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AFIS LENGTH DISTRIBUTION IN COTTON SPINNING PREPARATION

Mourad Krifa
International Textile Center
Texas Tech University
Lubbock, TX

Abstract

The presence of excessive amounts of short fibers in cotton bales is unanimously identified as a high priority issue for the cotton industry. Significant productivity and quality losses are related to short fibers. Moreover the problem has recently become an international trade issue and attempts are made to include a measure of short fibers in the cotton commercialization system. Examination of fiber length distribution in the course of spinning preparation revealed that the current parameters used to characterize the length distribution, particularly the Short Fiber Content (SFC), present multiple shortcomings and are not representative of the fiber-process interactions and of the phenomena related to short fibers. The SFC parameter is not reliably usable for fiber quality improvement, cotton commercialization, or process optimization. A new length parameterization is necessary. A new parametric model is being evaluated for fitting the cotton fiber length distribution.

Introduction

The adverse effects of short fibers have become the subject of a unanimous consensus amongst all sectors of the cotton industry, which made the objective of minimizing short fibers a top priority in cotton research. In the course of this research effort, a variety of length measurement methods were used to quantify short fibers. Different parameters were defined for this purpose. For instance, Tallant *et al.* (1960) defined the short fiber content as the percentage of fibers ?" and shorter. Lord (1961) used the percentage of fibers shorter than half the effective length as definition. He also introduced the percentage of fibers shorter than a fixed length as a possible useful definition for some particular purposes. Ultimately, all definitions evolved into a single measure arbitrarily defined as the percentage of fibers less than ½" in length, and designated as the "Short Fibers Content" or SFC.

Efforts to alleviate the short fiber problem are inhibited by the lack of fundamental knowledge about cotton fiber length distribution. This lack of knowledge translates into an incomplete characterization of the distribution pattern and an inadequate prediction of the cotton processing performance and product quality. The cotton industry relies mainly on arbitrary long-established parameters, such as the Short Fiber Content (SFC), that poorly reflect the processing and product performance of the cotton.

Significant research work has been accomplished over several decades to expand the base of knowledge by modeling the entire length distribution and its interaction with the process. Despite these efforts, the probability density function of cotton fiber length distribution remains unknown. Empirical observation and parameterization attempts using mathematical breakage models (Robert and Blanchard, 1991, 1997; Robert *et al.*, 2000) are the only approaches reported in the literature, which limits the usability of the distribution information by the industry.

Reported here are experimental results substantiating some of the shortcomings of the current parameterization of cotton fiber length, particularly the SFC. The length distribution pattern, as provided by AFIS measurement, is examined with respect to the carded spinning preparation, and a candidate parametric model for the distribution function is introduced.

Materials and Methods

A range of 38 upland cotton bales was processed through carded spinning preparation. The card settings were typical for a ring spinning application. Fiber samples were taken at each step of the preparation process: card chute, card sliver, breaker drawing (D1) and finisher drawing (D2) slivers. All fiber samples were analyzed on AFIS and fiber length distribution data was retrieved.

Results and Discussion

AFIS test provides several length parameters deduced from individual fiber measurement. The main include: the mean length, the length upper percentiles, the length CV%, and the Short Fiber Content (defined as the percentage of fibers less than ½'' in length). Fiber length information is provided as number- or weight-biased data (by number / by weight). The length distribution by weight is determined by the weight-frequency of fibers in the different length categories, i.e., the proportion of the total weight of fibers in a given length category. The length distribution by number is given by the proportion of the total number of fibers in the different length categories. The length parameters by weight and by number are computed from the two distributions accordingly.

The AFIS instrument is based on the measurement of individual fibers, as mentioned above, and therefore on the number-frequency methodology. Once the length distribution by number is determined, the apparatus computes the length distribution by weight using the assumption that all the fibers within the tested specimen have the same fineness. Therefore, the distribution by weight is actually a length-biased distribution, where the frequencies, obtained from the original measurement (by number), are weighted (multiplied) by the fiber length they represent.

In what follows, length parameters by number are considered with respect to the changes they reflect after the carding process. It must be noted that length parameters by weight were treated in a similar way and showed analogous result.

Length Parameters

Figures 1 to 4 represent the relationships between length parameters before and after carding (AFIS measurements on card chute and card sliver, respectively). The regression parameters estimates and the corresponding confidence intervals at $\alpha = 0.05$ are summarized in Table 1.

A first observation arising from these exhibits is that all length parameters are highly significantly correlated before and after carding. This implies that the sample preparation (bulk card chute or relatively organized sliver) did not result in a significant alteration of the cottons ranking based on length parameters.

It is apparent from Figures 1 to 4 that, for a large majority of length parameters, the scatter plots relating the pre- to the post-carding results follow closely the equality line. The examination of the regression parameters (Table 1) shows clearly that, in most cases, the y-intercept was non significant and the slope non different from the unity at a 5% confidence level. Among all length parameter, the coefficient of variation (CV%, Figure 2) was the only variable showing a significant deviation from the equality line, which indicates an alteration of length distribution not reflected on the other measured parameters.

Based on the experimental results reported above, the changes occurring to the fiber length distribution during the carding process appear to be rather limited. However, given the aggressive mechanical actions taking place during carding, one would expect the effects on the fiber length distribution to be more substantial than shown by the experimental data. The fact that the experimental results show quite limited changes when considering length parameters would therefore mean that these parameters are not representative enough of the distribution pattern, and thus do not reflect the variations to which the length distribution is subjected.

These results are a clear confirmation of the fact that the short fiber content does not always reflect the phenomena occurring to the length distribution during the different mechanical actions constituting the cotton process. Moreover, this was the case of all other length parameters provided by the AFIS with the exception of the coefficient of variation (CV%). In order to identify these phenomena, it is necessary to consider the entire length distribution pattern as opposed to the parameters treated above. This is done in the following section.

Length Distribution in the Process of Carding

The effect of carding on length distribution is illustrated on Figure 5 for one cotton sample selected as an example. The figure exhibits the plots of length distributions observed on card chute and on card sliver samples. A third plot representing the difference in frequencies of the different length categories was added to the figure in order to better visualize the changes occurring to the distribution pattern.

Figure 5 shows that fiber fragments, below 0.25'' to 0.3'' in length, appear to be reduced after carding. The percentage of fibers between 0.3'' and approximately 0.8'' to 0.9" in length was increased, while the longer fibers decreased. The attenuation of the ?" peak might indicate a fiber fragments removal during carding. Another explanation is that in the card sliver, the fibers are less entangled and better aligned than in the bulk card chute, and therefore, there might be less breakage by the AFIS opener. In any case, these results offer an explanation to the fact that the SFC did not vary after carding. In fact, the decrease in the percentage of fibers shorter than 0.3" and the increase of those between 0.3 and 0.5" resulted in a globally unchanged short fiber content.

The effects explained above were globally common in nature to all the cottons examined. However, the amplitude of the changes in the distribution pattern appeared more sizable for immature-weak cottons than for mature-strong ones.

Modeling Cotton Fiber Length Distribution

The results presented in the previous paragraphs demonstrated the possibility of extracting significant information regarding the length distribution relationship to mechanical processing. This was possible by examining the empirical distribution and visually observing its features. On the other hand, the existing parameters, essentially the short fiber content, failed to represent these features and did not lead to adequately express their variation during processing.

In order to overcome this lack of adequate parameters, it is necessary to derive a new fiber length parameterization based on the entire distribution pattern and representative of the fiber-process interactions. This new parameterization should be useful for fiber quality improvement (breeding) as well as for process optimization (ginning, spinning…). This task was undertaken using finite mixture distribution models (Medgyessy, 1977; Everitt and Hand, 1981; Titterington *et al.*, 1985) to fit a probability density function to the empirical length distribution. The mixture models showed very satisfactory fits and allowed deriving a parametric expression of the length distribution features at different stages of the cotton process. The model is still under scrutiny and detailed results will be provided in subsequent publications.

Conclusion

The fiber length characteristics provided by the measurement instruments currently used in the industry do not fully describe the length distribution features, and are not always representative of the phenomena resulting from the fiber-machine interactions (e.g., fiber damage). Taking into account the entire distribution pattern, as suggested by Lord and others since many decades (Lord, 1961), is necessary in order to overcome this lack of adequate parameterization and provide the tools for dealing with the short fibers problem.

Acknowlegement

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Table 1: Parameters estimates of the regression between fiber length characteristics before and after carding (n=38).

Length Parameter	R^2	Intercept	Confidence Interval		Slope	Confidence Interval	
Mean Length (")	0.95	0.024	-0.032	0.080	0.964	0.887	1.042
Length CV (%)	0.84	**8.496**	**2.462**	**14.530**	**0.799**	**0.682**	**0.915**
SFCn (%)	0.92	1.042	-1.953	4.037	0.958	0.859	1.056
5% percentile (")	0.98	-0.034	-0.097	0.028	1.029	0.980	1.078

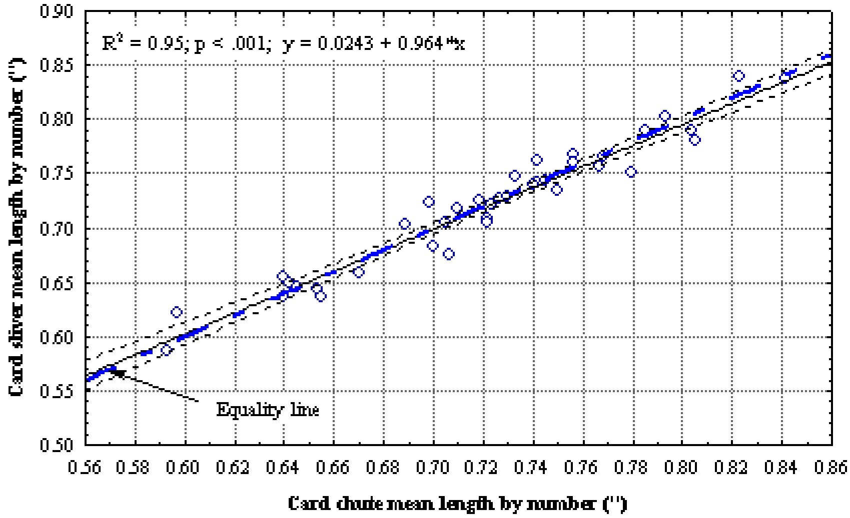

Figure 1: Effect of carding on AFIS mean length by number (Ln ”).

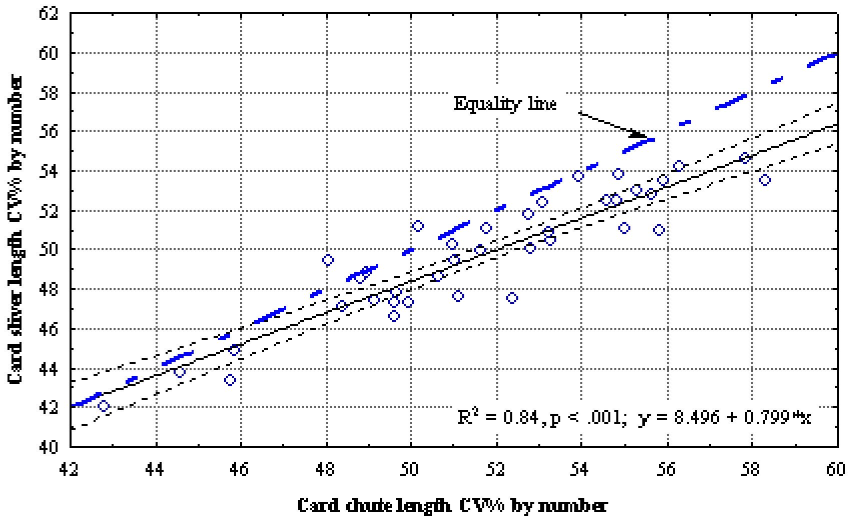

Figure 2: Effect of carding on AFIS length CV by number (LnCV %).

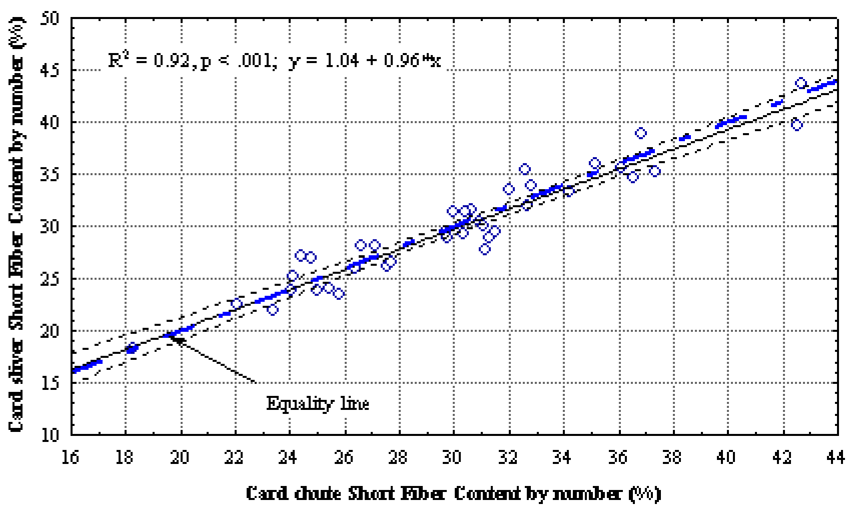

Figure 3: Effect of carding on AFIS Short Fiber Content by number (SFCn %).

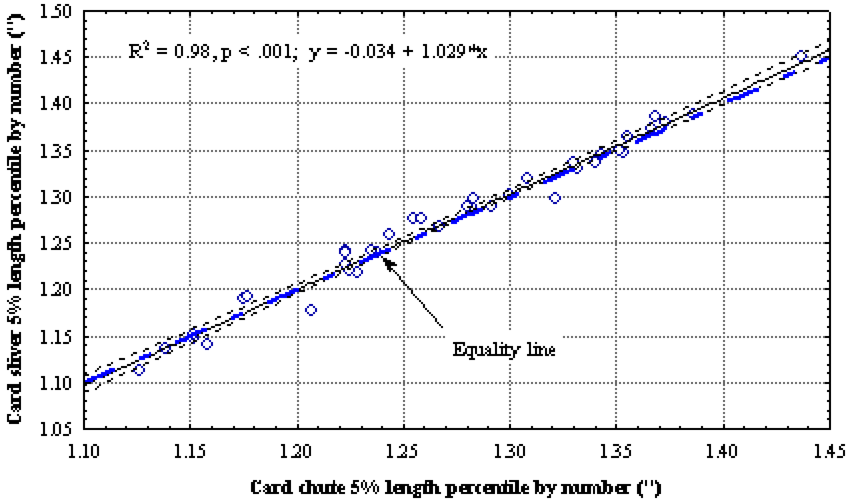

Figure 4: Effect of carding on AFIS 5% length percentile by number (").

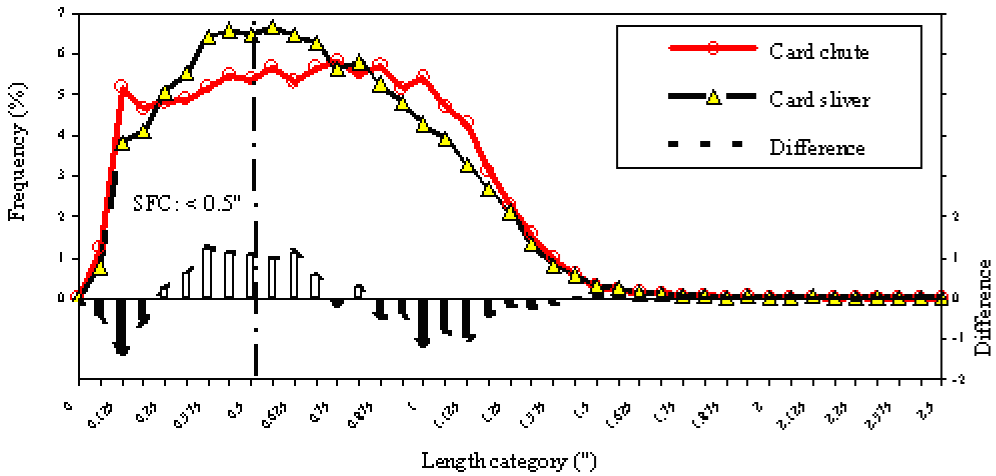

Figure 5: Effect of carding on fiber length distribution.