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STATISTICAL PARAMETERS OF COTTON SHORT FIBERS

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Abstract

Various statistical parameters of cotton fiber length distributions were calculated from AFIS (Advanced Fiber Information System) test data of 21 cottons of different varieties and growth locations. The results show that the SFC (short fiber content) defined by 0.5 inches is a good indicator of short fibers in a sample based on the high correlation coefficients with short fiber content values defined by other lengths such as 0.4 or 0.6 inches. However, the measured short fiber content has very high variation, as high as 6.8 times the CV% of UHML (Upper Half Mean Length). The high variation of SFC is one of the major problems hindering its use in the cotton classing system. The LHML (Lower Half Mean Length), a new parameter of short fibers is introduced in this study. The results show that the LHML has very high correlation coefficient with short fiber content, but much lower variation, only 1/3 of the CV% (Coefficient Variance) of the SFC. Therefore, the LHML is a good candidate for substituting the short fiber content. The uniformity index that is used in the U.S classing system correlates to the SFC, but the Upper Half Mean Length has very low correlation with the SFC.

Introduction

Short fiber content is an important quality parameter of cotton. Cotton with low short fiber content can produce strong, fine, and uniform yarns, which also increases the efficiency in textile processing because of less yarn breakage or ends-down. In a recent survey by ITMF (International Textile Manufacturers Federation) of 174 textile companies in 13 countries, 162 companies identified that short fiber content is important or very important for processing cotton. The most commonly used parameter for cotton short fibers is the short fiber content. The definition of short fiber content in the U.S. is that the weight or number percentage of fibers with length less than 0.5 inches ($SFC_{0.5}$), while the Chinese method defines the short fiber content using 16mm (0.63 ≈ 5/8 inches) for short staple cotton and 20 mm (0.79 inches) for long staple cotton. With the increasing international trade of U.S. cotton, it is important to understand the relationship between the different parameters of short fibers.

In responding to the demand from the textile industry and international trade of cotton, the National Cotton Council passed a resolution to study the feasibility of adding short fiber content measurement to the current cotton classing system. The USDA ARS (Agricultural Research Service), AMS (Agricultural Marketing Service) and the Cotton Incorporated have been conducting research on this issue [Cui, Knowlton]. One of the most difficult problems is the very high variation in the measured short fiber content. Therefore, we studied other statistical parameters of cotton fiber length distribution that also characterize the shorter fiber portion. Those parameters include "Lower Quartile Length" (LQL), and "Lower Half Mean Length" (LHML). The definition of LQL is the length that 25% fibers by weight or by number is short than. The definition of LHML is that the mean length by number of the shorter one-half (50%) by weight of the fibers.

Materials and Methods

Samples were taken from a set of 21 bales of U.S. Upland cotton in an ATMI (American Textile Manufacturers Institute) spinning study headed by David McAlister at the USDA ARS Cotton Quality Research Station (CQRS) at Clemson, South Carolina. The cotton variety and growth area (state) are listed in Table 1.

Each sample was conditioned under the standard atmosphere for testing textiles (temperature 70±2 °F, relative humidity 65±2%), and tested on an AFIS with 5 replications and 5,000 fibers in each replication. The test data was stored in the computer for further data analysis. A computer program was designed using C Language to calculate fiber length parameters including SFC by weight defined by length limits of 0.3, 0.4, 0.5, 0.6, and 0.7 inches ($SFCw_{0.3}$, $SFCw_{0.4}$, $SFCw_{0.5}$, $SFCw_{0.6}$, $SFCw_{0.7}$), LQL_n (Lower Quartile Length by Number), LQL_w (Lower Quartile Length by weight), LHML, etc. Two other length parameters (Modal Length and Quality Length) that are used in China are also included in the study in view of the expanding cotton export to China. The definition of the Modal Length is that the length of fibers that account for the most weight or number in the fiber length distribution. The definition of the Quality Length is that the average fiber length by weight of fibers longer than Modal Length. The relationships among these parameters and the variation of these parameters were analyzed. The bales were converted into open-end, ring, and Vortex yarns at CQRS. The simple correlation coefficients among the length parameters and yarn properties as well as the spinning performance were analyzed. The results involving yarn data will be reported in future.

Results and Discussion

A summary of the average values of the length parameters characterizing shorter fibers is listed in Table 2-a and characterizing longer fibers Table 2-b. The value of short fiber content increases non-linearly as the increase of the limiting length. For instance, the difference between $SFCw_{0.3}$ and $SFCw_{0.4}$ is 2.6%, while the difference is 6.1% between $SFCw_{0.6}$ and $SFCw_{0.7}$.

It is noticed from the data (in Table 2-b) that the UQL_w and the UHML have very similar values. The difference between the UQL_w and the UHML is only 0.01 inch based on the average data. Perhaps, this is the main reason people usually say "staple length" without specifying UQL_w or UHML. However, the Quality Length used by the Chinese (also referred as staple length) is much higher (about 0.10 inches) than UQL_w or UHML.

A summary of the coefficient of variation (CV%) of the various fiber length parameters is given in Tables 3-a and 3-b. The CV of short fiber content decreases as the limiting length defining the short fiber content increases. It is important to notice that the CV of the short fiber content is about 6.8 times higher than that of UQL_w and UHML, while the CV of LHML (Lower Half Mean Length) is much lower than that of short fiber content, only about 1/3 of the latter. This indicates that the LHML may be a good substitute for short fiber content.

Although LHML has its advantages over SFC in terms of variation, it does not provide direct percentage of short fibers in a cotton, which may be more desirable to know in certain situations such as estimating combing waste. Our results show that the SFC can be estimated with good accuracy based on LHML. Based on the data from this study, a simple linear regression yields R^2 of 0.9749 as can be seen from Figure 1.

It is interesting to notice that the CV of the Quality Length used in China is almost 3 times as high as that of the UHML, which is caused by the high variation in the Modal Length (CV% of 6.37% on average) that defines the Quality Length. By definition, the Quality Length is the average fiber length by weight of fibers longer than the Modal Length, and the Modal Length is the length that accounts for the most weight in the fiber length distribution. The noise (lack of smoothness) of the length distribution curve, especially when the sample size is relatively small (a couple of thousand fibers), significantly affects the determination of the peak, and in turn affects the determination of the Modal Length, and this consecutively affects the determination of the Quality Length.

Table 4 lists the simple correlation coefficients among the various fiber length parameters. Some interesting data have been shaded. The short fiber content defined by 0.5 inches shows very high correlation coefficients with short fiber content defined by other lengths (R = 0.954 to 0.994). The LHML also showed a very high correlation coefficient (R = -0.987) with short fiber content $SFC_{0.5}$. In combination with its low variation, the LHML becomes a good candidate for characterizing short fibers of cotton. Based on the data, the Uniformity Index does contain significant amount of information about short fiber content (R = 0.791). On the other hand, the UHML and UQL_w seem to contain very little information on short fiber content (R = 0.072 and 0.028, respectably) based on the data. This contradicts our general beliefs and needs to be further investigated.

Conclusions

The results based on the AFIS data on 21 cottons show that the short fiber content defined by 0.5 inches is a good indicator of short fibers in a sample based on the high correlation coefficients with short fiber content values defined by other lengths from 0.3 to 0.7 inches. However, the measured short fiber content has very high variation, as high as 6.8 times the CV% of fiber Upper Half Mean Length. The results show that the LHML has very high correlation coefficient with short fiber content, but with much lower variation, only 1/3 of the CV% of the $SFC_{0.5}$. Therefore, the LHML is a good candidate for substituting the short fiber content. The Uniformity Index correlates to the SFC, but the Upper Half Mean Length has very low correlation with the SFC.

References

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Table 1. Variety and growth location of the samples used.

Variety	Location	Variety	Location	Variety	Location
Fibermax 832	TX	Paymaster 2326	TX	Delta Pearl	MS
Paymaster 2800	TX	Delta Pine Land 491	GA	PSC 355	MS
Paymaster 2200	TX	PhytoGen 355	GA	Fiber Max 832	MS
Fibermax 819	TX	Fibermax 966	GA	Delta Pine Land 491	MS
Fibermax 989	TX	Delta Pearl	GA	Fibermax 966	MS
Fibermax 958	TX	Fibermax 832	GA	Sure Grow 747	MS
Fibermax 966	TX	Suregrow 747	GA	Paymaster 1218	MS

Table 2-a. Summary of the various fiber length parameters characterizing shorter fibers

	$SFC_{0.3}$ (%)	**$SFC_{0.4}$ (%)**	**$SFC_{0.5}$ (%)**	**$SFC_{0.6}$ (%)**	**$SFC_{0.7}$ (%)**	**LQL_n (in)**	**LQL_w (in)**	**LHML (in)**
Average	2.96	5.59	9.16	13.84	19.97	0.511	0.766	0.600
Maximum	3.61	6.69	11.14	16.52	23.47	0.671	0.829	0.675
Minimum	1.87	3.34	5.31	8.58	13.53	0.457	0.719	0.561

Table 2-b. Summary of the various fiber length parameters characterizing longer fibers

	UQL_n (in)	**UQL_w (in)**	**UHML (in)**	**ML_n (in)**	**ML_w (in)**	**UI (%)**	**Modal L (in)**	**Quality L (in)**
Average	1.089	1.206	1.217	0.804	0.980	80.590	1.120	1.309
Maximum	1.147	1.283	1.296	0.850	1.034	84.560	1.206	1.411
Minimum	1.041	1.129	1.147	0.758	0.937	78.916	1.016	1.174

Table 3-a. Summary of the Coefficient of Variation (CV%) of the various fiber length parameters (shorter fibers)

	$SFC_{0.3}$	**$SFC_{0.4}$**	**$SFC_{0.5}$**	**$SFC_{0.6}$**	**$SFC_{0.7}$**	**LQL_n**	**LQL_w**	**LHML**
Average (%)	10.33	9.58	8.97	8.05	7.31	5.09	2.66	2.98
Maximum (%)	19.36	18.33	18.28	15.63	14.55	10.39	5.15	6.07
Minimum (%)	3.56	4.02	3.67	3.88	3.41	1.67	1.13	1.21

Table 3-b. Summary of the Coefficient of Variation (CV%) of the various fiber length parameters (longer fibers)

	UQL_n	**UQL_w**	**UHML**	**ML_n**	**ML_w**	**UI**	**Modal L**	**Quality L**
Average (%)	1.81	1.31	1.31	2.34	1.61	0.55	6.37	3.81
Maximum (%)	3.29	2.95	2.93	4.89	3.39	1.21	11.77	6.41
Minimum (%)	0.68	0.54	0.62	0.94	0.70	0.20	3.95	2.08

Table 4. Correlation coefficients among fiber length parameters

	$SFC_{0.3}$	$SFC_{0.4}$	$SFC_{0.5}$	$SFC_{0.6}$	$SFC_{0.7}$	LQL_n	LQL_w	LHML
$SFC_{0.3}$	1.000	0.982	0.954	0.924	0.913	-0.939	-0.867	-0.972
$SFC_{0.4}$	0.982	1.000	0.988	0.970	0.958	-0.967	-0.912	-0.990
$SFC_{0.5}$	0.954	0.988	1.000	0.994	0.984	-0.968	-0.937	-0.987
$SFC_{0.6}$	0.924	0.970	0.994	1.000	0.995	-0.952	-0.954	-0.977
$SFC_{0.7}$	0.913	0.958	0.984	0.995	1.000	-0.925	-0.976	-0.977
LQL_n	-0.939	-0.967	-0.968	-0.952	-0.925	1.000	0.833	0.942
LQL_w	-0.867	-0.912	-0.937	-0.954	-0.976	0.833	1.000	0.951
LHML	-0.972	-0.990	-0.987	-0.977	-0.977	0.942	0.951	1.000
UQL_n	-0.416	-0.378	-0.348	-0.337	-0.396	0.151	0.542	0.461
UQL_w	-0.025	0.033	0.072	0.091	0.030	-0.252	0.126	0.050
UHML	-0.068	-0.010	0.028	0.045	-0.018	-0.213	0.174	0.094
ML_n	-0.875	-0.866	-0.849	-0.834	-0.860	0.729	0.905	0.911
ML_w	-0.413	-0.375	-0.349	-0.335	-0.395	0.157	0.531	0.459
UI	-0.682	-0.751	-0.791	-0.807	-0.770	0.866	0.651	0.710
Modal L	-0.059	-0.017	0.013	0.033	-0.018	-0.204	0.180	0.090
Quality L	0.037	0.097	0.134	0.157	0.100	-0.318	0.063	-0.020

Table 4. (continued) Correlation coefficients among fiber length parameters

	UQL_n	UQL_w	UHML	ML_n	ML_w	UI	Modal L	Quality L
$SFC_{0.3}$	-0.416	-0.025	-0.068	-0.875	-0.413	-0.682	-0.059	0.037
$SFC_{0.4}$	-0.378	0.033	-0.010	-0.866	-0.375	-0.751	-0.017	0.097
$SFC_{0.5}$	-0.348	0.072	0.028	-0.849	-0.349	-0.791	0.013	0.134
$SFC_{0.6}$	-0.337	0.091	0.045	-0.834	-0.335	-0.807	0.033	0.157
$SFC_{0.7}$	-0.396	0.030	-0.018	-0.860	-0.395	-0.770	-0.018	0.100
LQL_n	0.151	-0.252	-0.213	0.729	0.157	0.866	-0.204	-0.318
LQL_w	0.542	0.126	0.174	0.905	0.531	0.651	0.180	0.063
LHML	0.461	0.050	0.094	0.911	0.459	0.710	0.090	-0.020
UQL_n	1.000	0.895	0.915	0.784	0.992	-0.271	0.828	0.839
UQL_w	0.895	1.000	0.997	0.456	0.904	-0.658	0.875	0.957
UHML	0.915	0.997	1.000	0.496	0.925	-0.622	0.878	0.956
ML_n	0.784	0.456	0.496	1.000	0.784	0.362	0.448	0.381
ML_w	0.992	0.904	0.925	0.784	1.000	-0.278	0.818	0.843
UI	-0.271	-0.658	-0.622	0.362	-0.278	1.000	-0.540	-0.683
Modal L	0.828	0.875	0.878	0.448	0.818	-0.540	1.000	0.964
Quality L	0.839	0.957	0.956	0.381	0.843	-0.683	0.964	1.000

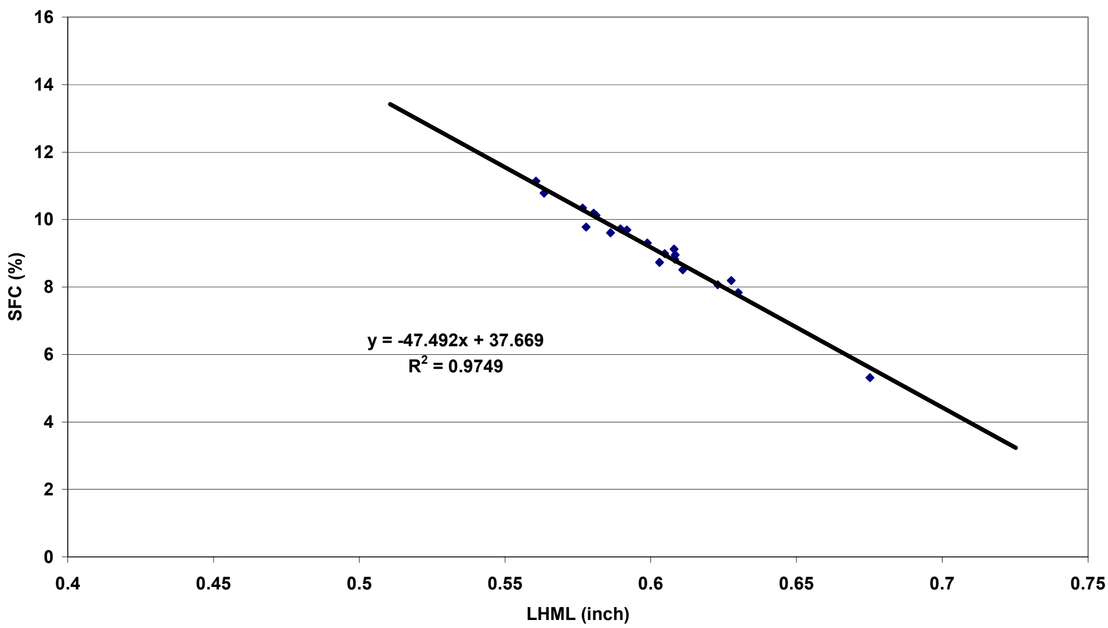

Figure 1. Predicted SFC (Short Fiber Content) from LHML (Lower Half Mean Length).