# A Reference Test for HVI Strength Measurements. Part 1: Description of Instrument and Hardware Requirements

*C.K. Bragg[1], J.P. Gourlot[2] and J.D. Wessinger[3]*
[1]USDA-ARS, Clemson, SC,[2] CIRAD, Montpellier, France, and [3]USDA-ARS, Clemson, SC

## ABSTRACT

*The equipment used in the Reference Strength Tester working group is described. A normal length/strength measurement on a 910B module of a Zellweger Uster Spinlab HVI line is used to measure length distributions and record the force that is necessary to break tapered beards. The fibers are then cut in one specific location that permits it to relate to the weight of the broken fibers. A detailed description of the method that is applicable by each owner, is given.*

## Introduction

An arbitration or reference method for determining the tensile strength of bundles of cotton fibers based on the High Volume Instrument (HVI) procedure is being developed. The method is a variation of the standard operating procedure for determining the tensile strength of cotton beards by commercial HVI (1). Hardware requirements include an instrument equivalent to a Model 900-B HVI system (manufactured by Zellweger Uster, Inc.) interfaced with an external IBM compatible computer. The HVI must be set up and adjusted to operate according to the mechanical and electronic specifications recommended by the manufacturer; however, no cotton is used for calibration. Also required is a mechanism for precision positioning and cutting of beard segments and a sensitive balance with accuracy $\pm$0.01 milligrams. Special software allows fundamental test data to be exported from the HVI to the external computer. Test results include measurements of optical amounts along the test beard (fibrogram), the gravimetric weight of a specific segment of the beard remaining in the specimen clamp after the beard is broken, and force measurements at precise displacement points in the breaking cycle. The tensile strength of the fiber bundle and the force-extension curve are calculated from these measurements for use in various analyses, such as determining the bundle modulus and monitoring consistency of specimen preparation.

## Test Method

The HVI system employs a light source and detector 50 mm in width to determine the optical density of cotton beards in 3.175 mm segments along the length of the beard. This 3.175-mm by 50 mm area is the basis for all optical measurements. The beard specimen is prepared using the standard Model 192 Fibrosampler with a template inserted to limit beard width to 50 mm. As in the standard operation mode, the beard is brushed and inserted for measurement with the fibers aligned by vacuum between the light source and detector. The measurements result in a fibrogram (Figure 1) in which the optical density is known for precise locations along the length of the beard protruding from the clamp. Positioned immediately behind the light source and detector is a set of jaws that grasp the beard at a specified location determined from the fibrogram (Such as the 30% Span Length). The front jaws are stationary. The rear jaws, connected in series with a strain gauge, grip a 3.175 mm segment of the beard and are displaced by a closely controlled stepping motor to elongate the bundle until all the fibers are broken. Force data are collected from the strain gauge in synchronization with pulses to the stepping motor. After the beard is broken and the jaws are opened, the fiber tails remaining in the rear jaws are exhausted by vacuum to a waste bin. In this manner precise measurements of the force required to elongate the beard are collected for the entire breaking cycle. A typical force-extension curve is shown in Figure 2. Force measurements are collected in steps at a rate of 1200 per inch (47.244 per millimeter) of displacement. Peak force is estimated from a quadratic fit in the region of the observed peak. The displacement corresponding to the estimated peak is calculated for use as one point in determining bundle modulus. The other point is determined by fitting a straight line in the region of the force-extension curve equivalent to one-half the estimated peak force. This line is projected to the x-axis (allowing for force tare if necessary) to obtain the second point required for the elongation measurement. The elongation, as a percentage of the gauge (3.175 mm), is calculated as two-thirds the difference between the two points since there are 47.244 measurement steps per mm. The measurements produced from this part of the testing sequence are the peak force during the breaking cycle and bundle elongation to the point of peak force.

Two basic factors determine tenacity, the peak force required to break the beard and the linear density of the bundle of fibers in the broken beard. The force required to break the bundle of fibers is measured directly as outlined above and can be affected by moisture content, fiber orientation and alignment, and the displacement rate of the jaws. The effect of variations in moisture must be controlled by carefully conditioning the cotton samples using recommended levels of temperature and relative humidity and maintaining this moisture content throughout the testing cycle. Fiber orientation and alignment are standardised by adjusting the combing and brushing mechanisms to manufacturer's specifications. Displacement rate, though affected to a small degree by the level of force during the breaking cycle, is essentially held constant by the instrument.

In addition to measurements of breaking force as outlined above, measurements of the linear density of the beard are required to determine tenacity. Since the portion of the beard held in the rear jaws represents the linear density of the broken beard and is removed by vacuum after the break, no direct measurement of linear density can be obtained. Least squares regression is used to estimate linear density. The optical data necessary for establishing the required regression relationship are obtained by reinserting the specimen clamp after the beard is broken to obtain a fibrogram of the beard remaining in the clamp after braking (Figure 3). Since the optical amount readings that produce the fibrogram are obtained in 0.635 mm increments (steps) and the measurement segment is 3.175 mm, the optical amounts at every fifth step on the fibrogram are summed, beginning at a predetermined step (such as step 4) to obtain the total optical amount of the beard. This is divided by the number of 3.175 mm segments in this broken beard to obtain the average optical amount.

The specimen clamp is then placed manually onto a separate, carefully adjusted, platform (Figure 4) that is closely synchronised with the beginning position used to determine the optical mass of the beard. The fibers are aligned in position by vacuum. A pneumatically controlled cutter bar clamps the beard to permit manual cutting of the fibers from the clamp at the beginning position using a roller knife. The gravimetric weight of this portion of the broken beard corresponding to the optical mass determined above is then obtained on the balance.

Using this procedure, the average optical amount and the corresponding average gravimetric weight of 3.175 mm segments are obtained for a number of beards over a wide range of beard weights. Regression is then used to establish a quadratic relationship between average optical amount and average gravimetric weight assuming that the regression equation passes through the origin.

From this regression relationship, optical break amounts of the beard, as determined from the original fibrogram, can be used to estimate with reasonably high precision the linear density of the fiber beard at any point (including the segment held by the rear jaws during the breaking cycle). Typical measurement results for one cotton using this method are shown in Figure 5 for 30 beards. With these values and the previously calculated peak force estimates for each beard, linear regression is used to calculate the relationship between estimated breaking force (grams) and estimated linear density (tex) of beards for this cotton (Figure 6). Tenacity is, by definition, the ratio of these values.

Figure 7 shows the tenacity of the 30 beards as a function of linear density (tex), illustrating the effect of the experimentally determined beard weights on tenacity. The relationship between tenacity and bundle weight is somewhat similar to that observed by Suh (1994) in analyses of bundle tenacity efficiency simulated from single fiber tests and indicates that variability of tenacity measurements increases when beard linear densities are allowed to vary widely. These results also imply that heavier beards result in more consistent strength measurements than lighter beards.

Figure 8 shows the relationship between tenacity and optical break amount instead of linear density, and indicates that optical break amounts of 100 or greater should provide better precision in measuring HVI strength even though there is still a small effect of beard weight as tenacity approaches a limit asymptotically. From this it appears that, in actual practice, precision might be increased by adjusting HVI strength to a standard optical break .

## References

ASTM Designation D 4605-86, Standard Test Methods for Measurement of Cotton Fibers by High Volume Instruments (HVI) (Spinlab System of Zellweger Uster, Inc.) Annual Book of ASTM Standards, Vol. 07.02.

Suh, M.W., Xiaoliang Chi and P.E. Sasser. (1994): New understanding on HVI tensile data based on Mantis single fiber test results. In: Proc. Beltwide Cotton Conf. D.J. Herber and D.A. Richter (Ed). Natl. Cotton Council, Memphis TN. Pp. 1400-1403.

**Figure 1. Typical Fibrogram from HVI system.**

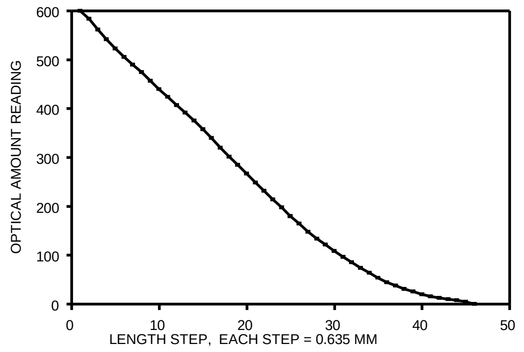


**Figure 2. Stress-strain curve from HVI system.**

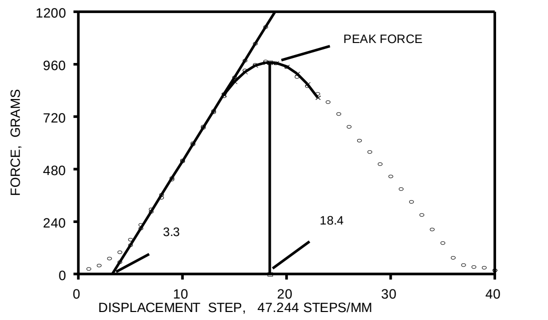


**Figure 3. Fibrograms before and after breaking.**

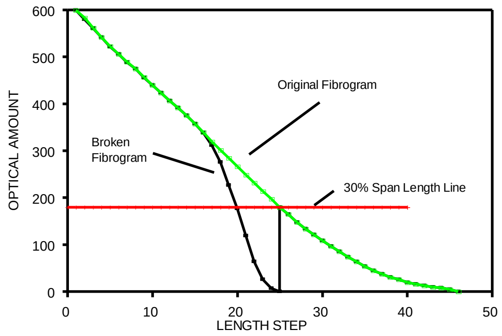


**Figure 4. Mechanism for cutting beards.**

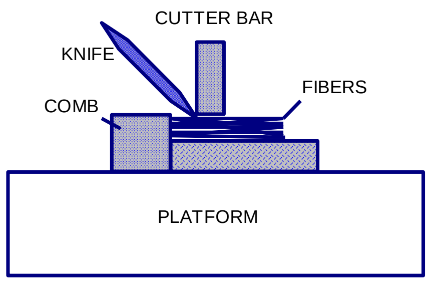


**Figure 5. Weight and optical amount for 3.175 mm segments of HVI beards.**

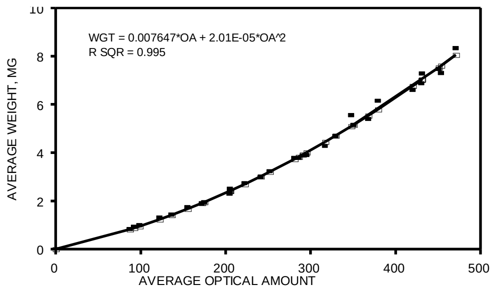


**Figure 6. Peak force and linear density for HVI beards.**

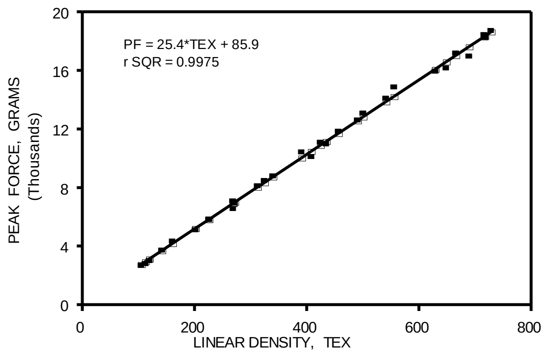

**Figure 7. Tenacity and linear density for HVI beards.**