values) showing the relationships between the six measures of short fiber content and the other fiber physical properties as measured by HVI, AFIS, and Suter Webb are given in Table VI. Both HVI measures of short fiber content are strongly negatively correlated with the other fiber properties (especially Uniformity) except micronaire. The other fiber properties are strongly correlated with the exception of micronaire, which shows little correlation with the other fiber properties. The AFIS short fiber content measures generally show weaker negative correlations with other fiber properties that the HVI measures with the exception of micronaire. The AFIS measures are significantly negatively correlated with micronire. SW short fiber content shows marginally stronger negative correlations with other fiber properties than do AFIS measures with the exception of micronaire.

Step-wise multiple regression analyses were applied to develop reasonable models for the HVI SFI in terms of all of the measured fiber properties. The best fit regression equation for HVI SFI is:

HVI SFI = 122 - 10.0 Length - 1.29 Uniformity + 0.151 Strength (1)

with: S = 0.71002 R-Sq = 94.1% R-Sq(adj) = 93.7%

where S denote the standard deviation of the residuals.

The plot shown in Figure 2 depicts the actual values of HVI SFI plotted against the predicted values from the model developed in Equation 1. The relation is nonlinear and the fit is quite tight with the exception of the high short fiber values where there appears to be more scatter.

In the same fashion step-wise regression models were developed for predicting SFCw1 in terms of all of the measured fiber properties. SFCw1 is the AFIS short fiber content measured at SRRC. The best fit regression equation for SFCw1 is:

SFCw1 = 129 - 1.12 Uniformity - 0.457 Strength - 2.75 Micronaire (2)

with: S = 1.0168 R-Sq = 94.3% R-Sq(adj) = 93.9%

Note the similarities between the two models (Equations 1 and 2). In the model for SRCw1 (Equation 2) Micronaire replaces Length, R -squares are about the same as for HVI SFI (Equation 1), but the standard deviation of residuals (S) is somewhat larger, reflecting the greater variability in the AFIS measurements.

Finally, step-wise regression models were explored for predicting SW (Suter-Webb short fiber content) in terms of all of the measured fiber properties. The best fit regression equation for SW is:

SW = 236 + 7.59 Length - 2.80 Uniformity - 0.103 Strength (3)

with: S = 1.6681 R-Sq = 90.4% R-Sq(adj) = 89.8%

The SW model (Equation 3) consists of the same parameters as the model for HVI SFI (Equation 1). However, the standard deviation of residuals (S) is more than double that for HVISFI and the R-squares are somewhat smaller but still quite significant. SUMMARY AND CONCLUSIONS

Results of a rather extensive study of the effectiveness of several instrumental measurements of the short fiber content of cotton have been reported. The three approaches studied included using the HVI, AFIS, and Suter-Webb array. This study included a large number of repetitions per measurement which would not be possible under usual operations. This was done so as to take into account the normal variability of cotton and thus have a more unbiased evaluation of each of the techniques on their own merit. Our results lead to the following conclusions:

- All of the variables show a strong degree of linear association with one another.
- The two HVI variables show the strongest correlation (0.9775).
- The three AFIS measurements are highly correlated with one another (0.9728, 0.9642 and 0.9760).
- SW correlates slightly more with HVISFI than with the AFIS variables.
- Among the short fiber content measures, the HVI ones show the strongest negative correlations with the other fiber properties except micronaire.

- The AFIS measures exhibit the strongest association with micronaire.

- HVI SFI, SFCw1 and SW can be predicted from other fiber properties—length, strength, uniformity and micronaire—with R^2 values of 94.1%, 94.3% and 90.4% respectively.

Finally, although we have thoroughly characterized the three approaches to measuring the short fiber content of a bale of cotton in this paper, the only way to actually evaluate the worth of any of these is to study its use in predicting the quality of the textiles produced from the raw cotton. That work will be discussed in a forthcoming publication.

LITERATURE CITED

ASTM Standard D1440. Standard Test Method for Length and Length Distribution of Cotton Fibers (Array Method).

Backe, E.E. 1986. Effect of Short Fiber Content on Plant Performance and Quality. *Textile Res. J.* **56**(21), 112-115.

Bragg, C.K. and Shofner, F.M. 1993. Rapid, Direct Measurement of Short Fiber Content. *Textile Res. J.* **63**(3), 171-176.

Cui, X., Calamari, T., Robert, K.Q., and Krowicki, R. 1997. An Investigation of Cotton Fiber Lengths Measured by HVI and AFIS. Proceedings Tenth EFS System Research Forum. 115-123.

Cui, X., Calamari, T., Robert, K.Q., Price, J.B., and Watson, M.D. 2003. Measuring the Short Fiber Content of Cotton. *Textile Res. J.* **73**(10), 891-895.

Gipson, L. 1999. HVI Short Fiber Content Measurement. *Proceedings of the Beltwide Cotton Conference*. pp. 1406-1407.

Knowlton, J.L. 2001. HVI Short Fiber Measurements. *Proceedings of the Beltwide Cotton Conference*. pp. 1245-1247.

Knowlton, J.L. 2004. Evaluation of Short Fiber Measurement Methods. *Proceedings of the Beltwide Cotton Conference*. pp. 2370-2377.

TABLE I. The range of HVI properties of the twenty-nine cottons in this study.

	Length (in)	Unif. (%)	Str. (g/tex)	Miconaire	HVI SFI (%)	Pred.SFI (%)
Max	1.21	84.40	33.85	5.52	17.13	15.95
Min	0.92	77.80	23.87	2.92	6.86	7.10
Avg	1.09	81.60	28.97	4.34	10.13	9.93

TABLE II. Definitions of the six measures of short fiber content used in this study.

HVISFI	Short Fiber Index as measured by the AMS HVI
PredSFI	Short Fiber Index as predicted from standard HVI data
SFCw1	AFIS SFC(w) measured at SRRC
SFCw2	AFIS SFC(w) measured at CI
SFCw3	AFIS SFC(w) measured at CQRS
SW	% SF measured by the Suter-Webb array at CQRS

TABLE III. Descriptive statistics of the six short fiber measurements in this study.

	HVISFI	PredSFI	SFCw1	SFCw2	SFCw3	SW
N	29	29	29	29	29	29
Mean	10.13	9.93	12.09	11.12	9.73	13.17
SD	2.83	2.63	4.09	3.333	3.32	5.19
C.V.	27.94	26.49	33.90	29.94	34.17	39.39
Min.	6.86	7.09	5.61	6.23	4.67	6.40
Med.	8.76	8.74	12.03	10.69	9.12	11.60
Max.	12.13	15.95	19.76	17.88	17.62	26.60

TABLE IV. The correlation matrix (Pearson's R-values) showing the relationships between each of the six measures of short fiber.

	HVISFI	PredSFI	SFCw1	SFCw2	SFCw3
PredSFI	0.978				
SFCw1	0.886	0.849			
SFCw2	0.903	0.881	0.973		
SFCw3	0.886	0.857	0.964	0.976	
SW	0.945	0.902	0.898	0.928	0.905

TABLE V. Definitions of general fiber properties as measured by HVI, AFIS, and Suter Webb array.

Length	Upper half mean length measured by AMS HVI
Uniformity	uniformity index measured by AMS HVI
Strength	strength measured by AMS HVI
Micronaire	micronaire measured by AMS HVI
AFIS Le1	AFIS fiber length measures at SRRC
AFIS Le2	AFIS UQL fiber length measured at CI
AFIS Le3	AFIS UQL fiber length measured at CQRS
SWUQL	Suter Webb Upper Quartile Length

TABLE VI. The correlation matrix of relationships between the six measures of short fiber content and the other fiber properties.

	HVI SFI	**PredSFI**	**SFCw1**	**SFCw2**	**SFCw3**	**SW**
Length	-0.846	-0.914	-0.662	-0.702	-0.654	-0.736
Uniformity	-0.961	-0.958	-0.915	-0.939	-0.918	-0.949
Strength	-0.811	-0.849	-0.765	-0.771	-0.721	-0.309
Micronaire	-0.278	-0.194	-0.568	-0.493	-0.562	-0.309
AFIS Le1	-0.914	-0.940	-0.84	-0.856	-0.821	-0.844
AFIS Le2	-0.876	-0.942	-0.721	-0.754	-0.707	-0.773
AFIS Le3	-0.873	-0.938	-0.704	-0.746	-0.713	-0.760
SW UQL	-0.880	-0.937	-0.689	-0.738	-0.691	-0.796

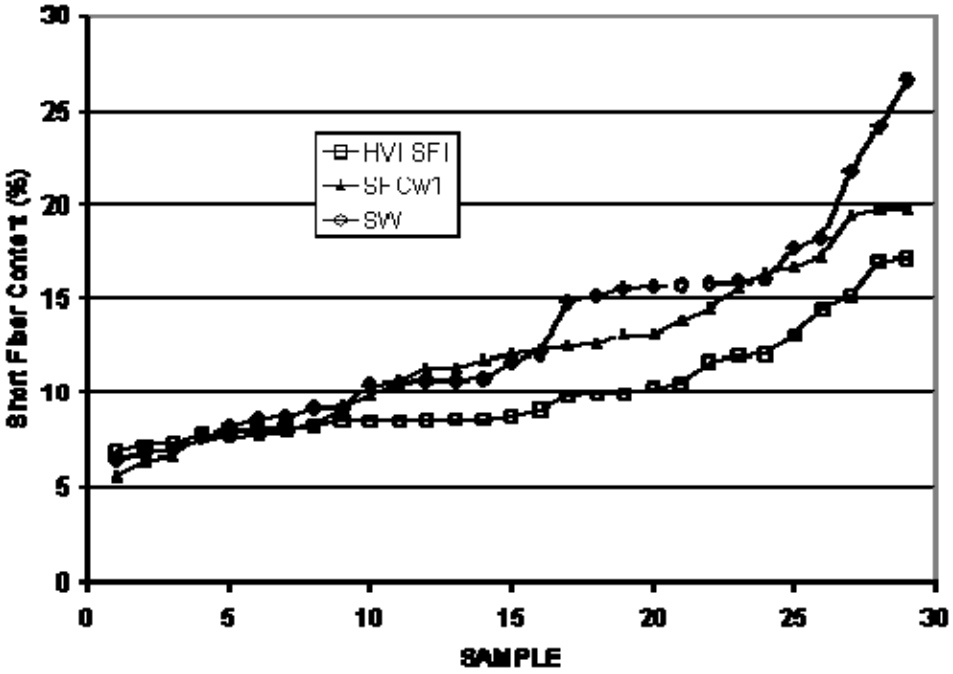

Figure 1. A comparison of the short fiber measurements for the three methods included in this study: a) HVI (SFI); b) AFIS; and c) Suter-Webb.

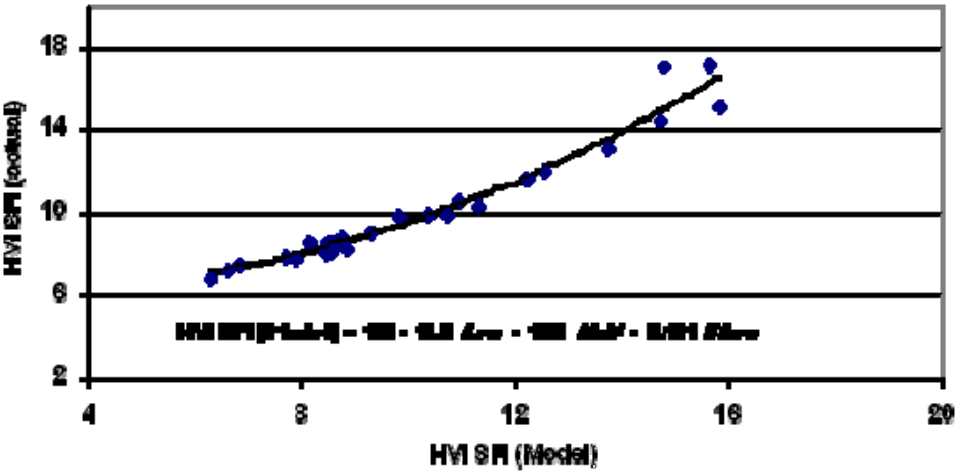

Figure 2. Step-wise multiple regression model for HVI SFI in terms of fiber properties.