MODELING THE FIBER LENGTH DISTRIBUTION FROM DATA OF THE BEARD TESTING METHOD

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Abstract

Current rapid length measurement instruments utilizing the beard testing method don't report the entire length distribution of the measured sample, but only several length parameters. Making the length distribution available will not only enable the computation of different length parameters, but, more importantly, also provide complete information for evaluating the sample's length characteristics and thus its quality. We present a method that can utilize experimental data from the beard testing method to obtain the sample's entire length distribution. Staple diagrams of samples were established based on fiber length data of the tested portion of a fiber beard. A computer model was developed to utilize the staple diagrams of the tested portions to find the entire length distributions of the original samples. These distributions calculated from the beard method were compared to AFIS measured data of the original samples. The results showed good agreements.

Introduction

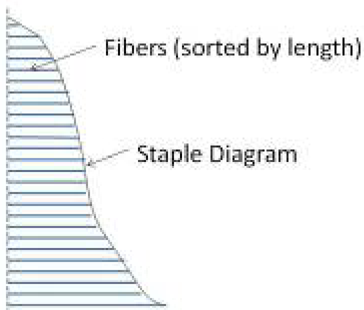
Cotton fiber length is a key property of cotton in marketing and yarn processing. Many methods have been developed to measure different cotton length parameters. Among these methods, the beard testing method can rapidly report length parameters. By using optical or other methods, the beard testing method scans a fiber beard instead of individual fibers. This method is based on the fibrogram theory, which was developed by Hertel in 1940's (Hertel 1940). Various length parameters can be obtained from the fibrogram. However, when applying the fibrogram theory in real measurements, the device could alter the observed original fiber length distribution, which causes challenges in obtaining the entire original length distributions of the original cotton samples (Suh *et al* 2006, Cai *et al* 2009).

Current rapid length measurement instruments utilizing the beard method don't report the entire length distribution of the measured sample, but only several length parameters such as Mean Length (ML), Upper Half Mean Length (UHML), Short Fiber Content (SFC), and Uniformity Index (UI). Obtaining the entire fiber length distribution instead of a limited number of length parameters will enable a more complete evaluation of the cotton sample's quality. For example, if the entire length distribution can be rapidly obtained from the beard testing method, we can compute any length parameters to suite our customers' needs globally (Cai *et al* 2011). The change of the length distribution curve (probability density function, PDF) may indicate impacts from different cotton processing stages (Krifa 2008). In addition, it may provide a new improved procedure of instrument calibration.

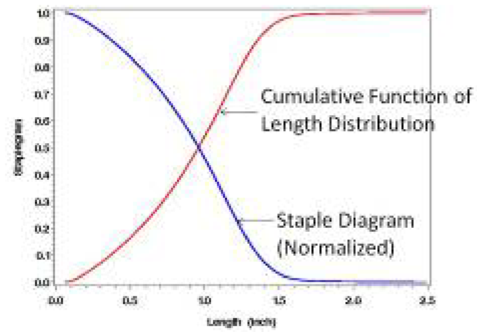
For the purpose of improving cotton fiber length measurements and expanding the application of the beard test results, a research has been carried out to obtain the fiber length distribution from the rapid beard testing method. We have been developing different approaches, such as using the Partial Least Squares (PLS) regression method to study the inferences between the scanned fiber length distribution and the original distribution (Cui *et al* 2009, Cai *et al* 2010). In this paper, we present a method that can directly handle the scanned staple diagram of a fiber beard.

Materials and Method

If all individual fibers in a cotton sample are arranged into an array in such a way: sort the fibers from the shortest to the longest, put fibers side by side evenly, and align all leading ends at one straight line; then all the trailing ends form a contour. This contour is the staple diagram (Figure 1a). The relationship between the staple diagram and the cumulative distribution function is that, the normalized staple diagram is the complement of the cumulative function by number, as shown in Figure 1b. Therefore, if we can obtain the staple diagram of the original fiber beard, we can obtain the cumulative function of the original beard, and then compute the distribution density function form the cumulative function.



(a)



(b)

Figure 1. (a) Fibers arranged to form a staple diagram (b) Relationship between the normalized staple diagram and the cumulative function of fiber length distribution

The fibrogram is directly related to the staple diagram. It is a result of the integration of the staple diagram (Equation 1):

$$G(x) = \int_y^L (1 - F(y))dy \tag{1}$$

in which $G(x)$ is the fibrogram and $F(y)$ is the cumulative distribution function. From the above discussions we can see that modeling the staple diagram has the advantage of connecting the fibrogram and the distribution density function together.

In the beard testing for length measurement, not the entire fiber beard, but a portion of it is actually scanned by the device. We define the scanned portion as the projecting portion. Experimental data show that there is an apparent discrepancy between the staple diagrams of the original beard and the projecting portion of the fiber beard (Figure 2).

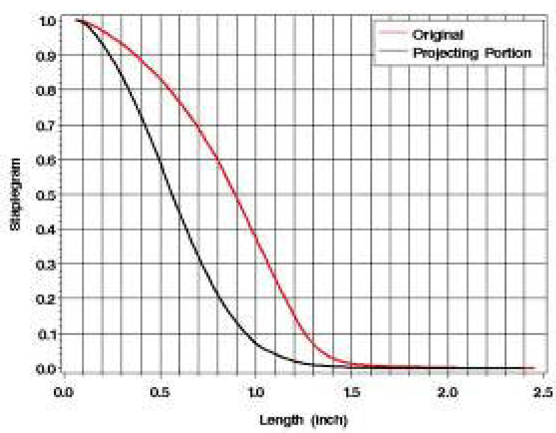


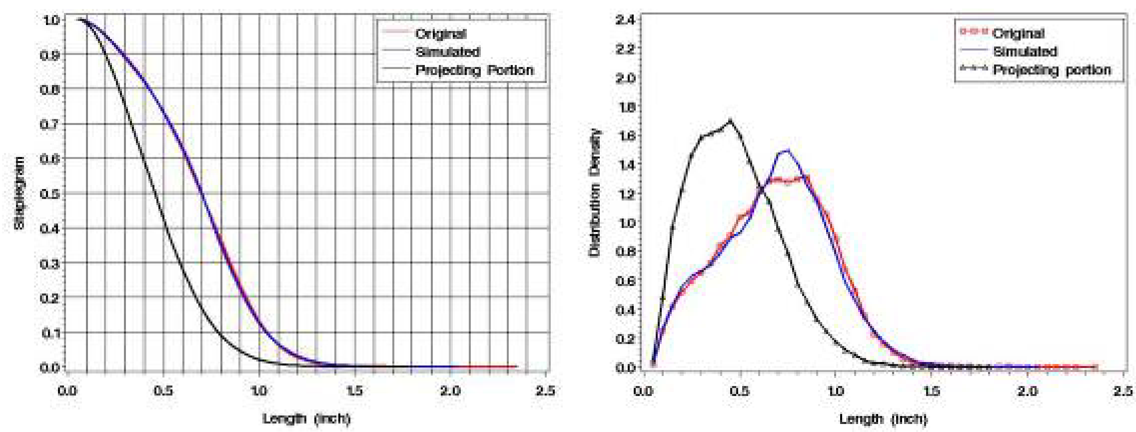
Figure 2. The staple diagrams of the original fiber beard and the projecting portion

We developed a method to compute the staple diagram of the original beard from that of the projecting portion. In order to model the difference between the two staple diagrams, we used our earlier findings in fiber length distributions. We have reported that the mixed Weibull distribution can be used to describe the distributions of the original beard and the projecting portion (Cui *et al* 2009). Since the staple diagram is the complement of the cumulative function, it is logical to adopt the form of the cumulative function (Equation 2) of the Weibull distribution to describe the staple diagram that is used for adjusting the projecting portion.

$$S(x) = 1 - e^{-\theta x^{\lambda}} \tag{2}$$

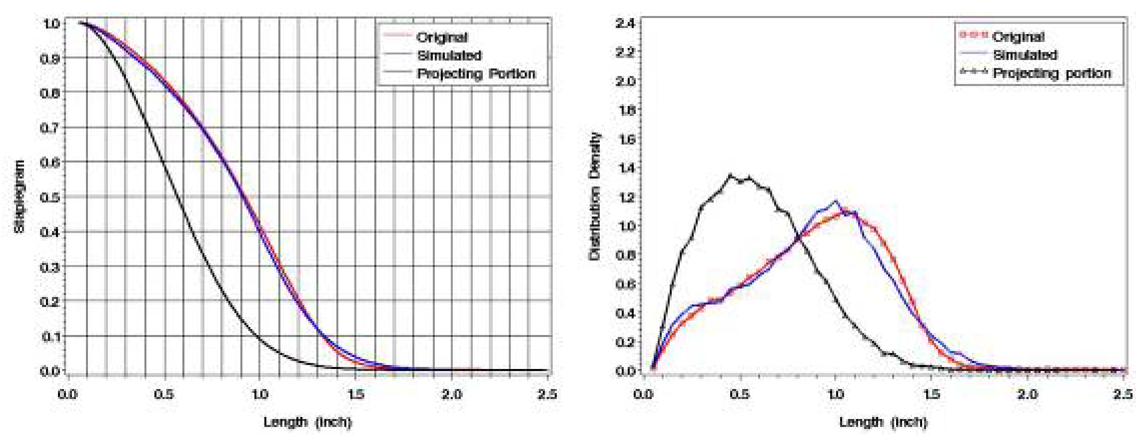
Results

We used experimental data from AFIS to generate the staple diagrams of the projecting portion. These generated staple diagrams were used as inputs to the model. AFIS measures individual fiber lengths. Therefore, in theory, the staple diagram of the projecting portion constructed from AFIS data should be the same as the scanned staple diagram of a beard. The staple diagram of the original beard then was calculated using the model and compared to experimental data. The results from our model matched the experimental results very well (Figures 3 and 4). Figure 3a shows the staple diagram simulated by using the model and Figure 3b shows the PDF of the distributions of a cotton sample that has a mean length by weight of 0.809 inch. Figures 4a and 4b show the results of a cotton sample that has a mean length by weight of 1.04 inch. The PDF curves were computed from the staple diagrams since PDF is the first derivative of the cumulative function, which is the complement of the staple diagram.



(a) (b)

Figure 3. Staple diagrams and PDFs of the original beard and the model result (mean length by weight: 0.809 inch)



(a) (b)

Figure 4. Staple diagrams and PDFs of the original beard and the model result (mean length by weight: 1.04 inch)

From the modeled staple diagrams and PDFs, we also computed the length parameters and compared them to experimental results. These parameters are Mean Length by weight (MLw), Mean Length by number (MLn), Upper

Half Mean Length (UHML), Lower Half Mean Length (LHML), Upper Quartile Length by weight (UQLw), Upper Quartile Length by number (UQLn), Shorter Fiber Content by weight (SFCw), and Short Fiber Content by number (SFCn). In addition to R^2s, we compared the differences between the modeled values and tested values. The comparison is listed in Table 1, which has 14 samples. The unit for length is inch. These preliminary results show that the modeled parameters and the tested parameters are comparable. We are continuing this work to add more samples and to refine our models.

Table 1. Differences between modeled and tested length parameters

Sample	SFCw	SFCn	UQLw	UQLn	MLw	MLn	UHML	LHML
1	0.4%	0.4%	0.009	0.011	0.005	0.002	0.006	0.001
2	0.7%	0.8%	0.013	0.005	0.009	0.009	0.012	0.007
3	1.0%	1.9%	0.002	0.004	0.007	0.012	0.004	0.014
4	0.0%	0.5%	0.014	0.002	0.010	0.004	0.015	0.001
5	0.5%	0.4%	0.014	0.002	0.019	0.013	0.021	0.010
6	0.3%	1.1%	0.002	0.021	0.001	0.010	0.003	0.013
7	0.2%	0.4%	0.025	0.002	0.017	0.010	0.028	0.003
8	0.0%	1.1%	0.027	0.002	0.016	0.000	0.028	0.009
9	0.2%	1.5%	0.039	0.012	0.025	0.006	0.039	0.006
10	0.2%	0.8%	0.013	0.032	0.013	0.009	0.013	0.007
11	1.3%	2.9%	0.002	0.002	0.007	0.014	0.001	0.017
12	0.3%	0.1%	0.000	0.003	0.005	0.006	0.001	0.006
13	0.3%	0.4%	0.014	0.004	0.003	0.004	0.012	0.007
14	0.5%	0.4%	0.027	0.011	0.028	0.018	0.034	0.011
Average Difference	SFCw	SFCn	UQLw	UQLn	MLw	MLn	UHML	LHML
	0.42%	0.92%	0.014	0.008	0.012	0.008	0.016	0.008

Conclusions

Current rapid length measurement instruments utilizing the beard testing method only report several length parameters. Obtaining the length distribution will not only enable the computation of different length parameters, but also provide complete information for evaluating the sample's length characteristics and thus its quality. A new model has been developed to obtain the entire length distribution of a cotton sample by modeling the staple diagram of the scanned projecting portion of a beard. Comparisons between model results and AFIS data show good agreements, indicating that the proposed approach is a very promising technique for obtaining fiber length distributions from the beard testing method.

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References

Cai, Y., X. Cui, J. Rodgers, V. Martin, and M. Watson. 2009. A Study on the Hidden Portion of the Fiber Beard in Cotton Length Measurements. *Proceedings of the 2009 Beltwide Cotton Conference*. 1498.

Cai, Y., X. Cui, R. Belmasrour, L. Li,, C. Delhom, J. Rodgers, V. Martin, and M. Watson. 2010. Using Partial Least Squares Regression to Obtain Cotton Fiber Length Distributions from the Beard Testing Method. *Proceedings of the 2010 Beltwide Cotton Conference*. pp1411-1413.

Cai, Y., X. Cui, J. Rodgers, D. Thibodeaux, V. Martin, M. Watson, and S.S. Pang. 2011. An investigation on different parameters used for characterizing short cotton fibers. *Textile Research Journal*, 81(3). http://trj.sagepub.com/content/early/2010/09/16/0040517510380105

Cui, X., J. Rodgers, Y. Cai, L. Li, and R. Belmasrour. 2009. Obtaining Cotton Fiber Length Distributions from the Beard Test Method, Part 1 - Theoretical Distributions Related to the Beard Method. *Journal of Cotton Science*. 13(4) 265-273.

Hertel, K.L. 1940. A method of fiber-length analysis using the fibrograph. *Textile Research Journal*. 10:510-525.

Krifa, M. 2008. Fiber Length Distribution in Cotton Processing: A Finite Mixture Distribution Model. *Textile Research Journal*. 78:688-698.

Suh, M.W., S.J. Doh, and M.D.Watson. 2006. Short Fiber Content Estimation – New Findings and A New Approach. *Proceedings of the 2006 Beltwide Cotton Production Conference*. pp1963-1969.