FIBER MASS, COUNT AND BREAKING FORCE FROM STELOMETER TEST

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Abstract

A fundamental understanding of the relationship among cotton fiber mass, count, and breaking force is important, as bundle fiber tenacity, elongation, and linear density can be calculated from these three parameters. In this study, the Stelometer instrument was employed, mostly because it is the traditional fiber strength reference method and could be still preferred as a screening tool due to its significant low cost and portable attributes. By examining the plots of either tenacity vs. linear density or fiber count vs. mass, the fibers were subjectively divided into fine or coarse class. Under this conception, both tenacity and single fiber breaking force increase linearly with linear density among the respective fine or coarse fibers. In general, HVI^{TM} micronaire and AFIS fineness increase with fiber linear density.

Introduction

The relationship among cotton fiber mass, count, and breaking force as well as fiber strength/tenacity and linear density is of great interest, because this knowledge could be of value to cotton breeders for cotton enhancement and to fiber processors for improved yarn quality measurement. For example, Abbot et al. (2009) have reported that cottons with the same micronaire values can have different yarn strengths, and also that the linear density is a much better predictor of yarn strength than micronaire.

Cotton micronaire is determined by both maturity (degree of secondary cell wall development) and fineness (weight per unit length) of the fibers, and an empirical relationship among them was proposed by Lord (1956).

Currently, three different systems have been developed to measure the fiber maturity and fineness routinely, including the cross-section method, the Advanced Fiber Information System (AFIS) and the Cottonscope (Paudel et al., 2013). Other gravimetric methods have also been used to determine the fiber linear density (ASTM, 2012a; Hsieh et al., 1995). Frequently, fiber linear density is referred to as fiber fineness; to avoid the confusion from cross-sectional test, the term fiber linear density from gravimetric testing will be used in this study. Notably, the Cottonscope measurement is a gravimetric method, and the results were calibrated to the Cottonscan^{TM} fineness measurement (Rodgers et al., 2012).

The main objective of this study was to analyze such parameters as fiber count, weight and breaking force from Stelometer test. The Stelometer instrument was utilized, because (1) the bundle length within the Stelometer clamps is known (15 mm), so that the fiber linear density of a sample can be derived if the number of fibers in a weighted bundle is known, and (2) the Stelometer protocol is a traditional laboratory-based tenacity test (ASTM, 2012b) and is still preferred by cotton researchers and breeders as a simple screening tool due to its significant low cost and portability; however, it undoubtedly has a number of drawbacks compared to other strength measurement methods. For example, it is a tedious and labor-intensive procedure that requires experienced operators and generates only a few fiber quality indices. Other objective of this study was to correlate fiber linear density with High Volume Instrument (HVI^{TM}) micronaire and AFIS fineness.

Materials and Methods

Cotton Fibers

A total of 19 lint cottons from the 2009 crop-year were used. Among them, 11 cottons represented two U.S. Upland varieties and 8 fibers were from international growers (5 from 2 growing areas in an Asian country and 3 from another Asian country). These samples were well conditioned at a constant relative humidity of 65 ± 2% and temperature of 21 ± 2°C for at least 48 hours prior to any measurement.

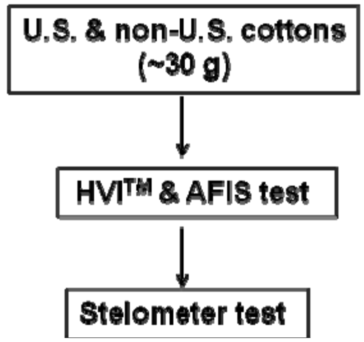

Figure 1. Experimental setup

Experimental Procedures

A flowchart of the experiment is briefly depicted in Figure 1. About 30 g of cotton fibers were collected from the respective large packages of samples. Following routine HVI™ and AFIS tests, Stelometer analyses were conducted. In which, a Stelometer flat bundle tester (Spinlab, Knoxville, TN) with 1/8-inch (3.2-mm) clamp spacing was employed to determine the cotton fiber Stelometer tenacity and elongation properties according to established protocol (ASTM 2012b). Commonly, two Stelometer parameters of individual cotton sample were obtained by two experienced operators as an average of six bundle breaks. All broken specimens were retained, but only one of two portions in one bundle breakage of six tests was counted under a desk magnifier with light and then analyzed in this preliminary study, because of obvious time-consuming and labor-intensive in counting the fiber number within an individual bundle.

Results

Relationship between Fiber Bundle Breaking Force and Mass

The Stelometer measures the force that is required to break a small, flat bundle of fibers. The broken bundle sample is then weighed. Figure 2 shows the relationship between fiber bundle breaking force and fiber bundle mass among 19 diverse fibers. It suggests a high determination of correlation (R^2 = 0.84), which is expected since it takes more force to break a heavy fiber bundle than a light one.

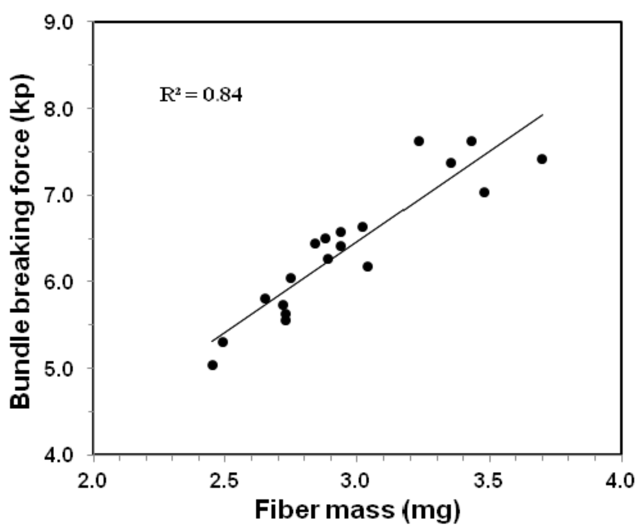

Figure 2. Relationship between fiber bundle breaking force and mass.

Relationship between Fiber Bundle Mass and Count

The corresponding plots linking fiber count with fiber bundle mass and breaking force are given in Figure 3 and 4, respectively. It is reasonable to observe a general increase in fiber bundle mass and breaking force with fiber number, but obviously with a much low R^2.

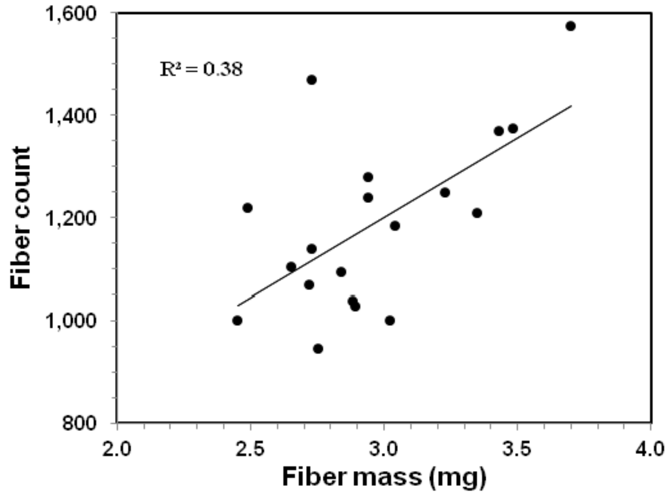

Figure 3. Relationship between fiber count and fiber bundle mass.

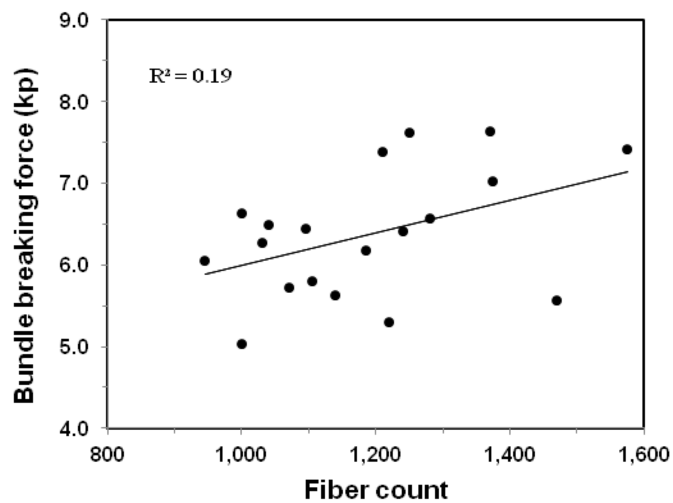

Figure 4. Relationship between fiber bundle breaking force and fiber count.

Discussion

Fiber Tenacity and Linear Density

Stelometer tenacity in the unit of g/tex (1 tex = 1 g/ km) is simply calculated using the bundle breaking force (Kp) and the known weight of fiber bundle mass. The fiber linear density in tex is estimated from the weight and fiber number within a fiber bundle. Figure 5 correlates the fiber Stelometer tenacity (that from the data in Figure 2) with fiber linear density (that from the data in Figure 3). In general, fiber tenacity increases with fiber linear density insignificantly.

Hsieh el al. (1995) examined the linear density values of developmental SJ-2 Acala cottons at various days post-anthesis (dpa). They derived these data from the weights of 100 1-cm long fibers, in which these middle 1 cm sections of fibers were cut from an array of combed and aligned fibers. The reported linear densities were 0.045, 0.055, 0.12, 0.16, 0.17, and 0.19 tex for the fibers with 21, 27, 29, 34, 47, and 62 dpa, respectively. Despite different method in assessing the linear density, the current results in Figure 5 are in good agreement with those from Hsieh et al. (1995). In addition, they observed that linear densities of the dried fibers show a significantly higher increase in fiber mass between 27 and 34 dpa, and a large increase in fiber mass coincides with the large breaking force increase of the dried fibers. A recent study suggested that fibers with less than 21–28 dpa could be classified as immature fibers (Liu 2013).

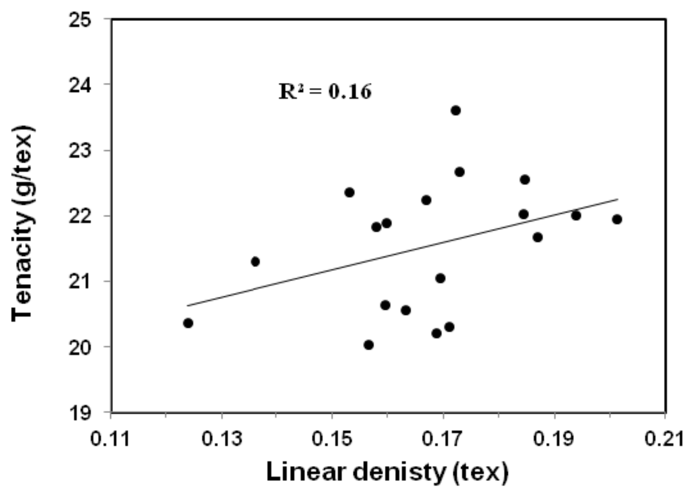

Figure 5. Relationship between fiber bundle tenacity and linear density.

Due to the scattered distribution in Figure 5, the samples were subjectively divided into two subsets as given in Figure 6. The corresponding samples in Figure 3 were represented and are shown in Figure 7.

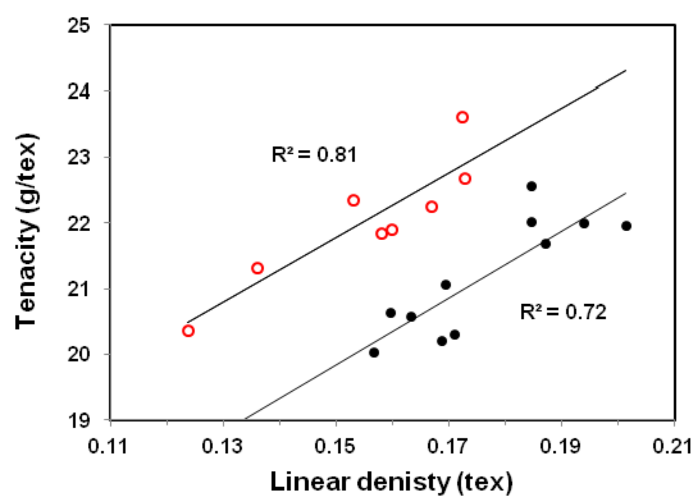

Figure 6. Representation of Figure 5 with two subsets of fine (○) and coarse (●) fibers.

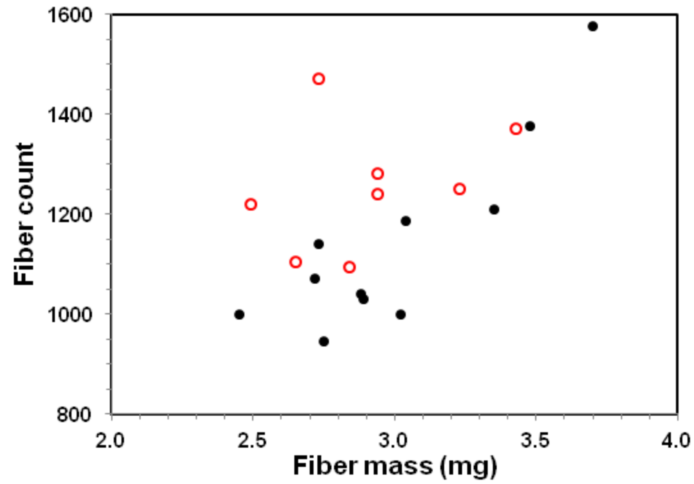

Figure 7. Representation of Figure 3 with two subsets of fine (○) and coarse (●) fibers.

As the samples having the same fiber mass contain differing fiber numbers (Figure 7), it might refer the samples with close weights to other ones but more fiber counts as fine fibers and, in turn, the samples with less fiber numbers as coarse fibers. In other words, fine fibers are relative to coarse ones when they have close mass. This led to 432 and 381 fibers / mg in respective fine and coarse Stelometer bundles. Notably, the subjective criterion of classifying the fibers into fine or coarse groups is based on the relationship between tenacity and linear density as well as between fiber count and mass.

Figure 8 depicts the single fiber breaking force of bundle fibers at various linear densities between fine and coarse fibers, both indicating a significant relationship ($R^2 > 0.95$). As a comparison to higher correlation ($R^2 = 0.90$) for all 19 samples in Figure 8, correlation between bundle breaking force and fiber linear density is much low ($R^2 = 0.12$).

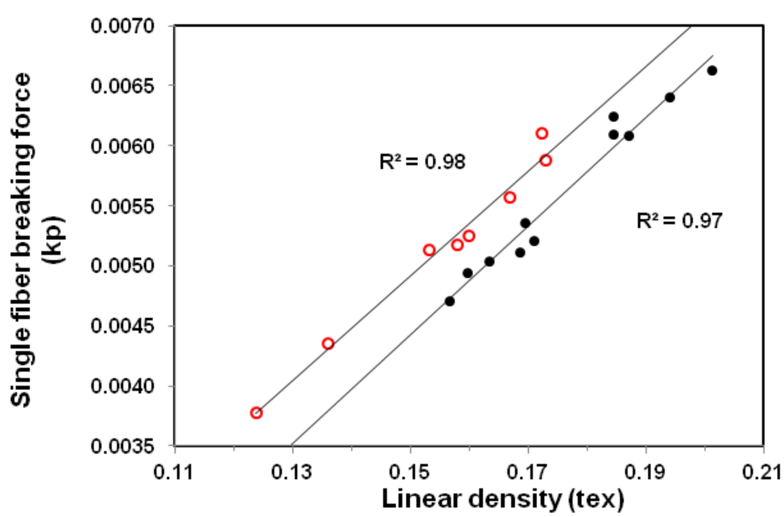

Figure 8. Relationship between single fiber breaking force and linear density among fine (○) and coarse (●) fibers ($R^2 = 0.90$ for all samples).

Fiber micronaire is an important physical property in raw cottons. Despite a much scattered pattern in Figure 9, it shows an overall increase in HVI^{TM} micronaire as linear density increases, at least for fine fibers. Comparison of maturity ratio (*M*) reading from the Cottonscope to the HVI^{TM} micronaire for all the 104 reference cottons shows that the relationship is not linear, whereas the relationship between fineness (*H*) from the Cottonscope and the micronaire shows a good correlation ($R^2 = 0.81$) (Paudel et al., 2013).

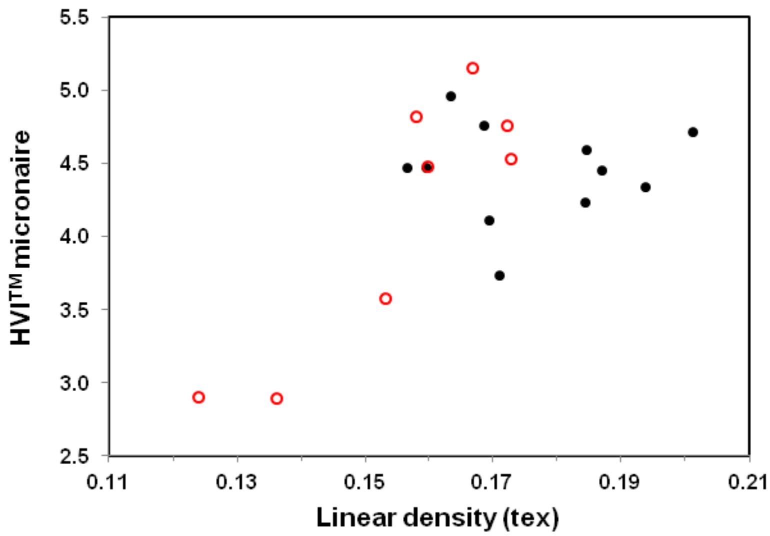

Figure 9. Relationship between HVI™ micronaire and linear density among fine (○) and coarse (●) fibers.

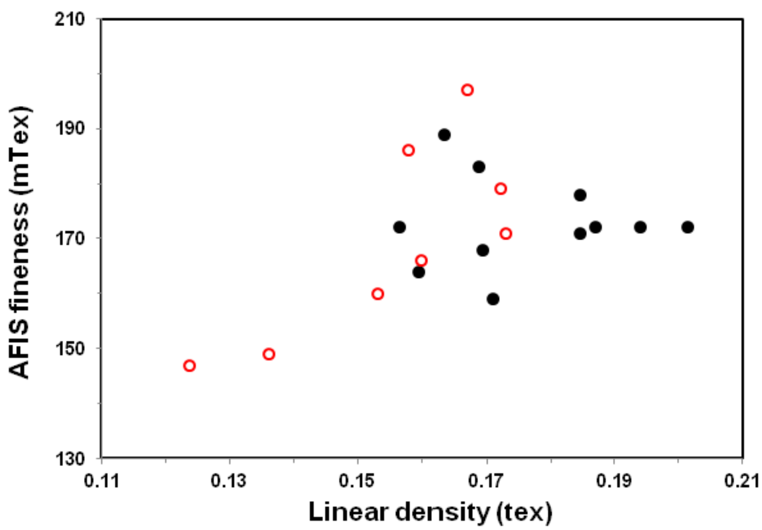

Figure 10. Relationship between AFIS fineness and linear density among fine (○) and coarse (●) fibers.

Fineness readings from AFIS exhibit some degree of correlation with fiber linear density, at least among fine fibers (Figure 10). Apparently, more studies are necessary to understand the similarities or differences between two approaches of determining fiber linear density, cross-sectional vs. gravimetric based.

Summary

Relating fiber mass, count, and breaking force to tenacity and linear density indices has been attempted by analyzing the data from Stelometer testing. The fibers consisted of diversified U.S. and non-U.S. Upland cottons. From the plot of tenacity against linear density and also the plot of fiber count vs. mass, the fibers were subjectively divided into two classes of either fine or coarse. That is, fibers with similar weights but more (or less) fiber counts are considered to be fine (or coarse) fibers. This led to averaged 432 and 381 fibers / mg in respective fine and coarse Stelometer bundles. Notably, both fiber tenacity and single fiber breaking force increase linearly with linear density among fine or coarse fibers. HVI™ micronaire and AFIS fineness were found to increase with linear density in general.

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Mention of a product or specific equipment does not constitute a guarantee or warranty by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

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