SPATIAL OPTICAL ATTENUATION CORRECTIONS FOR MASS DETERMINATION ACROSS NON-UNIFORM TAPERED BEARDS

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Abstract

When light is transmitted through a parallel array of fiber, it undergoes a non-linear attenuation with amount of mass. Therefore, the optical response must undergo a mathematical correction when the monitored signal is used as an indicator for fiber mass. This work compares the usual logarithmic correction on the average signal across the fiber beard to a point-by-point correction applied to the distributed light level across the fiber beard.

Introduction

A study has been in progress for some time at The University of Tennessee on the comparison of two distinctly different methods directed to the determination of linear density across a tapered beard using indirect measurement techniques of optical attenuation and resistance to air flow. The two methods used in Zellweger Uster and Motion Control HVI units have been examined in an effort to better understand the variations that arise in estimating specimen mass used in tenacity determination and to identify appropriate corrections required by different cotton cultivars. Specimen preparation was examined also in light of the different techniques of beard preparation used in the separate systems.

The project received new direction when Zellweger Uster became the single HVI manufacturer as a result of the acquisition of Motion Control, Inc. Optical methods as indicators for mass linear density became the appropriate choice, while sampling methods were yet to be decided. In any case, studies were redirected toward and focused on optical methods for assessing specimen mass. Since bulk within the tapered beard, brushing technique, and optical/mass overlap variations affect the optical attenuation, it was decided that the choice of a well-prepared parallel specimen as produced using a Pressley clamp might be beneficial to understanding light attenuation as a function of fiber mass. Perhaps more importantly, it was soon recognized that variations in fiber density across the specimen might affect the optical indicators since logarithmic corrections are made on the light transmitted through the beard of fiber. To examine variation in density distribution across the beard, a narrow beam of light was selected to scan the beard and eliminate the constraint of a single average measure of light attenuation. This would provide comparison between normal averaging techniques of current HVIs and signal integration averaging.

Materials and Experimental Procedures

Twenty research cottons were studied initially, although two additional cottons with widely varying micronaire values were introduced to extend the range of fiber fineness. The samples presented to the light beam in a scanning mode were parallel arrays prepared on Pressley clamps. The source of light used to scan the Pressley specimens was a He-Ne laser which produced light at a wavelength of 6328Å.

Results and Discussion

In the HVI optical system, a band of light is projected upon the beard and an average value of a wide beam passing through the beard is used to represent the mass response. A logarithm of this average is used to predict the mass, in conjunction with a fiber fineness correction. Our approach has been to look at the effect of overall signal averaging versus a point-by-point response across the fiber specimen. Using the scanning laser light beam, we can obtain differential responses (Fig.1). It is obvious in this figure that the optical response varies widely and that this variation is a response of nonuniformity in fiber distribution.

When the signal is normalized to unity (Fig.2), one still observes a distribution which is the same as in the previous figure. In this form, the light signal reading on the ordinate axis is equivalent to I/I_0, where I is the transmitted signal strength and I_o is the signal strength of light in the absence of a cotton specimen. The inverse of I/I_0 or I_0/I is a ratio that is related to the intervening mass (Fig.3). For light attenuation described by pure absorption, the connecting relationship is

$$\frac{I_o}{I} = e^{kM}$$

where k is some absorption coefficient and M is the mass generating the absorption. When written in logarithmic form, the mass distribution is given directly (Fig.4). Each position represents an increment of mass in the array and the area beneath the curve represents the cumulation of mass, i.e., total mass crossed by the scanning beam.

A series of response curves have been obtained on each of the twenty-two cotton cultivars. Specifically, twenty response curves were obtained on each of the cottons where the arrays were prepared in such a way as to provide a broad cut mass distribution. In this way, linear correlation analysis could be carried out between cut mass (between

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interior Pressley clamp faces at 1/8-inch gage) and attenuation representation by the response curves. The results of these analyses are summarized in the accompanying collection of data (Table 1).

Column 1 of Table 1 denotes the cotton identification number. Column 2, with the heading I_0/I_{Avg} , denotes the mass as represented by an *average* attenuation of transmitted light. There is no logarithmic correction involved. The correlations are all reasonably high, considering the errors that are inherent in the cut-and-weigh process. None of the correlations involve correction for fiber fineness since each is treated separately.

Column 3 is a closer representation of the mass indicator used in HVI systems, exclusive of fineness correction. Logarithmic response is assumed valid and the correlations are obtained by determining an average value for I across the scan, obtaining the ratio of I/I_0, and calculating the logarithm of the ratio. The correlation coefficients using this technique are, almost without exception, higher than those obtained without the use of exponential light attenuation. Hence, the HVI method enhances the indirect mass measurement.

It is in column 4 that we begin to treat the response curve point-by-point. Each data point of 300 total data points is used in determining the ratio I_0/I_i where i represents position along the scan from 1 to 300. Logarithmic corrections can be obtained on each of the 300 values of I_0/I_i and summed to represent the cumulative effect. The correlations between these results and cut mass are generally higher than the values in the previous two columns. Hence, scanning with a light beam across the fiber array is a better method for treating data for mass determination.

Spectral analysis of materials through ordinary techniques of dispersing light generate spectra which are influenced by the instrument. That is to say, an instrument function has the tendency to spread the spectral lines and reduce the resolution that is desired. There are mathematical techniques referred to as deconvolution that can be applied between the instrument function and the experimental result that will better represent the true spectra. In a way, our results are similar to those observed by the spectroscopist. But in our case, the instrument spread function is incorporated in the beam width of the light. If the beam were infinitely small, the light response of the fiber array would effectively characterize the real mass distribution. In an effort to approach a truer fiber response curve, the beam of light has been reduced with an aperture to about half of that without the aperture. Point-by-point treatment has been applied to these results and they are presented as correlation coefficients in the last column of Table 1. Here again is seen a rise in correlation between a logarithmically modified light attenuation response and the cut mass. This method is significantly enhanced over the results of light attenuation treatment not involving point-by-point correction.

Conclusions

Point-by-point corrections to light transmission across a beard of fiber offers the opportunity to more accurately represent the mass contributing to the attenuation of the transmitted light. In addition, the reduction of the beam used in the scanning of the fiber beard will add to the accuracy of the mass representation.

Acknowledgements

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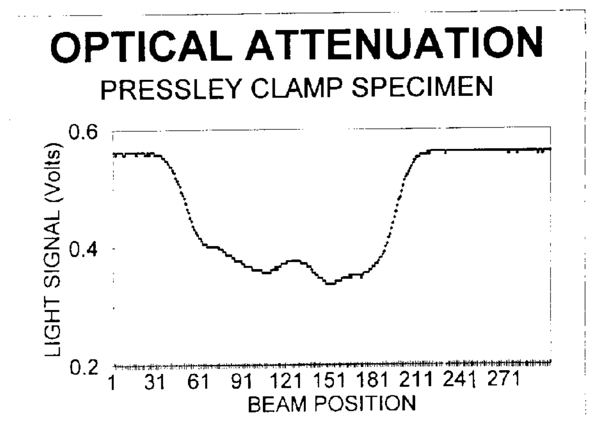

Figure 1. Optical attenuation curve across a parallel array of cotton fiber. (Original response curve).

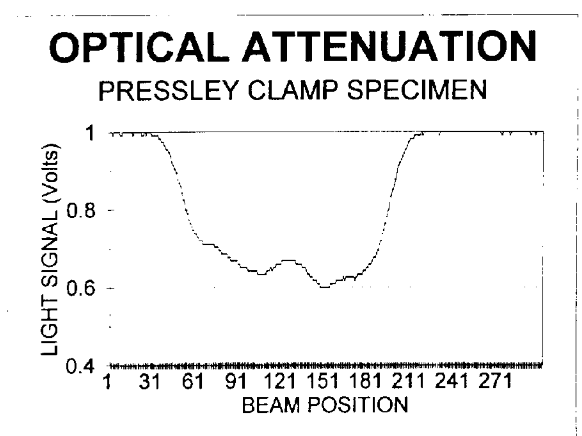

Figure 2. Optical attenuation curve across a parallel array of cotton fiber. (Data normalized to 1 volt full scale).

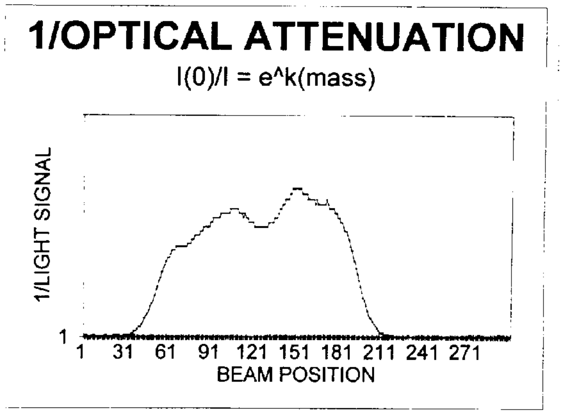

Figure 3. Ratio of unattenuated to attenuated light intensity.

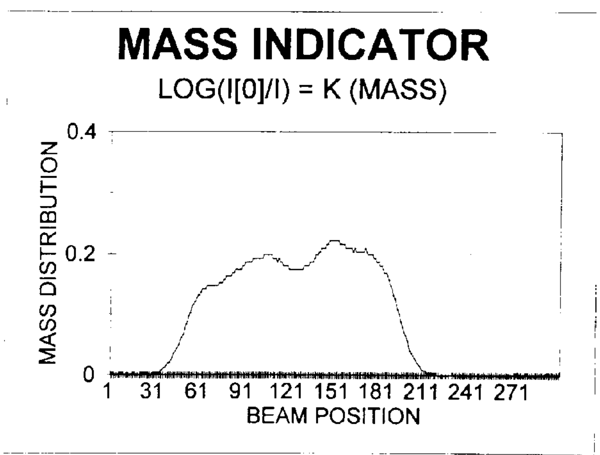

Figure 4. Logarithm of ratio of unattenuated to attenuated light intensity.

Table 1. Correlation Coefficients for Corrected Light Transmission Response versus Cut Mass.

ID	I_0/I_{Avg}	$LN(I_0/I_{Avg})$	$\Sigma_1[LN(I_0/I_i)]$	$\Sigma_2[LN(I_0/I_i)]$
G16	0.8730	0.8836	0.8785	0.9036
374	0.9200	0.9366	0.9409	0.9479
404	0.9018	0.8893	0.9014	0.9136
488	0.9020	0.9104	0.9270	0.9384
005	0.8976	0.9000	0.9459	0.9519
537	0.8560	0.8678	0.8914	0.9207
535	0.8795	0.8745	0.8887	0.9138
390	0.9022	0.9071	0.9087	0.9418
520	0.8969	0.9059	0.9224	0.9291
481	0.8573	0.8605	0.8956	0.9079
395	0.9005	0.8941	0.9300	0.9377
476	0.9357	0.9470	0.9395	0.9457
412	0.9089	0.8959	0.9423	0.9536
487	0.8664	0.8891	0.8989	0.9169
300	0.8849	0.8782	0.9132	0.9239
131	0.9285	0.9317	0.9505	0.9532
349	0.8988	0.9134	0.9283	0.9374
241	0.8616	0.8615	0.9132	0.9236
303	0.8629	0.9296	0.9244	0.9266
025	0.8678	0.8691	0.8917	0.9032
355	0.8592	0.8584	0.8767	0.9063
A19	0.9585	0.9585	0.9713	0.9730

$\Sigma_1[LN(I_0/I_i)]$ represents a point-by-point determination with **normal** laser beam width.

$\Sigma_2[LN(I_0/I_i)]$ represents a point-by-point determination with **reduced** laser beam width.