IMPACT OF FIBER LENGTH ON HVI STRENGTH

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Abstract

This study explores the influence of cotton fiber length characteristics on the HVI strength measurement. Using a set of cotton samples cut at different lengths from a common parent sliver, HVI strength data exhibited a consistent trend as a function of the fiber length properties. This data was analysed using the working hypothesis that the HVI estimates the total mass of fiber at a position between the jaws rather than the true mass, which contributes to the breaking force. A quantitative model was developed to correct for this overestimation based on the shape of the Fibrogram. It was found that the required correction factor is a function of the mean fiber length and various geometrical parameters of the HVI instrument. Application of the correction factor was able to remove the effect of fiber length on the corrected strength values.

Introduction

Cotton length and strength are two important fiber quality parameters that are commonly measured using the Uster High Volume Instrument (HVI) (eg ASTM Test method D 4605-86). It is generally assumed that fiber length and fiber strength measurements are independent. For example average length and strength values of US cotton have both steadily improved (Militký et al., 2004), and it is assumed that these values reflect real and separate improvements in both characteristics.

The HVI length measurements are based on the formation of a beard of aligned fibers with fibers forming the base of the beard gripped at random positions along their length. A non-destructive optical technique interrogates the thickness of the beard as a function of position along the beard to generate the 'Fibrogram', shown schematically in Figure 1. The reported fiber length characteristics are estimated from the Fibrogram (Hertel, 1940). The length parameters commonly used by the cotton industry are the upper half mean length (UHML, the average of the longest 50% of fibers by weight), the mean length and the uniformity index (the ratio of the mean length to the UHML).

Following the length measurement by the HVI, the same fiber beard is used for the strength measurement. Using a gauge length of ⅛ inch two sets of jaws clamp the beard at a fixed position close to the base of the beard as illustrated schematically in Figure 1. The breaking force is measured directly and the strength reported in Newtons per Tex is normalised using an estimation of the mass of fiber involved in the breaking force measurement based on the data from the optical sensor.

As part of his PhD studies Gourlot et al. (2002, 2003) undertook a small study into the effect of fiber length on the HVI Strength measurement. Using a cotton sliver, four samples were formed by repetitive cutting of the sliver at lengths equivalent to 0.5, 0.62, 0.75 and 0.87 times the UHML. For two different parent cottons (one Upland and one Pima cotton) it was found that the HVI fiber strength measurement changed significantly as a function of the different cutting lengths.

The current paper repeats and extends Gourlot's preliminary study to explore more fully the influence of fiber length characteristics on the HVI strength measurement.

Materials and Methods

A card sliver (approximately 4.5 ktex) was produced from a bale of commercially grown Australian Upland cotton. Using a rotary cutter, five approximately one kg samples were generated with nominal cut lengths of 15, 20, 25, 30 and 35 mm. HVI length and strength measurements were undertaken at a commercial classing facility. In total 16 HVI measurements per length category were obtained: 2 physical samples x 4 subsamples x 2 presentations per sub-sample.

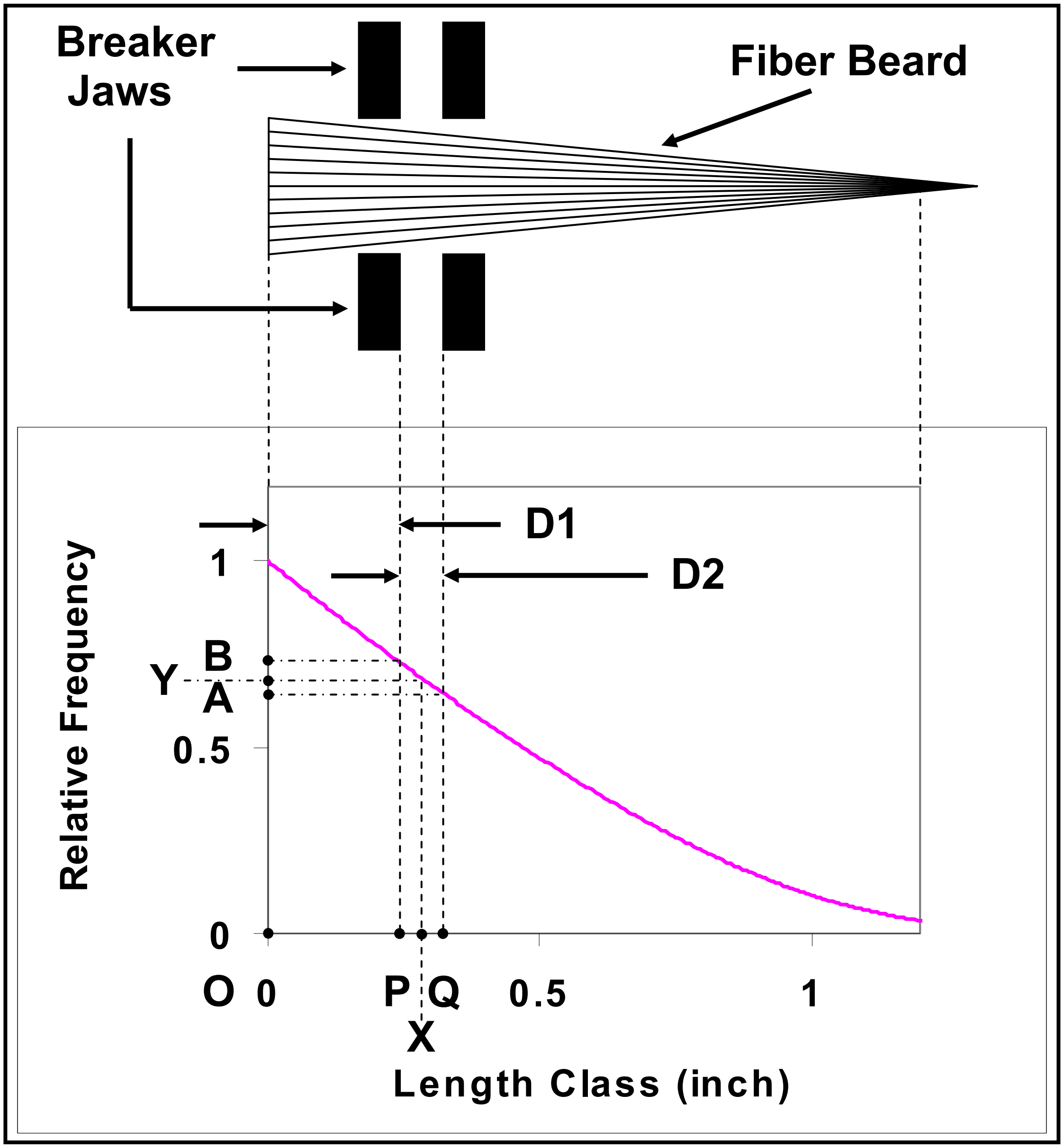

Figure 1. The top portion is a schematic diagram of the arrangement of the HVI beard and the jaws/clamps for the HVI strength measurement. This is aligned with the Fibrogram shown in the bottom portion of the figure.

Results and Discussion

HVI results are summarized in Table 1 and Figure 2. It can be seen in Table 1 that the various length parameters change as expected with increasing cut length i.e. the upper half mean length (UHML), mean length and length uniformity increase and the short fiber index (SFI) decreases.

As no fibers are lost during the cutting process used to generate the different samples, one might expect that the measured strength should be independent of the process. However it is clear in Table 1 and Figure 2 that fiber strength is definitely affected. This is very similar to the previous observations of Gourlot et al. (2002, 2003).

Table 1. Summary of HVI data presented as mean (standard error of the mean, sem) with n=16.

Sample ID (Nominal cut length in mm)	Length Parameters			Tensile Data
	UHML (in)	Length Uniformity (%)	Mean Length (in)	Strength (g/tex)
1 (15)	0.9071 (0.0046)	73.30 (0.16)	0.6649 (0.0033)	30.20 (0.20)
2 (20)	0.9363 (0.0037)	75.12 (0.15)	0.7033 (0.0028)	30.97 (0.22)
3 (25)	0.9776 (0.0024)	77.46 (0.15)	0.7573 (0.0019)	31.46 (0.15)
4 (30)	1.0151 (0.0019)	78.70 (0.13)	0.7989 (0.0015)	31.81 (0.21)
5 (35)	1.0404 (0.0019)	79.57 (0.13)	0.8278 (0.0015)	32.48 (0.20)

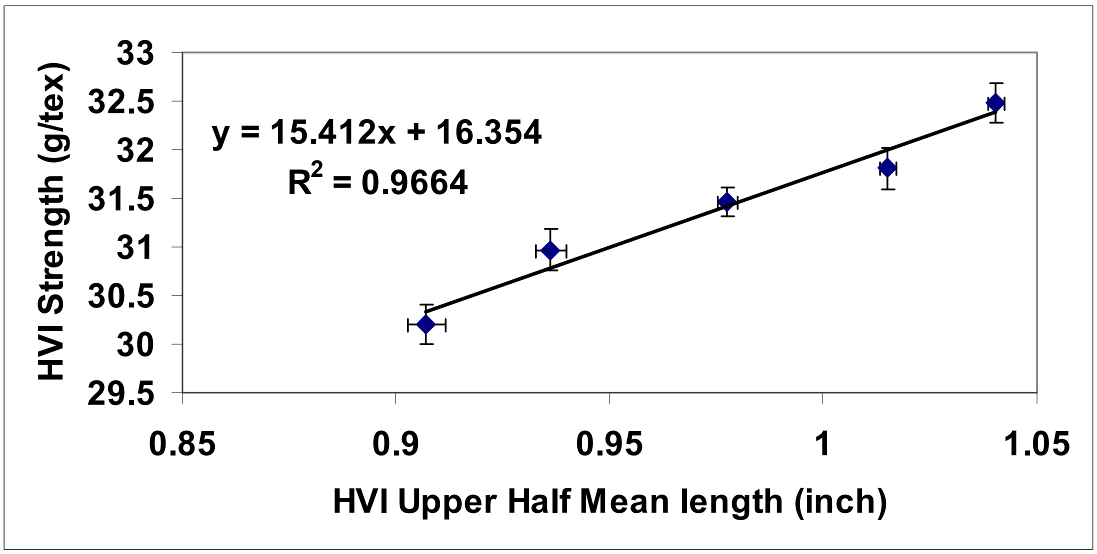

Figure 2. The observed change in measured HVI strength as a function of different HVI length parameters. The error bars on each data point represent the standard error of the mean value (sem).

Analysis

As noted in the introduction, in the HVI strength measurement the two sets of jaws clamp the beard towards the base of the beard. To understand the possible interaction of fiber length on the HVI strength measurement it is thus useful to revisit the characteristics of the HVI beard and Fibrogram, particularly the region where the strength measurement is made i.e. close to the base of the beard.

Figure 1 illustrates schematically the relative positions of the HVI Strengths jaws relative to the Fibrogram. During the HVI strength measurement the two sets of jaws clamp the beard at positions P and Q separated by the gauge length D2 (typically ⅛ inch) and the test measures the force to break during this bundle test. The force value is then normalised with an estimate of the mass of contributing fibers obtained optically by sensing the density/thickness of the beard in the region of the test.

Referring to Figure 1, the Fibrogram r(*l*), the fraction of fibers at each point along the beard that extends beyond that point, decreases monotonically with increasing distance from the base of the beard. Thus there will be a finite number of fibers that do not fully span the distance PQ between the two sets of jaws in the strength measurement. The number and mass of fibers that span the gauge length and contribute to the strength measurement is proportional to the value of the Fibrogram at position Q i.e. r(OQ).

As a working hypothesis, it is assumed that the HVI estimates the total mass of fibers at a position between the two sets of jaws, designated by the general position X in Figure 1. This value is proportional to the value of the Fibrogram at position X i.e. r(OX). Thus for all positions of X between the jaws except when X coincides with Q, the HVI will overestimate the mass of fibers contributing to the strength measurement, and this overestimate will be largest if X coincides with P.

Let the mass of fibers estimated by the HVI optical measurement be M, which includes an overestimate *m*. The fractional overestimation of the mass (*m*/M), and the corresponding underestimation of the strength is given by:

m/M = [(Fraction of fibers protruding beyond X) – (Fraction of fibers protruding beyond Q)]/ [Fraction of fibers protruding beyond X]
= [r(OX) – r(OQ)]/r(OX)
= [OY – OA]/[OY] (1)
where the various symbols are as defined in Figure 1.

Under this hypothesis the potential error is clearly dependent on the shape and in particular the 'steepness' of the Fibrogram between the length positions P and Q. An interesting general feature of the Fibrogram is that it is approximately linear for small length values of length with a slope of $(1/l_{mean})$ (Morton and Hearle, 1975). This can be used to evaluate the potential fractional error of the estimation of the mass (and thus strength):

$$m/M = [r(OX) - r(OQ)]/ r(OX)$$

$$= [(D1+D2)-OX]/[l_{mean} - (D1 + D2)] \quad (2)$$

A corrected strength value S_{corr} can then be obtained from the observed strength S_{ob} as follows:

$$S_{corr} = S_{ob} + S_{ob} *(m/M)$$
$$= S_{ob} * (l_{mean} - OX)/[l_{mean} - (D1 + D2)]) \quad (3)$$

Let OX = D1 + x.D2 where 0<x<1, then

$$S_{corr} = S_{ob} * [(l_{mean} - (D1 + xD2)]/[l_{mean} - (D1 + D2)]) \quad (4)$$

It is known that the gauge length D2 is ⅛ inch. The value of D1 is not well documented. Figure 3 shows the corrected strength values as a function of mean fiber length for the case x = 0.5 (i.e. the HVI senses the mass of fiber midway between the positions P and Q) and assuming a fixed value for D1 of 0.25 inch. These are reasonable first estimates of the two parameters x and D1. Comparing Figure 3 with Figure 2, this correction has removed the dependence of the corrected strength value on fiber length.

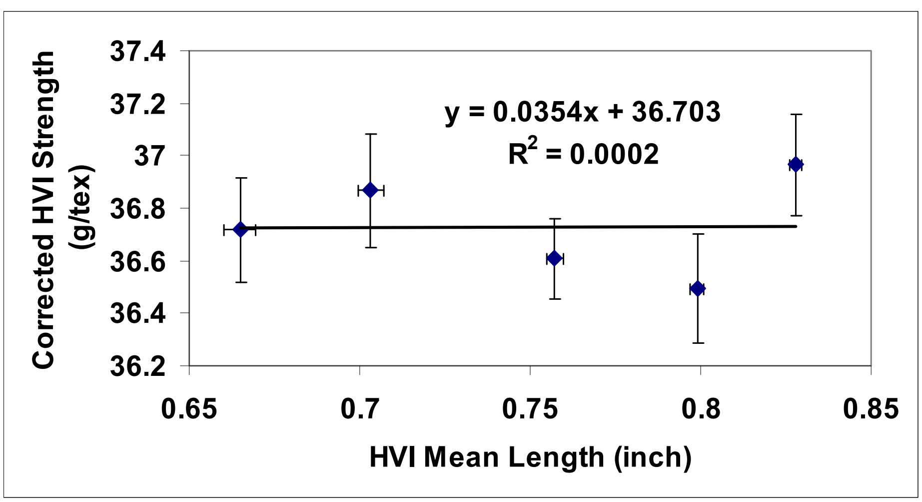

Figure 3. A plot of the corrected HVI strength as a function of mean length assuming that the distance D1 is 0.25 inch, and that the HVI estimates the mass of fiber half way between the jaws. This illustrates that the correction has removed the effect of mean fiber length. As in Figure 2, the error bars on each data point represent the standard error of the mean value.

The similar analysis applied to Gourlot et al's original data is shown in Figure 4. Again the application of a correction factor with reasonable values for x and D1 removes the otherwise unexplained effect of fiber length on the strength data.

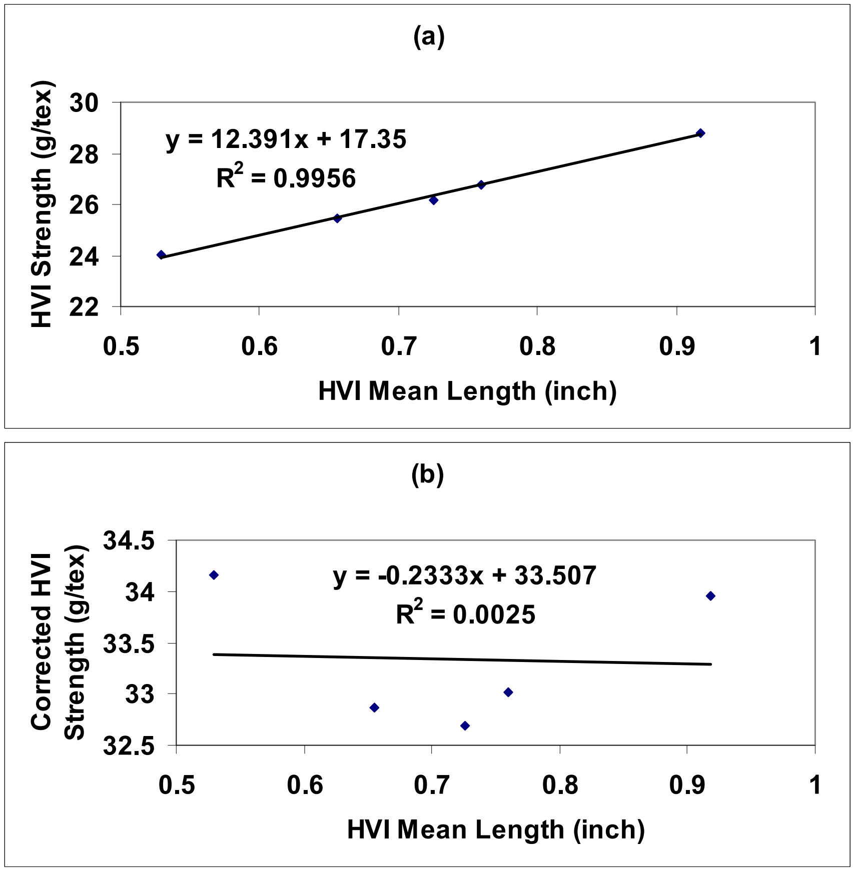

Figure 4. A plot of the HVI strength as a function of mean length for Gourlot et al's data (2002,2003). (a) is the original data, and (b) is the corrected HVI strength data assuming x = 0 and D1= 0.12 inch.

Summary

By examining a set of cotton slivers cut at different lengths this paper has confirmed experimentally that the HVI measured strength varied between the samples i.e. the HVI strength values were dependent on the fiber length characteristics. Using a working hypothesis that the HVI estimates the total mass of fiber at a position between the jaws rather than the true mass, which contributes to the breaking force, a quantitative model was developed to correct for this overestimation. A relatively simple correction factor was developed that is a function of the mean fiber length and various geometrical parameters of the HVI instrument. Application of this hypothesis and model in combination with realistic values of the HVI geometrical parameters was able to remove the effect of fiber length on the corrected strength values.

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