SIGNIFICANT EVENTS LEADING TO THE DEVELOPMENT OF HIGH SPEED MEASUREMENTS OF COTTON FIBER STRENGTH

Harvin R. Smith, Assistant Director (Retired)

This report is a companion to one published in the Winter 1996 issue of Textile Topics, relating to the development of the micronaire test.[18] As with the previous report, former colleagues in the USDA AMS Cotton Division provided critical file copies and published references needed to document the information in this report. Special gratitude goes to Mr. S. R. Griffith of the Washington Management Staff and to Dr. H. H. Ramey in the Cotton Division office of the Deputy Director for Field Operations; these men contributed a major portion of the information referenced here.

Early Work

Cotton fiber strength is a primary contributor to yarn and fabric strength. Early measurements consisted mainly of slow, tedious and imprecise single fiber measures. Cotton classers also attempted to assess fiber strength by "snapping" the staple pull and using such subjective terms as "strong," "weak" or "perished."

In the 1920s, efforts were made to break groups of fibers with the ends glued to cardboard or paper. After mounting in the breaker, the cardboard was slit and the fibers broken. Some researchers attempted to twist the fibers to simulate yarn. All of these were unsatisfactory and showed little relationship to actual yarn or fabric strength.[10]

The Round Bundle Test

In 1926, Dr. E. E. Chandler reported on a new method for breaking cotton fibers by using a bundle of fibers wrapped with a No. 20 cotton thread.[8] The Tensile Testing machine used was a pendulum type, very similar to the one in use here at ITC for breaking skeins of yarn. The bundles were wrapped under tension and extreme care was used in the sample preparation. The size of the bundle was determined by measuring the length of 10 turns of the thread and calculating the circumference and area of the bundle.

Test results were reported in thousands of pounds per square inch. Chandler reported a standard deviation of 300 pounds per square inch for repeated single measures and recommended that at least 10 breaks be performed per sample in order to produce a reliable average. This method was published as a tentative ASTM standard in 1935 under the title "General Test Methods of Testing Cotton Fibers" Method D-414.[1]

A more detailed report on the Chandler Strength Test was published by Richardson, Bailey and Conrad in USDA Technical Bulletin 545, January 1937.[15] This report not only gives more details of the Chandler method, but provides a good summary of previous methods as well.

The Pressley Flat Bundle

The Pressley Flat Bundle test was developed by Dr. E. H. Pressley in 1939. Dr. Pressley was a cotton breeder at the University of Arizona at the time, but he had been trained in textile manufacturing at Clemson University. He became acquainted with a precision machinist by the name of Joseph M. Doebrich, who actually produced the testing instrument using Pressley's designs.

This test method used a simple inclined plane breaker and simple specimen preparation and clamp loading techniques. The Pressley tester operated 6 to 8 times faster than the Chandler method and correlated well with it. Since the area of the flat bundle could not be readily determined, Pressley recommended that a simple ratio of the breaking load and the bundle weight be used for reporting the results. However, because of the strong relation with the Chandler test (correlation coefficient = .971), an empirical relationship and "look up" tables were developed to convert the Pressley index to the equivalent Chandler in thousands of pounds per square inch.[14] The USDA lab at Stoneville, Mississippi published a complete evaluation of the Pressley tester in June 1943.[18] To do the study, eight testing machines and four operators were used in measuring 24 cottons. The results showed significant differences between both operators and instruments, which made clear the need for operator training, instrument adjustment, and standard cottons for calibration. An average of ten breaks was recommended with two operators making five breaks for each sample. The Pressley method was first published by ASTM in 1952.[2]

The Pressley machine was quickly adopted by the industry and is used to this day in laboratories all over the world. The ITC currently has two functioning Pressley instruments to provide these measurements when requested by customers.

The Issue of Gauge Length

The gauge length or jaw spacing for cotton fiber bundle strength tests was a matter of speculation and research as early as 1926. At this time, the practice was to put the jaws in contact with each other, leaving no length of cotton fibers in a space; this was called a "zero gauge test". Both the Chandler Round Bundle test and the Pressley test adopted the zero gauge test.

Pierce[13], working with single fibers, was perhaps the first to advance the "weak link theory", holding that fibers broken at a finite jaw spacing were much weaker than when broken with no space between the jaws. In 1948, Phillips[11], [12], working at the Goodyear Tire & Rubber Company, reported that cotton fiber bundles lost about half of their strength when broken at a 5 mm gauge length instead of a zero gauge. Phillips used a modified Scott tester for this work and adapted the Pressley clamps to it, enabling varying jaw spacing and simulation of the same rate of loading used for yarns. He also demonstrated that the 5 mm gauge length was a significantly better predictor of the strength of tire cords made from the cotton.

New Instruments for Breaking Flat Bundles

Hugh Brown[5],[6], working with the New Clemson Flat Bundle tester, recommended that a gauge length of 3 mm be used for testing cotton fibers. The Clemson test instrument could be set to five different gauge lengths: 0, 2, 4, 6 and 8 mm. Subsequent models Following this, new models of the Pressley tester were equipped with slots to accept clamps without a spacer or using a ⅛ inch gauge metal spacer between the clamps. The ⅛ inch spacer was used because 3 mm steel stock was not readily available in the U.S. at the time. The ⅛ inch spacer was the closest equivalent available at 3.2 millimeters.

Shortly thereafter, or perhaps within the same time frame, the Spinlab company produced a bundle test instrument called the Stelometer. [9] This machine provided a constant rate of load and a measurement of fiber elongation as well as the breaking strength at both ⅛ inch and zero gauge lengths. This test method was first published by ASTM in 1952.[3]

An extensive study of these three machines operating at both zero gauge length and at 2, 3 and 4 millimeter spacing was reported by Burley and Carpenter of the U.S. Department of Agriculture in 1955.[7] This work was done using a modified Pressley instrument and the Clemson tester. The Stelometer became available later in the study and only the ⅛ inch gauge data was reported for this instrument.

This report concluded:

a. One machine was not superior to another in explaining test variation or in predicting yarn strength

b. Maximum significance was obtained at the ⅛ inch gauge spacing

c. All three testers produced results on different test levels

The Clemson tester never came into wide use because of the difficulty and associated errors in reading the charts used with it. The Stelometer, because of the pretensioning device and the constant rate of load, became the instrument of choice for making ⅛ inch span length measurements. The Pressley continued in wide use for making zero gauge measurements. These values were already in wide use in evaluating commercial shipments of cotton, with calibration provided by the USDA to control test levels.

The ⅛ inch gauge test was readily accepted in the scientific community, especially among cotton breeders who were developing new varieties. Eventually, however, the large difference in test levels between laboratories and between the Stelometer and Pressley, however, became a matter of concern. In 1964, Joseph T. Rouse published a letter to the editor of the Textile Research Journal on the subject.[16] In this letter, Rouse presented data showing that the Stelometer strength measurements were 10 to 15 percent lower than the Pressley measurements, and used correction factors computed from standard calibration cotton to adjust these data to produce good agreement between the two machines.

Pursuit of Faster Instruments

At the urging of the National Cotton Council and the Cotton Producers Institute, the Stanford Research Institute engaged in research and development directed toward building a faster cotton strength test machine.

This device was reported by Berriman and Levy during the 1965 Cotton Research Clinic.[4] The prototype machine was designed to produce over 200 tests per hour with good correlation with existing testing machines. The machine was composed of a turntable with six stations where the cotton was mechanically prepared and analyzed for strength and elongation. The turntable was driven by a variable speed electric motor and hydraulic pressure was used to activate the clamps. The six stations consisted of feeding the fibers, combing out loose fibers, brushing and straightening, measuring fiber density, tensile testing, and clamp cleaning.

This research indicated that high speed strength tests could be done. This prototype was never produced commercially, however, because of its size, complexity and cost.

The HVI Strength Tester

During the early 1960s, Glen Witts, president of Motion Control, Inc. in Dallas, Texas, began working to develop an automated strength test instrument.[17] His early work was supported by the Plains Cotton Cooperative Association of Lubbock, Texas. The overriding objective, moreover, was to assemble a series of high speed test instruments to rapidly measure all the important quality characteristics of cotton. A fiber strength instrument was at that time seen as the missing link. This work gained the interest and support of USDA, and a contract for the development of a complete system, including strength, was issued in 1967 and demonstrated by USDA in 1968. The Motion Control strength test instrument was unique in several respects:

- It operated at acceptable speeds (less than 10 seconds).
- Leather jaw facing was replaced by a series of moving paper tapes.
- It utilized the length gauge to sense the beard mass and signal the strength tester when the proper mass was reached, enabling the specimens to be broken at a constant mass, thus eliminating the necessity for weighing.
- All test data was calculated and transmitted automatically, freeing the operators of this burdensome task.

Today all HVI systems incorporate the ideas generated in this first machine. The most significant improvement has been the replacement of the moving jaw paper with a special wear-resistant plastic jaw surface.

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