WHY WE NEED A STANDARD STRENGTH TEST FOR COTTON VARIETY SELECTION

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Abstract

A program is underway to develop a mechanized strength testing instrument with improved precision, accuracy, and reproducibility. Instrument calibrations are based on force and mass. Therefore, it should provide better long term stability than other methods using cotton samples for calibration. Using a partially-developed laboratory unit, fiber strength for 12 cotton varieties grown on adjacent experimental plots was in good agreement with ring and rotor spun yarn strength. Regression coefficients were similar to Stelometer strength and significantly better than readings from two high volume instruments.

Introduction

Cotton producers, merchants and textile mill managers have expressed concern about the reliability of High Volume Instrument (HVI) strength measurements. Additionally, cotton breeders question the accuracy of using these measurements as a selection criteria in developing new varieties for stronger yarns. In an effort to improve cotton strength measurements, this laboratory has conducted numerous experiments to investigate factors which contribute to measuring errors.

The tensile strength of fibers has long been recognized as an important property of cotton. Strength affects processing performance and product quality. With acceptance of HVI systems for marketing cotton, rapid measurements of bundle strength have received considerable attention. High speed sensors are now available to accurately record the entire stress-strain curve while tensile testing. Other mechanical properties can also be obtained from a stress-strain curve (e.g. modulus and elongation). Its shape can be used to monitor reproducibility of the specimen preparation.

Various methods have been employed to determine the strength and extensibility of cotton fibers. An early method, Pressley (1), used a flat bundle of fibers and a simple beam-lever mechanism to break them. To improve reproducibility and add a measure of extensibility, Hertel (2) developed the Stelometer. Major contributions in its development were improved specimen preparation and an accurate control of the specimen loading. Hertel used Pressley jaws but added fiber combing and tensioning devices to provide better fiber alignment. His tensile testing device used a dashpot system to accurately control the rate of loading. All fiber specimens were prepared and pre-tensioned by hand which introduced operator differences. Strength normalization was performed by periodically retesting a reference cotton.

Universal Method

A new instrument is being developed to improve the precision and accuracy of laboratory strength measurements (3). A high level of mechanization is included to reduce operator errors and the number of reference measurements required. Fiber specimens are prepared by sampling, combing and brushing with automated techniques used by HVI systems. Fibers tested for strength are captured in a second clamp and combed in the opposite direction to form a non-tapered specimen. They are loaded into Pressley jaws under a controlled level of tension and tested at the HVI rate of extension. The linear density is determined gravimetrically. In this study, strength values were calculated directly from maximum force and linear density but not scaled or adjusted for results from a calibration or reference cotton.

Regional Cotton Variety Test

Each year, cotton breeders at several experiment stations cooperate in a national cotton fiber quality evaluation program (5). They have been reporting HVI measurements of fiber properties since 1980. Average fiber and yarn strength values for selected high quality varieties grown at several locations, reveals some interesting trends (Table 1). Stelometer strength values for these cottons have been steadily increasing at a rate of 0.44% per year since 1980 (Figure 1) while HVI strength readings have been increasing at a rate of 1.05% per year (Figure 2). Even when HVI strength data for 1980 was excluded as a possible outlier, the rate of increase was 0.87% per year. Therefore, HVI readings have been creeping up at a rate in excess of Stelometer between 0.43% and 0.62% per year.

After excluding outliers, year-to-year variation in the HVI strength data remained at about two times the variability in the Stelometer data (i.e., 3.22% compared to 1.54%; Figure 1 and 2). HVI calibration creep was likely caused by the use of old calibration cottons to establish strength values for new calibration cottons. This conclusion was reached because Stelometer readings are made with fiber crimp removed and its strength level is frequently compared to reference readings of force and mass. HVI measurements include fiber crimp and strength levels are compared to measurements on calibration cottons which also include fiber crimp. Research at this laboratory has shown that cotton ageing can cause a reduction in the HVI strength reading (4) which in turn causes a calibration level increase each time an old cotton is used to calibrate HVI systems when developing new calibration cottons.

High quality regional cotton variety test data also showed that manufactured yarn strength values have been decreasing (Figure 3). However, a significant level shift occurred in 1987 when a different vendor was selected to provide fiber and yarn quality test services. There has been no effort to adjust or normalize reported yarn strength data.

Experimental Program

Twelve different cotton varieties were selected for production on small experimental plots at the ARS Experiment Station, Florence, SC. These cottons were planted in 1993 using a randomized complete block design with four replications generating a total of 48 experimental samples. After harvesting and processing each sample separately, measured results were averaged over replications to establish the variety performance. Except for our universal strength data, all fiber and yarn quality measurements were performed at the USDA, AMS testing facility Clemson, SC (Table 2). Both skein and single-end yarn strength were measured on 22's ring and rotor spun yarns (Table 3).

Fiber and Yarn Strength Comparisons

Simple correlations between fiber and yarn strength results showed that all fiber measurements agreed best with rotor spun yarns strength (Avg. 0.68 compared to 0.59; Table 4). The agreement between Stelometer and rotor spun yarn strength was significantly (R^2 = 0.72; Figure 4) better than results from either HVI system (R^2 = 0.14 and 0.18; Figures 5 and 6). Universal fiber strength measurements provided the best agreement for these yarns (R^2 = 0.82; Figure 7). Because strength testing variability on samples from experimental plot was greater than expected, we also tested them after fiber blending. As expected, blending reduced testing variability (not reported) but it failed to affect the yarn strength comparison (Figure 8).

Experimental Yarn Quality

Modern textile mills are acutely aware of the yarn quality expected when they process cottons with established fiber qualities. However, within the scope of our limited experimental program, we were unable to anticipate an acceptable level or standard for the strength of our ring and rotor yarns. To evaluate our processing performance, we compared our yarn strength results with test results published by USDA, AMS, Cotton Division for leading varieties grown during the same year (6). Four varieties were common to both studies (Table 5). Cottons for both studies were processed through the same facility and spun into 22's yarn on the same spinning frame. Additionally, they were tested for yarn strength in the same laboratory (i. e., AMS, Clemson, SC). However, leading variety cottons were sampled from commercial bales after a full ginning and lint cleaning procedure. Whereas, our experimental samples were ginned by a small laboratory gin and not processed through lint cleaners. These shortcuts yielded lower grades and reducedyarn strength values. Both skein and single-end strength values for our yarns averaged about 10% lower than those processed in the leading variety study (i.e., 1760 compared to 1950 CSP and 10.6 compared to 11.54 cN/tex; Table 5).

Conclusions

Due to the method of instrument calibration, HVI strength readings for high quality cottons grown in the U.S. has been increasing at a rate between 0.43 and 0.62%/year above Stelometer. This trend was equivalent to an average yearly increase between 0.12 and 0.17 gf/tex in HVI strength readings. This difference could not be traced to fiber or yarn quality increases. Yearly variations in the HVI strength data for high quality cottons was 3.22% compared to 1.54% for Stelometer. Therefore, additional improvements are needed in the HVI reference method to reduce calibration level changes and control drift.

Cotton breeders should continue to use Stelometer data as a selection criteria for stronger varieties. In this study, the Stelometer method was significantly better than either HVI system at estimating 22s ring and rotor yarn strength. Data from our new strength testing method (under development) was also in good agreement with yarn strength data.

For accurate and reliable yarn quality evaluations, future experimental research should duplicate the best available harvesting, ginning, and lint cleaning procedures. Additionally, the National Cotton Variety Test program should consider a well established "control cotton" to be processed and tested for yarn quality concurrently with each batch of experimental cottons. Data from the control cotton can be used to evaluate processing and normalize other yarn test results.

References

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Table 1. High quality regional cotton variety test average strength.*

Growth Year	Varieties	Stelometer	HVI	Yarn
	(no./year)	(mN/tex)	(gf/tex)	(mN/tex)
1980	19	202.1	24.9	151.1
1981	16	206.9	26.4	154.2
1982	20	204.8	27.0	151.1
1983	15	211.6	27.5	156.2
1984	16	197.1	26.9	145.9
1985	13	209.0	26.8	147.0
1986	19	207.0	29.6	149.1
1987	19	214.1	23.5	131.4
1988	19	213.1	21.5	119.5
1989	20	206.7	28.3	127.2
1990	19	211.0	29.3	134.7
1991	21	216.4	28.1	132.0
1992	20	218.2	29.7	135.2
	AVERAGE	**209.1**	**26.9**	**141.2**

* U.S.D.A. Annual Quality Survey Data (5)

Table 2. Experimental cotton fiber strength results.

	Variety	Stelometer* T1	HVI** MCI	HVI** Zellweger	Universal*** Raw	Universal*** Blended
		(gf/tex)	(gf/tex)	(gf/tex)	(gf/tex)	(gf/tex)
1	Georgia King	20.5	28.4	29.0	20.0	20.6
2	DPL Acala 90	20.8	29.7	31.1	20.9	21.2
3	DPL 50	20.1	26.9	26.0	18.4	18.9
4	DPL 5415	19.9	30.0	30.1	19.6	18.9
5	Coker 315	21.0	26.1	27.5	20.2	20.7
6	Coker 320	21.7	25.7	27.3	20.0	21.0
7	PD 3	21.3	27.3	27.4	20.3	21.2
8	PD 5363	21.8	29.5	30.0	21.7	21.6
9	PD 5529	22.4	27.1	26.4	20.9	21.7
10	DES 119	20.8	28.3	26.0	19.3	19.3
11	Acala 1517-88	23.4	31.0	31.4	22.8	23.7
12	HS 46	20.9	30.7	30.2	20.7	21.3
	AVERAGE	**21.2**	**28.4**	**28.5**	**20.4**	**20.9**

* Normalized with ICCS cotton
** HVI calibration cotton
*** Force and mass calibrations

Table 3. Experimental cotton yarn strength results.

	Variety	22s Ring Spun Skein Test	22s Ring Spun Single End	22s Rotor Spun Skein Test	22s Rotor Spun Single End
		(lbfxcount)	(cN/tex)	(lbfxcount)	(cN/tex)
1	Georgia King	2465	13.8	1753	10.5
2	DPL Acala 90	2378	13.4	1851	11.3
3	DPL 50	2009	11.9	1658	9.7
4	DPL 5415	2146	12.8	1686	10.1
5	Coker 315	2404	13.8	1886	10.9
6	Coker 320	2478	13.8	1801	10.4
7	PD 3	2512	14.9	1933	11.4
8	PD 5363	2521	14.7	1948	11.3
9	PD 5529	2574	14.6	1955	11.7
10	DES 119	2263	13.4	1720	10.6
11	Acala 1517-88	2346	13.5	1846	11.1
12	HS 46	2346	13.5	1846	11.1
	AVERAGE	**2396**	**13.9**	**1844**	**11.0**

Table 4. Fiber vs. yarn strength correlation coefficients for 12 experimental cottons.

Fiber Measurement		Ring Yarns Skein	Ring Yarns Single End	Rotor Yarns Skein	Rotor Yarns Single End
STELOMETER	(T1)	0.90	0.85	0.9	0.85
HVI (MCI)	(H1)	0.07	0.14	0.25	0.37
HVI (USTER	(Z1)	0.26	0.26	0.39	0.42
UNIVERSAL					
RAW	(U1R)	0.84	0.82	0.92	0.91
BLENDED	(U1B)	0.89	0.86	0.95	0.91
AVERAGE		**0.59**	**0.59**	**0.68**	**0.69**

Table 5. Comparison of 22s rotor spun yarn strength results.

No.	Variety	1993 AMS* Leading Varieties Skein	1993 AMS* Leading Varieties Single End	1993 Experimental Plots Skein	1993 Experimental Plots Single End
		(lbfxcount)	(cN/tex)	(lbfxcount)	(cN/tex)
2	DPL Acala 90	2030	12.25	1851	11.3
3	DPL 50	2040	10.95	1658	9.7
4	DPL 5415	1849	11.70	1684	10.1
12	HS 46	1882	11.95	1846	11.1
AVERAGE		**1950**	**11.54**	**1760**	**10.6**

* USDA Leading Variety Results (6)

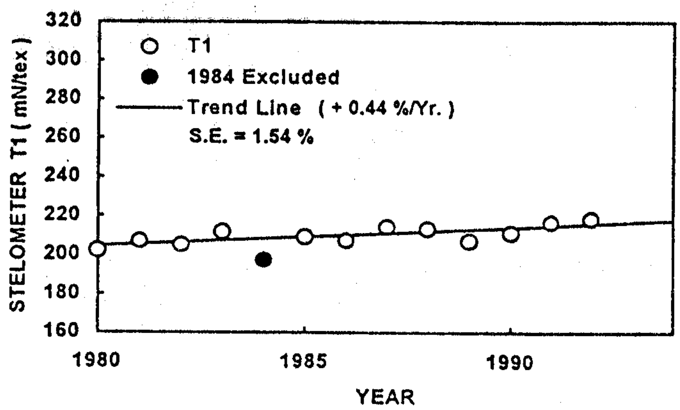

Figure 1. High Quality Regional Cotton Variety Test.

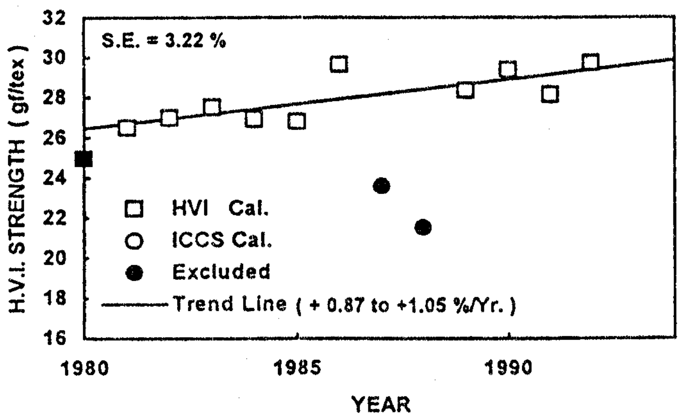

Figure 2. High Quality Regional Cotton Variety Test.

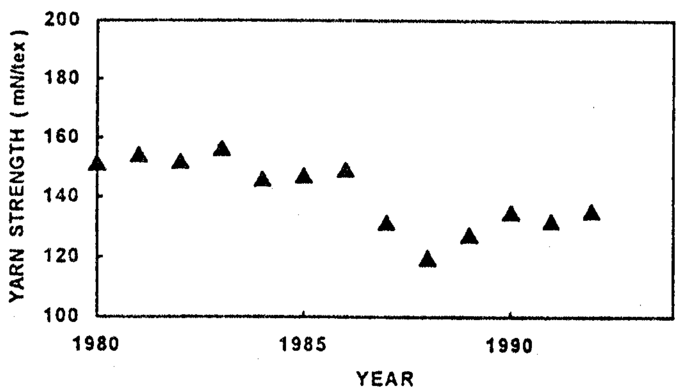

Figure 3. High Quality Regional Cotton Variety Test.

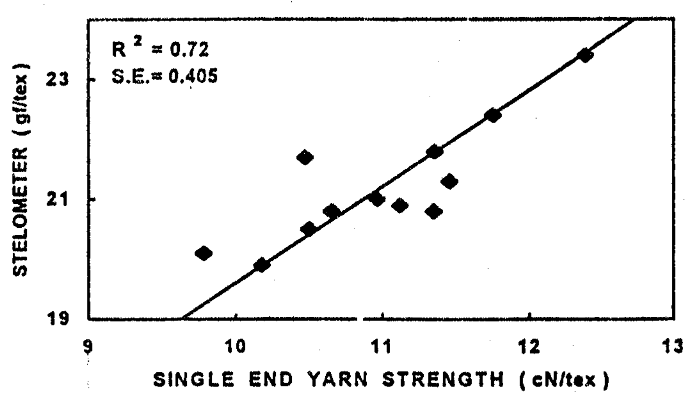

Figure 4. Measured Strength of 22's Rotor spun Yarn.

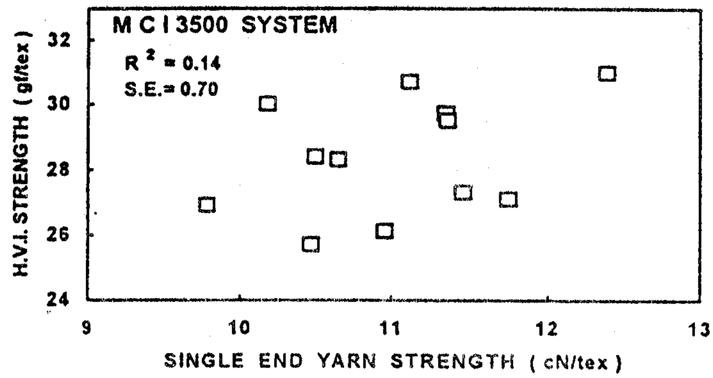

Figure 5. Measured Strength of 22's Rotor Spun Yarn.

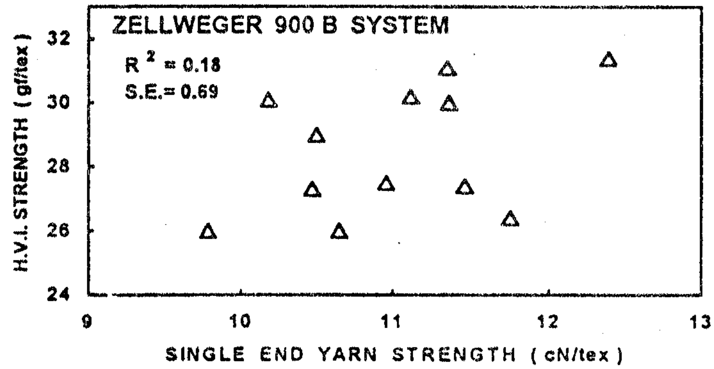

Figure 6. Measured Strength of 22's Rotor Spun Yarn.

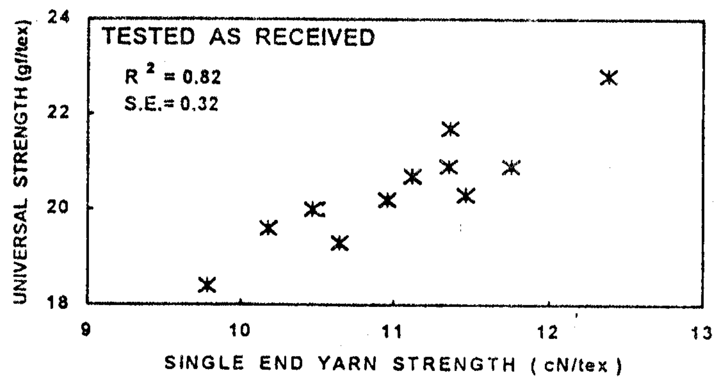

Figure 7. Measured Strength of 22's Rotor Spun Yarn.

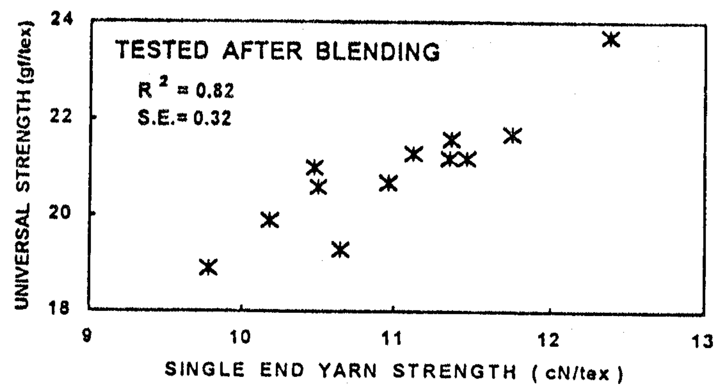

Figure 8. Measured Strength of 22's Rotor Spun Yarn.