Development of Characterization Methodologies of Fiber surface Characteristics: Surface/Process Analysis

Code: F96 - A3

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Goal

1. To develop methodologies that can be utilized for fiber surface characterization. Those methodologies should simulate the interactive nature between fibers and fibers/other solids.
2. To verify the benefits of those methodologies in relation to both fiber processing and yam quality.

Abstract

It is well known that both fiber-to-fiber and fiber-to-metal friction are involved in the entire textile process, so that the understanding and measurement of fiber friction behavior are critically important in order to efficiently control the processing of fibrous assemblies and obtain high quality yam and fabrics. Along with our comprehensive study of fiber friction, we have developed a novel test procedure, Auburn Beard Test, to measure the inter-fiber friction. Recently, we have modified this method, designed and constructed an instrument. To evaluate this new instrument, cotton and polyester staple fibers have been systematically tested and the friction profiles of those fibers have been recorded. The evaluating results indicate that the Auburn Beard Test instrument has a good reproducibility and a high sensibility for both fiber-to-fiber and fiber-to-metal friction.

The friction behavior of yam is another important aspect in textile processing. It plays a key role in weaving efficiency and in performance of the final fabrics. Normally, yams from different spinning system will differ in their surface structure, which will be reflected in their frictional behavior. In addition, yams after different chemical or physical finishing tend to give different surface characteristic and thus different friction behavior. We have expanded Auburn Beard Test

instrument to measure yarn friction profile. The friction behavior of various as-spun yams and sized yams has been investigated, and some of results will be presented in this report.

Technical Approach

Two uniquely different approaches have been taken: (1) tension-based, (2) compression-based.

1. Tension-Based Approach

The Installation of Auburn Beard Test

Figure 1 shows a block diagram of the new Auburn Beard Test instrument.

The specimen unit is the core of this instrument. For fiber beard testing, the unit consists of three parts: the top clamp, two bottom clamps and the lateral pressure pistons. The top clamp is attached to a load cell with load capacity of 2.5 LBS. Two bottom clamps are mounted with an angle on a movable platen, which can be driven by a step-motor. The lateral pressure pistons are connected to two metal plates, through which the lateral pressure is applied using a pneumatic system. For yam friction testing, the unit is simply a metal plate on which six frictionless pulleys are fixed as shown in Figure 1. The bottom of the metal plate is mounted on the movable platen.

The step-motor, driving the platen up and down, can be programmed and controlled by a motion controller through a computer terminal. The load cell converts force to a voltage signal proportionately. The signal is digitized and displayed as individual friction force by a programmable digital indicator. The signal is then transmitted to the computer via a serial interface.

A Labview® program has been created under Windows 9.5 to communicate with serial port, acquire and analysis the testing data, display the data in chart form and finally save the data in a spreadsheet tile. The program can be modified to suit the test requirements for fibers with different staple length and various yams and fabrics.

Testing Procedure

For the measurement of fiber-to-fiber friction, three fiber beards are prepared on the HVI fibrograph sample preparation station. The top beard clamp is put in a frame that is attached to the load cell. Two bottom beard clamps are mounted on either side of the top beard and attached to the platen, and then clapped together to form a friction surface on both sides of the top beard as shown in Figure 1. The pneumatic pistons from opposite sides of the beard allow the desired level of lateral pressure to be applied to fiber beards through two metal bars connected with the pistons. As two bottom beards start to move down with the platen, friction between both sides of the top beard and the inner sides of two bottom beards is produced, and the friction profile is generated. Consequently, friction parameters can be obtained by further analysis of this friction profile.

For the measurement of yarn friction, the yarn is placed over the pulleys following two paths which then cross over each other to form different turns of twist. The upper free ends of yam are attached to the load cell, and the lower free ends are tied with two equal weights. As the metal plate starts to move downward with the platen, friction occurs between the twisted yams and the friction profile is generated, from which the friction coefficient can be calculated.

2. **Compression-Based Approach**

The approach being pursued at NC State is the utilization of a compression cell to measure fiber friction. The specially designed compression unit affords a controlled displacement cycle. A weighed sample of the fiber to be tested is loaded into the apparatus and is subjected to a compression-relaxation cycle. The load experienced by the sample is recorded throughout the test and the data is collected for analysis. The data produced can be analyzed in different ways:

- traces of the load displacement curve can be created;
- the load experienced at a predetermined compression can be identified;
- if the load displacement curve is smoothed, the smooth curve can be subtracted from the original data to potentially yield an indication of stick-slip behavior.

Examples of the various representations of data are shown in the Figures 2 and 3.

The apparatus is presently being upgraded to permit more rapid data acquisition and analysis. It is then intended to evaluate the possible influences of testing conditions on the measured values, before carrying out comparative trials with the Auburn Beard Test.

Results and Discussion

1. Fiber Friction Test

Beard tests on cotton, polyester and micro-polyester all exhibit good reproducibility and show that the friction force increases gradually for both cotton and polyester fibers with increasing lateral pressure applied to the fiber beards (see Figure 4). Furthermore, the **difference** between polyester-polyester and cotton-cotton friction force decreases with increasing the lateral pressure.

At the lateral pressure level of 2 Psi, the friction force of polyester fiber is consistently larger than that of cotton fiber as the sliding speed increases; whereas at the pressure level of 10 Psi, the friction force of polyester fiber is larger at the lower sliding speed and smaller at the higher speed than that of cotton fiber. Such a variation of friction force might be due to the higher lateral pressure applied to fiber beard. Both results indicate that testing at the relatively lower lateral pressure will provide more information about the fiber surface than testing at the higher lateral pressure.

Normally, the HVI sample preparation routine, double combing and one brushing, is applied to fiber beards prior to testing. Increasing the combing time results in a decreasing of friction force of cotton fibers as shown in Figure 5. However, the decrease of friction force tends to level out until the combing action reaches four times, and then continual increase of combing times appears to have little effect on the friction force of cotton fibers.

The effect of fiber dimension, especially fiber length, on friction behavior of cotton fiber beards has been investigated and the results are shown in Figure 6. Those cotton fibers have identical surface characteristics and fineness, but different fiber length. Friction profiles of those fibers show that the initial maximum friction forces tend to stay in the same level as fiber length decreases, whereas the slope of profile increases steadily with decreasing fiber length. This, in turn, results in a linearly decrease of the area under the profile. This phenomenon implies that the maximum friction force would be essentially independent of fiber length. However, fiber length is an important factor to be considered if cohesion force is concerned. As seen in Figure 7, fiber cohesion force exhibits a linear increase with increasing the fiber length (Cohesion force is measured on a Cohesion Tester in this Lab.).

The contribution of fiber friction to final yarn qualities and fabric performances is always an important concern in whole textile process. In this study, we have measured the friction force of the forty-seven upland and four American Pima cotton bales used in the 1994-1995 USDA cotton crop survey report. Opening energy and sliver cohesion force have also been tested using Rotor-Ring and Cohesion Tester. Those cotton were selected from the different areas of the United States to represent leading cotton varieties. USDA Cotton Quality Research Station has conducted the measurements of fiber properties and spinning performance of those cotton samples. We will systematically study the relationships between friction behavior, processing performance and product quality, and present the results in the next report.

2. **Yarn Friction test**

The friction profiles of as-spun and sized cotton, cotton/polyester blended yams were obtained using our expanded Auburn Beard Test. The friction coefficients of those yams were determined from their friction profiles and are listed in Table 1. Generally, the friction coefficient of sized yam is slightly smaller than that of corresponding as-spun yam, indicating a lower friction of yams after being sized. The evaluation of testing condition shows that increasing initial weight T_0 from 20g to 50g hardly has any significant effect on friction coefficient μ although there is a tendency for μ to slightly decrease. However, increasing the turn of twist results in a visible decrease of friction coefficient μ.

Work Planned for The Next Year

Our Auburn Beard Test allows us to rapidly measure the friction profiles of various fibers and yams with easy sample preparation, high data reproducibility. We are continuing to work on the following subject during the next year:

1. Completing testing and analysis of the USDA cotton samples; Testing different types of textile staple fibers, such as polyester, nylon, acrylic and polypropylene, with different finishing and so different surface characteristics; Relating the friction behavior of various fibers to their spinning process and final product properties.
2. Testing various yams from different spinning system, e.g. air-jet yam, open-end yarn and friction-spun yam.

3. Based on above tests, building up a database for friction property of various fibers and yams.
4. Extending the instrument's capability to measure the friction behaviors of textile fabrics.
5. Investigating the use of sound produced by fibers during processing as a guide to friction behavior and process performance.

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Table 1. Friction coefficient μ of raw and sized yam at different initial weight and different turns of twist.

Yarn Samples	Turns of twist **=2**			Initial weight **=20g**		
	T_0=20G	**T_0=35g**	**T_0=50g**	**τ =1**	**τ =2**	**τ =3**
CTN raw	0.27	0.26	0.26	0.49	0.25	0.17
CTN sized	0.26	0.25	0.25	0.47	0.24	0.16
50/50 raw	0.28	0.27	0.27	0.49	0.26	0.19
50/50 sized	0.27	0.26	0.26	0.47	0.25	0.17
65/35 raw	0.28	0.28	0.27	0.49	0.27	0.19
65/35 sized	0.27	0.27	0.26	0.47	0.26	0.17

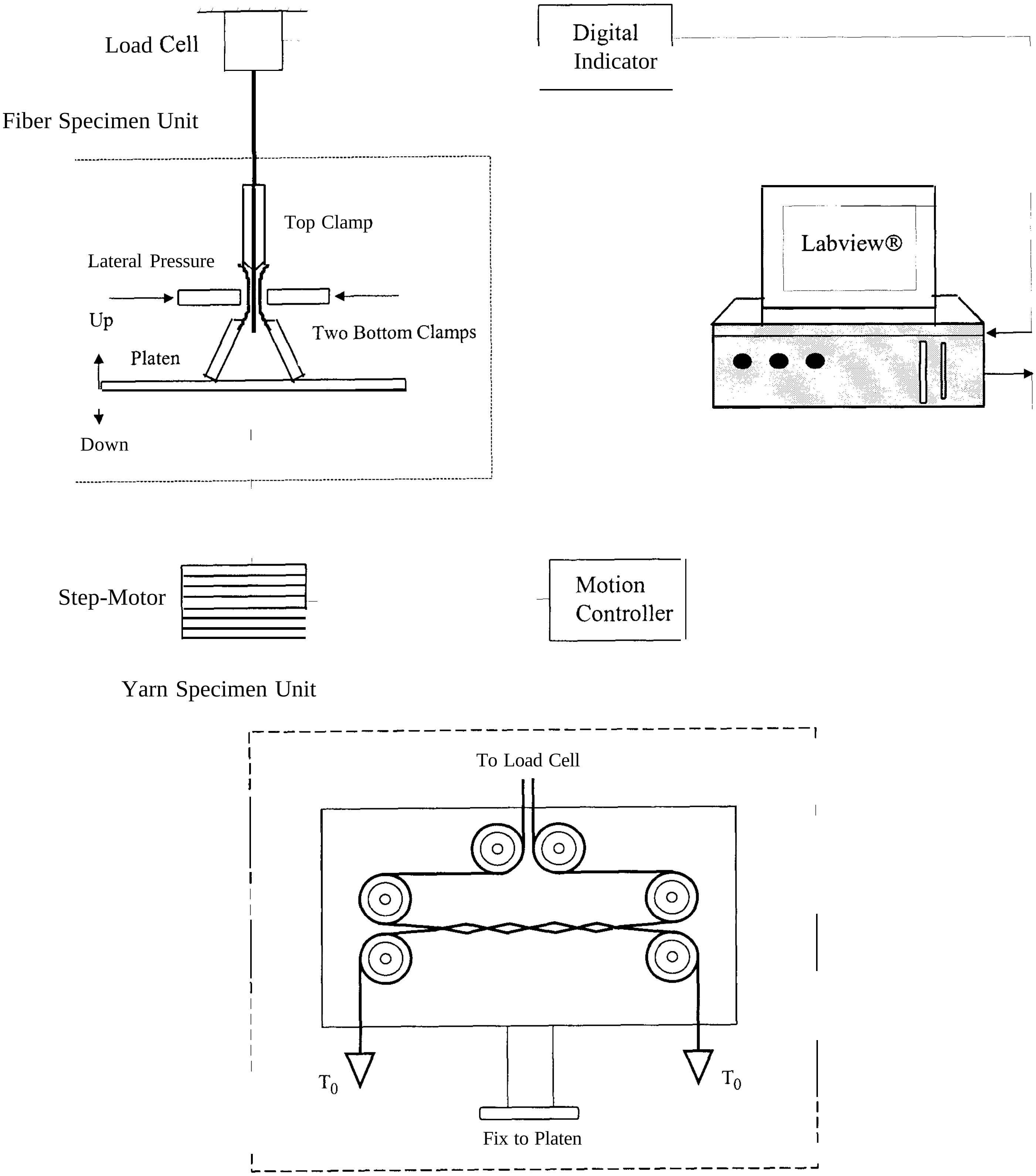

Figure 1. A schematic diagram of Auburn Beard Test Instrument

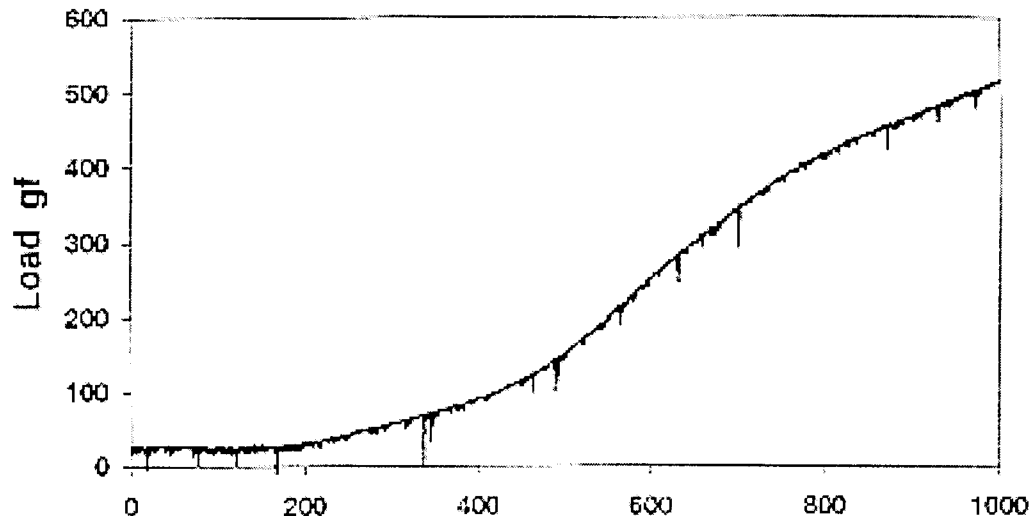

Figure 2. Compression curves of raw data

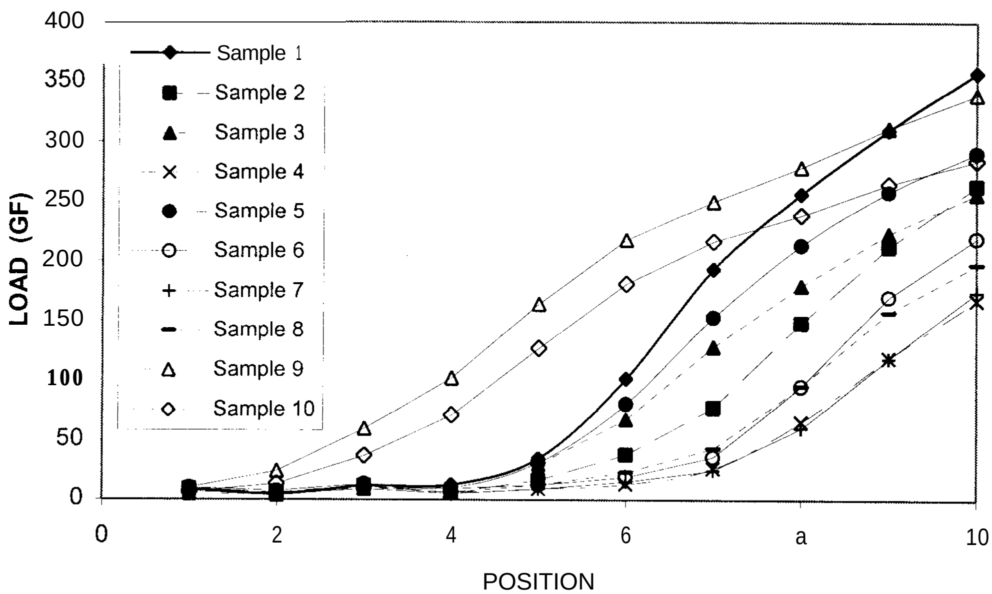

Figure 3. Load at different position of compression cycle

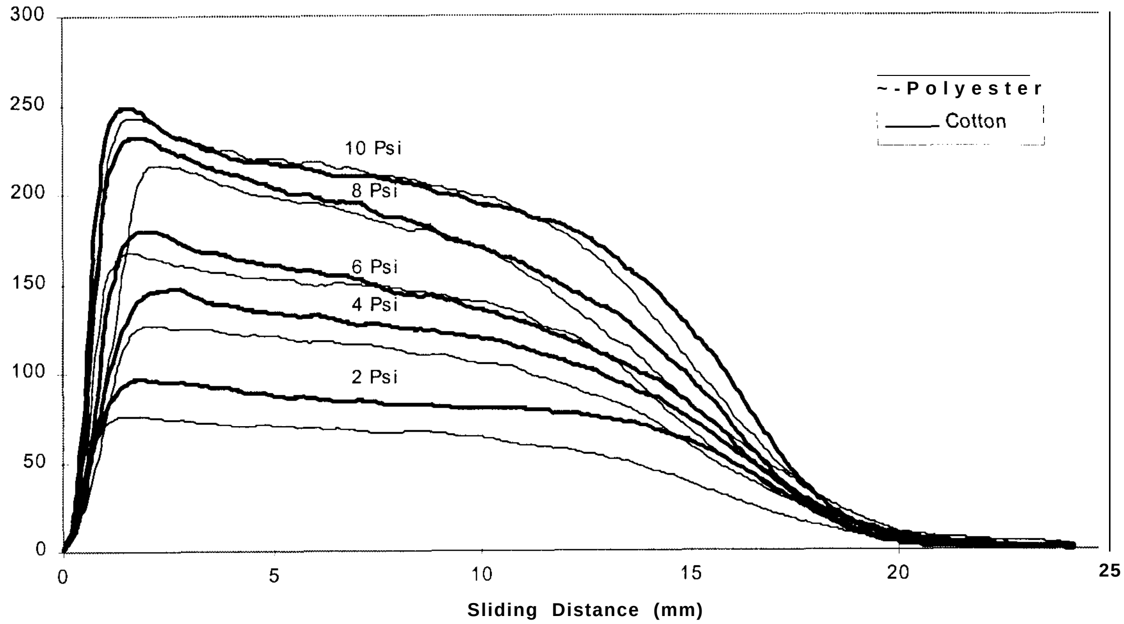

Figure 4. Friction profiles of cotton and polyester fibers obtained using Auburn Beard Test

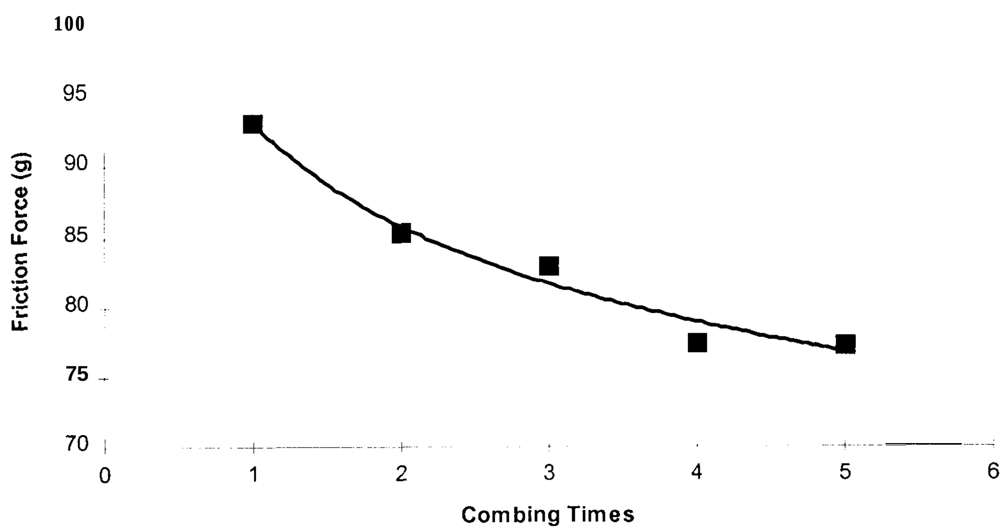

Figure 5. The maximum friction force vs. the HVI combing times for cotton fiber

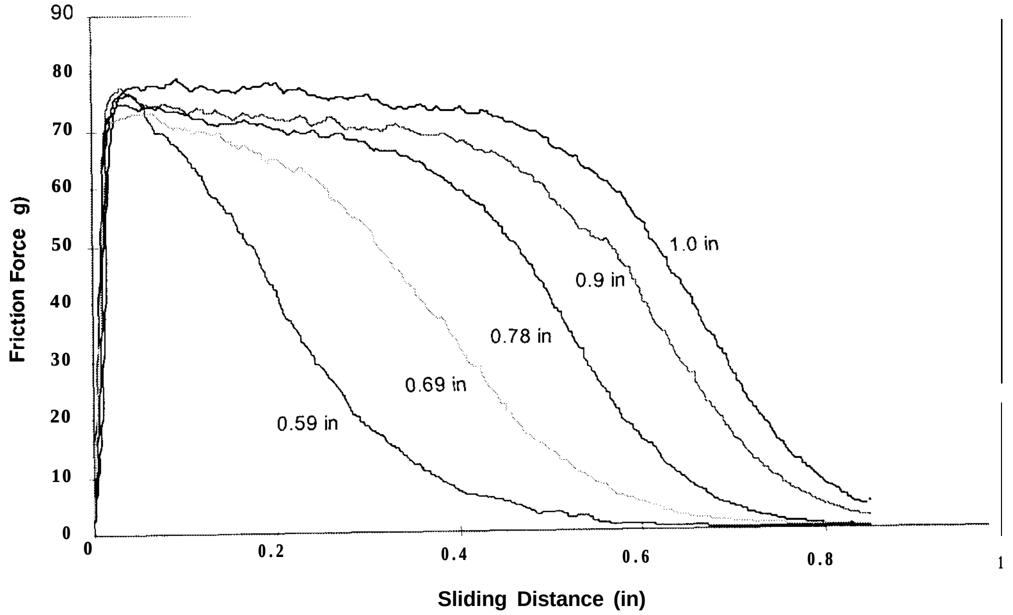

Figure 6. Friction profiles of cotton fibers at different fiber length

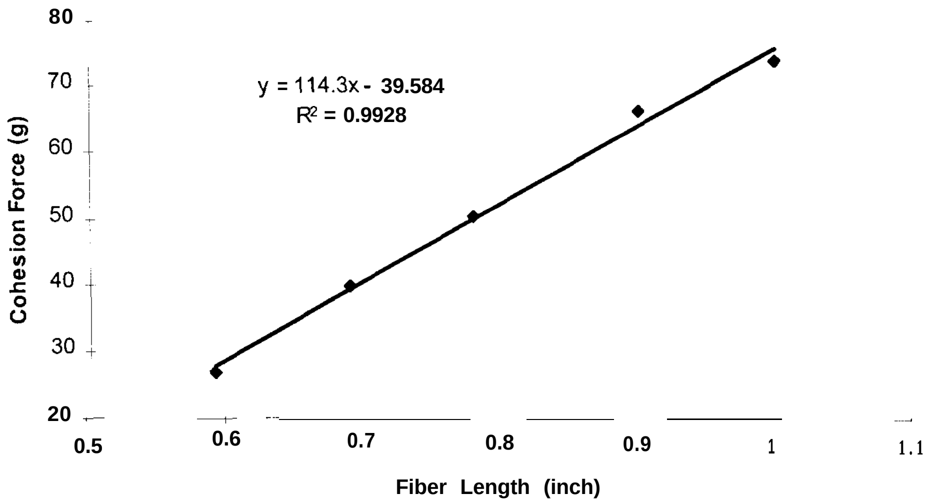

Figure 7. Cohesion force of cotton fibers vs. fiber length