USING PARTIAL LEAST SQUARES REGRESSION TO OBTAIN COTTON FIBER LENGTH DISTRIBUTIONS FROM THE BEARD TESTING METHOD

Yiyun Cai
Louisiana State University
Baton Rouge, LA
Xiaoliang Cui
USDA, ARS, SRRC
New Orleans, LA
Rachid Belmasrour
Linxiong Li
University of New Orleans
New Orleans, LA
Chris Delhom
USDA, ARS, SRRC
New Orleans, LA
James Rodgers
USDA, ARS, SRRC
New Orleans, LA
Vikki Martin
Mike Watson
Cotton Incorporated
Cary, NC

Abstract

The beard testing method for measuring cotton fiber length is based on the fibrogram theory. However, in the instrumental implementations, the engineering complexity alters the original fiber length distribution observed by the instrument. This causes challenges in obtaining the entire original length distribution of a cotton sample. For the purpose of improving cotton fiber length measurements and expanding the application of the test results, new approaches were explored to obtain the original length distribution from the rapid beard testing method. The Partial Least Squares Regression algorithm was applied to study the relationship between the observed length distribution in a fiber beard and the original length distribution. The new approach showed promising potential to estimate the original length distribution from the observed length distribution of a fiber beard.

Introduction

Cotton fiber length is a key property of cotton in marketing and yarn processing. Many efficient methods have been developed to measure cotton length parameters, such as Upper Half Mean Length, Upper Quartile Length, and Uniformity Index. These parameters can be measured by using AFIS (Advance Fiber Information System, Uster Technologies, Knoxville, TN) or HVI (High Volume Instrument, Uster Technologies, Knoxville, TN). The beard testing method can rapidly measure a fiber beard instead of individual fibers to obtain some important length parameters. The original fibrograph theory was developed by Hertel in 1940's. It has served as the basic theory of the beard testing method for obtaining fiber length parameters. Bundle testing devices (such as HVI) scan light attenuation or measure airflow change at different distances from the tip of the longest fiber in the beard to the baseline of the clamp, then determine the fiber mass at each length of the beard and construct the fibrogram. Various length parameters can be obtained from the fibrogram.

However, in the instrumental implementations of the fibrograph theory, the engineering complexity alters the original fiber length distribution observed by the instrument (Cai et al. 2009). This causes challenges in obtaining the original length distribution of a cotton sample. Current instruments only report a limited number of statistical parameters, not the entire length distribution of the measured cotton sample. Obtaining the entire fiber length distribution instead of 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, any length parameters can be calculated to suite our customers' needs globally. The change of the length distribution curve may indicate impacts from different cotton processing stages (Krifa 2008). In addition, it may provide a new improved procedure of length calibration on beard testing instruments.

For the purpose of improving cotton fiber length measurements and expanding the application of the test results, we have been exploring new approaches to obtain the fiber length distribution from the rapid beard testing method. The results from the Partial Least Squares regression method are very encouraging.

Materials and Method

In this investigation, we looked at the fiber length probability density function (PDF) of the beard portion that is scanned by the instrument (the projecting portion), then we compared it to the PDFs of the entire original beard. Both PDFs can be described by using mixed Weibull functions (Krifa 2008; Cui et al. 2009). Each mixed Weibull distribution is a combination of two Weibull functions and has five parameters:

$$f(x;\alpha,\lambda_1,\theta_1,\lambda_2,\theta_2) = \alpha f_1(x;\lambda_1,\theta_1) + (1-\alpha) f_2(x;\lambda_2,\theta_2) \tag{1}$$

For obtaining these parameters, eight cottons with different length characteristics were tested using AFIS and HVI. The data of the original fibers were directly tested by using AFIS. An HVI FibroSampler was used to make fiber beards. These beards were combed and brushed to remove loose fibers as did in HVI length testing with strength testing disabled. Then the projecting portions were cut off along the baseline of the clamp, collected, gently and thoroughly opened, formed into thin fiber slivers, and tested on AFIS. We computed each PDF based on at least 35,000 individual fibers.

With these experimental data, our efforts were to find a regression model that computes the five parameters of the original beard PDF from the five parameters of the projecting portion PDF. With this inference, we can obtain the entire fiber length distribution of the original beard from data of the scanned projecting portion. At first we tried the ordinary least squares regression to infer the parameters of the original length distribution from those of the projecting portion, but it did not yield satisfactory results mostly because of two reasons: relatively small sample size, and multicollinearity. We then used the Partial Least Squares (PLS) regression to carry out the inference. PLS is a recent statistics technique that generalizes and combines features from principal component analysis and multiple regression. PLS methods are less restrictive. It can better handle situations such as small sample size and multicollinearity (Garthwaite 1994). We used the Nonlinear Iterative Partial Least Squares Algorithm to carry out the PLS regression.

Results

Our results show a good match between the PDF from experimental data and the PDF predicted by the model. We also used the PLS predicted PDF to compute several length parameters such as mean length and upper half mean length. These calculated length parameters are in good agreement with experimental results (Table 1).
It should be pointed out that the results presented here serve as an illustration of our model development and calibration. We are continuing the experiments with new samples to generate “prediction” data set.

Table 1. Comparisons of some cotton fiber length parameters from experimental data and PLS

Sample	Source	MLn	UHML	LHML	SFCn(%)	UI(%)
30	Experimental	0.658	0.983	0.494	31.7	80.8
	PLS	0.654	0.977	0.492	31.5	80.5
31	Experimental	0.691	0.997	0.528	26.1	81.7
	PLS	0.682	0.996	0.518	27.8	81.4
33	Experimental	0.737	1.105	0.553	26.7	80.7
	PLS	0.787	1.122	0.607	20.5	81.8
34	Experimental	0.804	1.153	0.617	20.8	81.9
	PLS	0.803	1.154	0.615	21.1	81.9
35	Experimental	0.810	1.168	0.620	20.5	81.5
	PLS	0.818	1.163	0.630	19.4	81.9
36	Experimental	0.845	1.233	0.642	20.8	81.5
	PLS	0.834	1.192	0.641	19.4	81.8
37	Experimental	0.857	1.257	0.650	20.5	81.4
	PLS	0.837	1.248	0.629	22.8	80.9
38	Experimental	0.899	1.299	0.687	19.2	82.1
	PLS	0.891	1.293	0.680	19.8	82.0

Conclusions

The implementation of the PLS provides a new approach to predict the original length distribution from the length distribution of the projecting portion. The preliminary results indicate that the proposed PLS method is a very promising technique for obtaining fiber length distribution from the beard testing method.

Disclaimer

References

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

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

Garthwaite, P.H. 1994. An Interpretation of Partial Least Squares. *Journal of the American Statistical Association*. 89:123-127.

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.