ESTIMATION OF SHORT FIBER CONTENT

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Abstract

Cotton short fiber content (SFC) was estimated from the length statistics of longer fibers as measured by the Advanced Fiber Information System. Totals of 25,000 fibers from each of 15 calibration cottons were measured by AFIS. Regression analyses between SFC and mean length, coefficient of variation of length, and upper quartile length were performed. In order to investigate the impact of a biased fiber-sampling technique, a computer simulation using actual fiber length distributions from AFIS was devised. The computer program was used to electronically truncate the fibers by a normal distribution of length reduction having mean values of 1/8", 2/8", or 3/8", at values of CV = 15% and 30% each. Additional regressions were performed on the electronically modified data to study the degradation of accuracy and precision of SFC resulting from the simulated bias in the sampling. The authors conclude that SFC is highly correlated with other fiber length parameters (especially the variance of fiber length), and that the long-fiber parameters can be used to estimate or predict SFC measurements. The fiber length parameters from virtually truncated fiber distributions also predicted SFC with relatively good agreement. The shorter the truncation length and the lower the variation, the better the predicted results. This indicates that short fiber content can be estimated from a biased sample (such as measured by HVI) with an agreement depending on the mean length and its variation for fibers hidden in the comb (clamp), and that an improved sampling method for HVI should increase the accuracy of measured short fiber content.

Introduction

In earlier research on cotton short fiber content (SFC), the investigators found that the coefficient of variation of SFC is always higher than that of longer fiber parameters, such as mean length (ML), upper-half mean length (UHM) and upper quartile length (UQL). The SFC values obtained from different instruments always showed lower consistency than for ML, UHM and UQL. Therefore, efforts were made in this work to estimate the short fiber content from the length properties of longer fibers as measured by the Advanced Fiber Information System (AFIS). If the fiber length distribution of a sample being measured is different from the length distribution of the original sample (population), the sample is biased. For example, a high-volume instrument (HVI) beard is a biased sample because shorter fibers are less likely to be sampled by the comb than longer fibers. In addition, a part of each fiber is clamped inside the clamp, and most fibers are folded around the needles of the clamp; and there is a distance between the front edge of the clamp and the sensor of the HVI. The effect of sample bias can be reduced or eliminated through mathematical, statistical or calibrational methods. In order to investigate the accuracy of estimated short fiber content from a biased sample, a computer simulation using actual fiber length distribution from AFIS was utilized.

Materials and Methods

Cottons

With the help of the USDA-AMS Cotton Standards Division, 15 high-volume instrument (HVI) calibration cottons were selected. This set of cottons had UHM values ranging from 29/32" to 39/32" and corresponding values of SFC in the range from 17.7% to 5.6%.

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AFIS Test

The selected cotton samples were tested on the AFIS with the manufacturer modified measuring unit that has a two-piece nozzle. The AFIS software used was an R&D (Research & Development) version, which provided more fiber parameters than the commercial versions. All tests were performed under the standard atmosphere for textile testing. A total of 25,000 fibers were tested for each of the samples, and the individual fiber data were stored in a computer.

Regression Analysis

Based on the earlier work, the longer-length parameters of ML, CV of length (CV), and UQL, as measured by AFIS, were selected as the independent variables for estimating SFC as the dependent variable by linear regression analysis. The relation between weight-based short fiber content (SFC_w) and the weight-based parameters mean length (ML_w), coefficient of variation of length (CV_w) and upper quartile length (UQL_w) was determined in the form:

1. $SFC_w = A + B\bullet(ML_w) + C\bullet(CV_w) + D\bullet(UQL_w)$

where A, B, C, and D were the coefficients of the linear regression.

Computer Simulation of Biased Samples

In order to investigate the accuracy of estimation of short fiber content from a biased sample, a computer simulation using actual fiber length distributions from AFIS was employed. A computer program was developed for randomly selecting fibers from our database of fiber length and randomly truncating a portion of the fiber length. The program also excluded fibers shorter than the specified length (following a normal distribution as described later), and then calculated the fiber length parameters based on the new (cut or truncated) fiber length distribution. This simulated testing a biased sample, such as might be available in a clamped beard. Data of 25,000 fibers from each of the cottons measured by AFIS were used in the simulation. The computer program was used to virtually truncate the fibers by a random length, **n**, having normal distribution $\mathbf{n}(\mu, \sigma)$, where μ is the mean and σ is the standard deviation of the length reduction. In the simulation, μ was varied in three steps from 1/8" to 3/8", and two values of σ, corresponding to CV values of 15% and 30%. From the modified length distribution of the simulated "clamped" fibers, the new weight-based parameters of short fiber content (SFC_{wc}), mean length (ML_{wc}), coefficient of variation of length (CV_{wc}), and upper quartile length (UQL_{wc}) were calculated for each cotton at the three values of μ and two values of σ. Another regression analysis was then performed to define the relation between SFC_w and these new fiber length parameters of the biased sample. That new relation was determined in the form:

2. $SFC_w = A + B\bullet(ML_{wc}) + C\bullet(CV_{wc}) + D\bullet(UQL_{wc}) + E\bullet(SFC_{wc})$

where A, B, C, D, and E were the coefficients of the linear regression.

Results and Discussion

The coefficients of the regression of SFC_w onto the longer length parameters for the samples are given in Table 1. The estimation results are shown in Figure 1. The line shown in the figures is the 1:1 equality line for the estimated *vs.* measured SFC. The correlation between the SFC_w estimated from the AFIS length parameters and the SFC_w measured directly by AFIS was very high ($R^2 = 0.985$).

The results from the computer simulations are given in Table 2 and Table 3 as the coefficients of the regression of SFC onto the three longer length parameters plus the SFC_{wc} which were calculated from the truncated distributions. The corresponding estimation results for the electronically modified cotton distributions are shown in Figure 2 through Figure 7.

These data show that the fiber length parameters from the truncated fibers still predicted SFC with relatively good agreement. The consistent trend was that the shorter the truncated length and the lower the variation, the better the predicted results. This result supports the interpretation that SFC can be estimated from a biased sample (such as measured by HVI) with an agreement depending upon the mean length and the variation of fibers hidden in the comb (clamp). For example, when the average truncated fiber length is 1/8 inch with 15% CV, the correlation coefficient between the observed and estimated short fiber contents is $R^2 = 0.991$, and the differences between them range from - 0.55% to +0.0.47% (see Figure 2). When the average truncated fiber length is 3/8 inch with 30% CV, the correlation coefficient between the observed and estimated short fiber contents was reduced to $R^2 = 0.903$ and the differences between them were widened to a range of - 1.76% to +1.21% (see Figure 7). This indicates that an improved sampling method for HVI should increase the accuracy of measured short fiber content.

It can be noted that the range of SFC of the calibration cottons is wider than that of commercial cottons. A wider range usually yields a higher correlation coefficient in smaller sample sets. We are currently studying another, larger set of cotton samples which more closely resemble commercial cottons.

Based on the results of the AFIS tests and the computer simulation, the sample non-uniformity was found to contribute a major portion of the variation in the measured short fiber content (about 70% in terms of standard deviation). The confidence intervals were worse than ±1% for two tests, while the *best achievable* confidence intervals were about ±0.5% for two tests.

Conclusions

SFC has relatively high correlation coefficients with other fiber length parameters (especially the coefficient of variation of fiber length). These other parameters can be used to estimate or predict SFC. In addition, based on the results from computer simulation, the fiber length parameters from truncated fiber distributions still predicted SFC with relatively good agreement. The shorter the truncation length and the lower the variation, the better the predicted results. This suggests that short fiber content can be estimated from a biased sample (such as measured by HVI) with an agreement depending on the mean length and its variation for fibers hidden in the comb (clamp). Therefore, an improved sampling method for HVI should increase the accuracy of measured short fiber content.

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Table 1. Coefficients of the regression equation for estimation of SFC_w from longer-fiber parameters.

Length Parameter	Regression Coefficient	
const.	A	-50.99
ML_w	B	36.84
CV_w	C	1.52
UQLw	D	-27.23
	R^2	0.985
	Refer to:	Fig. 1

Table 2. Coefficients of the regression equation for estimation of SFC_w from longer-fiber parameters of the cut-fiber distributions and SFC_{wc} (Calibration cottons with truncation CV = 15%).

Length Parameter	Regression Coefficient	Truncation length 1/8"	2/8"	3/8"
const.	A	14.53	-19.68	-13.66
ML_{wc}	B	-8.94	-38.31	-99.42
CV_{wc}	C	0.0245	0.1134	-0.4399
UQL_{wc}	D	0.9383	44.91	84.36
SFC_{wc}	E	17.69	0.6168	0.4841
	R^2	0.991	0.952	0.914
	Refer to:	Fig. 2	Fig. 4	Fig. 6

Table 3. Coefficients of the regression for estimation of SFC_w from longer-fiber parameters of the cut-fiber distributions and SFC_{wc} (Calibration cottons with truncation CV = 30%).

Length Parameter	Regression Coefficient	Truncation length 1/8"	2/8"	3/8"
const.	A	18.45	18.44	39.85
ML	B	-23.10	-119.12	-183.77
CV	C	-0.406	-0.8521	0.9425
UQL	D	34.26	107.01	146.03
SFC_{wc}	E	0.8785	0.7350	0.4685
	R^2	0.974	0.923	0.903
	Refer to:	Fig. 3	Fig. 5	Fig. 7

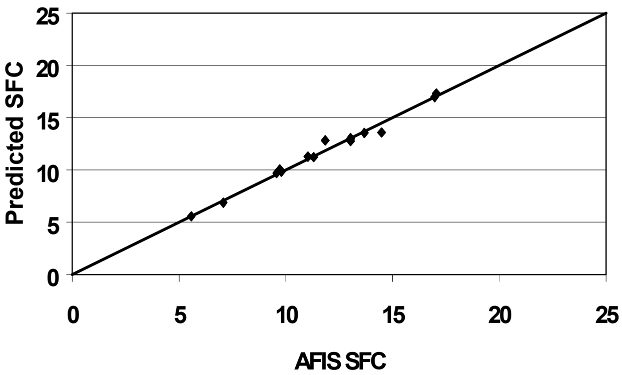

Figure 1. Estimation of SFC from Longer Fiber Properties (AFIS).

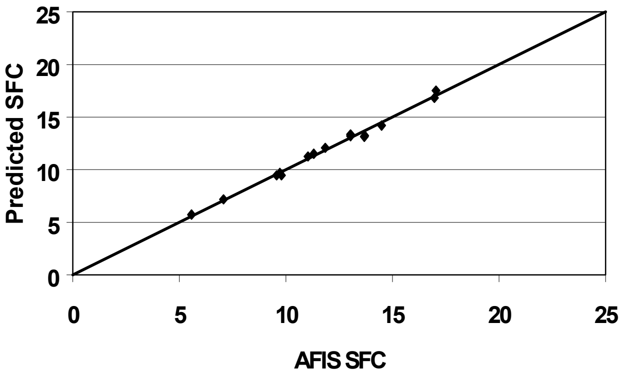

Figure 2. Estimation of SFC from Modified-Fiber Properties (AFIS) (Cut length = 1/8", CV = 15%).

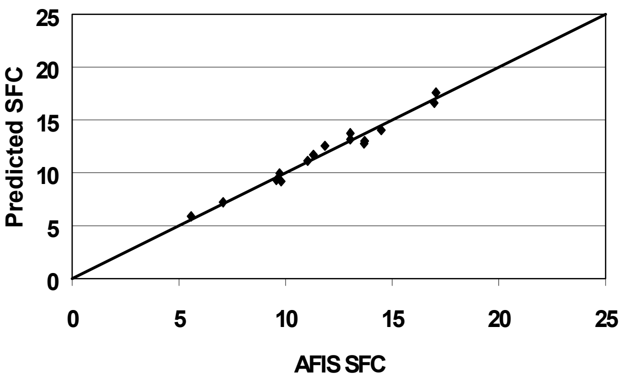

Figure 3. Estimation of SFC from Modified-Fiber Properties (AFIS) (Cut length = 1/8", CV = 30%).

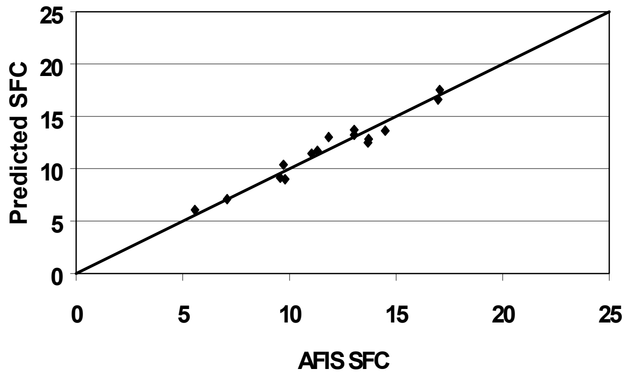

Figure 4. Estimation of SFC from Modified-Fiber Properties (AFIS) (Cut length = 2/8", CV = 15%).

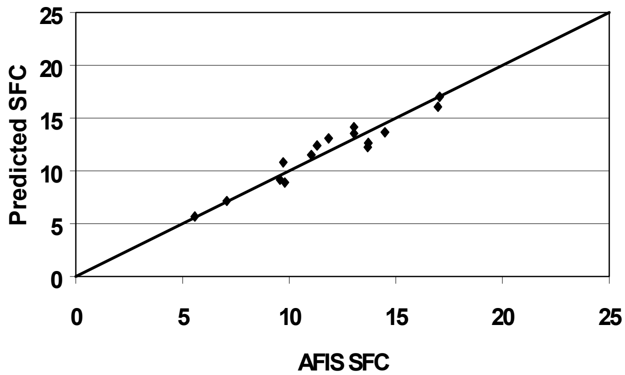

Figure 5. Estimation of SFC from Modified-Fiber Properties (AFIS) (Cut length = 2/8", CV = 30%).

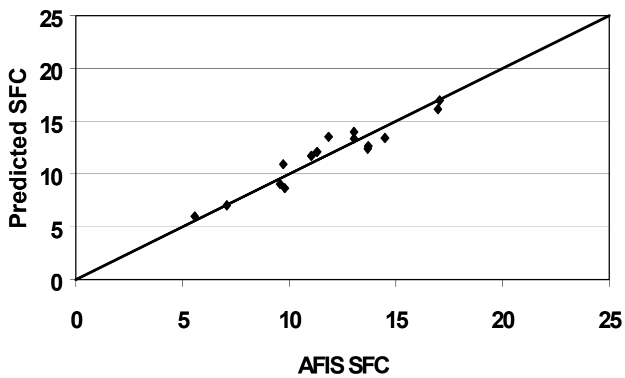

Figure 6. Estimation of SFC from Modified-Fiber Properties (AFIS) (Cut length = 3/8", CV = 15%).

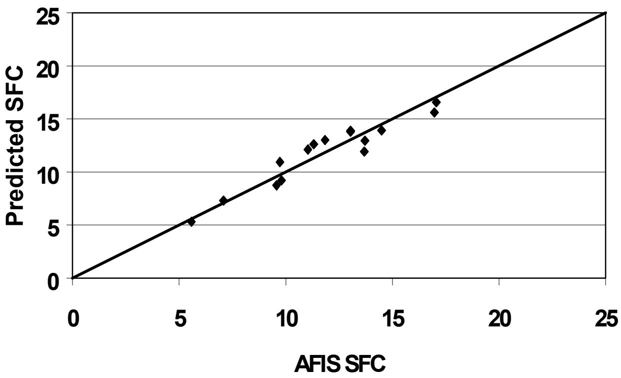

Figure 7. Estimation of SFC from Modified-Fiber Properties (AFIS) (Cut length = 3/8", CV = 30%).