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Cotton Fiber Quality: Characterization, Selection, and Optimization

Project: A92-1

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1. Cotton Quality Characterization

Cotton Fiber Friction:

The Beard-Friction testing technique developed by Auburn Textile Engineering has continued to prove its capability in characterizing the frictional behavior of staple fibers along their span length. The various parameters produced by this method have been utilized in a number of important applications including:
(a) providing a precise interpretation of the role of fiber friction in determining the tensile behavior of staple fiber yarns based on a modification of the Pierce approach [MS Thesis by Qin Wang, July, 1994], (b) characterizing the friction of blend components of cotton/polyester yarns [paper presented by El Mogahzy, in the Textile World Microdenier Conference, May, 1994], and (c) predicting the processability of wet-treated cottons in the nonwoven process [two-part paper written El Mogahzy, Broughton, and Qin Wang, International Nonwoven Journal, submitted July 1994, [in press].

This focus of this year work has been on a three main areas:

(i) Establishing standard friction values of raw, scoured and bleached, and finished cottons using the Auburn-Beard test.

(ii) Examining the capability of the Auburn-Beard test in predicting the processing performance of finished cottons during carding.

(iii) Modifying the Auburn-Beard test to make it independent of the Instron tensile tester by developing an independent drive system for the Beard test.

With regard to the first point, average levels of fiber/fiber and fiber/metal friction for raw and scoured/bleached cottons have been established. Figures 1 and 2 show typical values of fiber/fiber and fiber/metal friction, respectively. These Figures show an increase in fiber friction resulting from the removal of natural wax by the scouring and bleaching process.

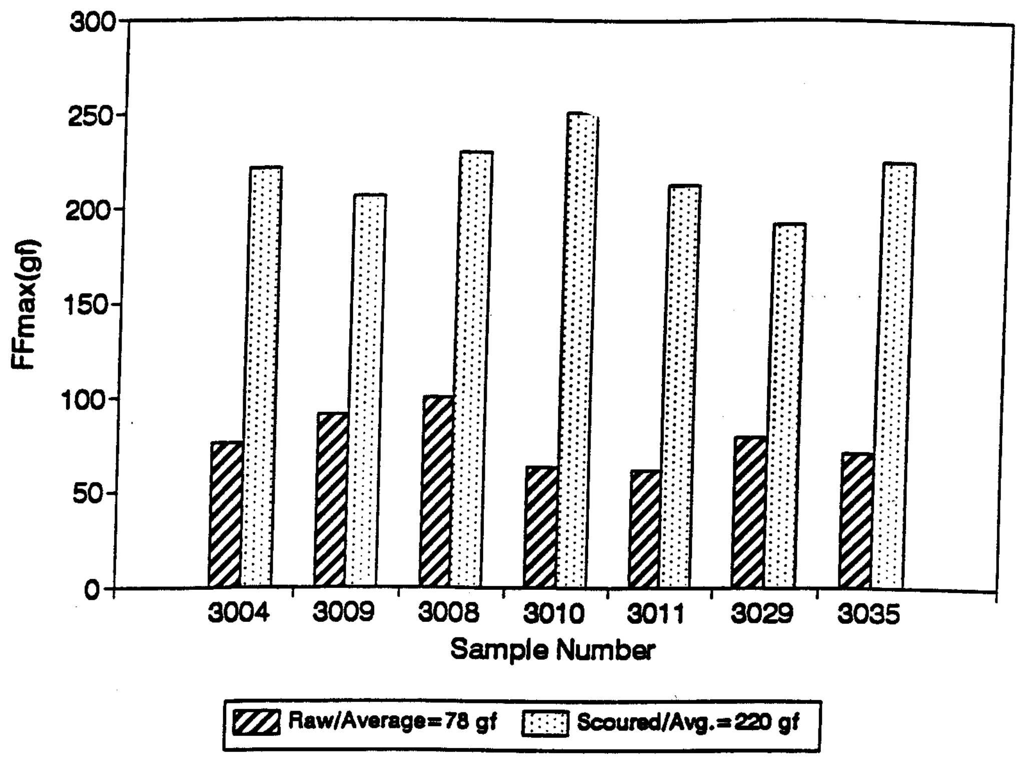


Figure 1 Maximum Interfiber Friction Force from Raw and Scoured Cotton (Beard Friction Test)

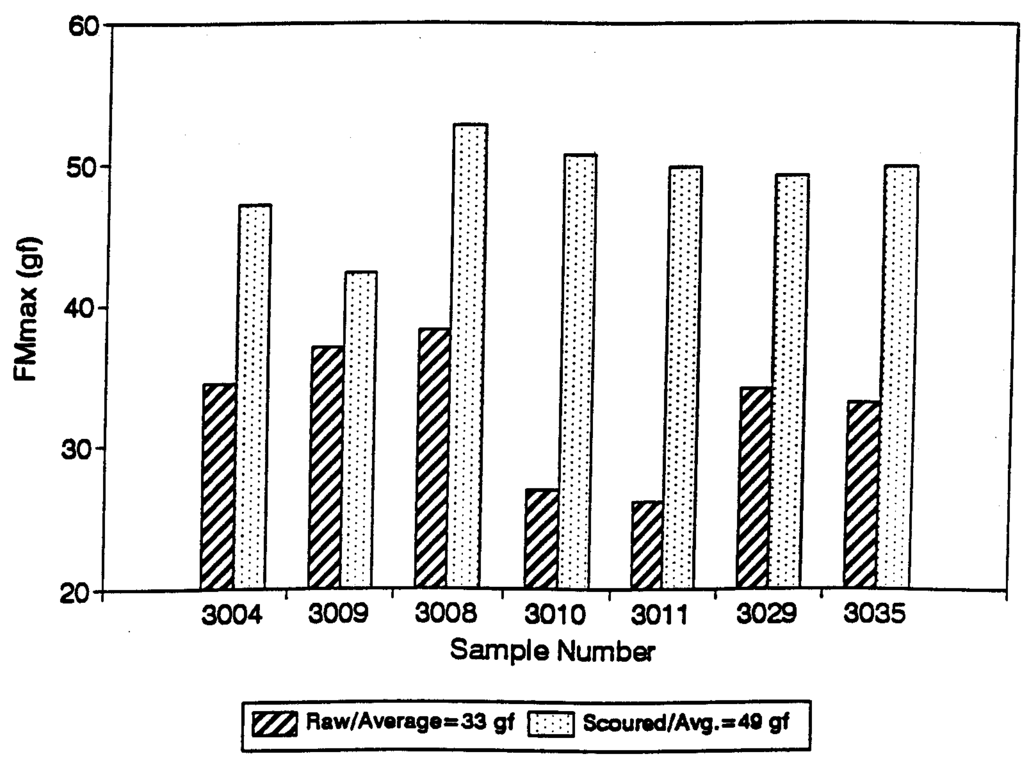


Figure 2. Maximum Fiber/Metal Friction Force for Raw and Scoured Cotton (Beard Friction Test)

Figure 3 shows friction profiles of raw, and scoured/bleached cottons with associated friction parameters produced by the Auburn-Beard test. These fundamental parameters are critical in rationalizing the effect of chemical treatment on the surface morphology of cotton fibers. Efforts are now focusing on rationalizing the differences in stick-slip patterns.

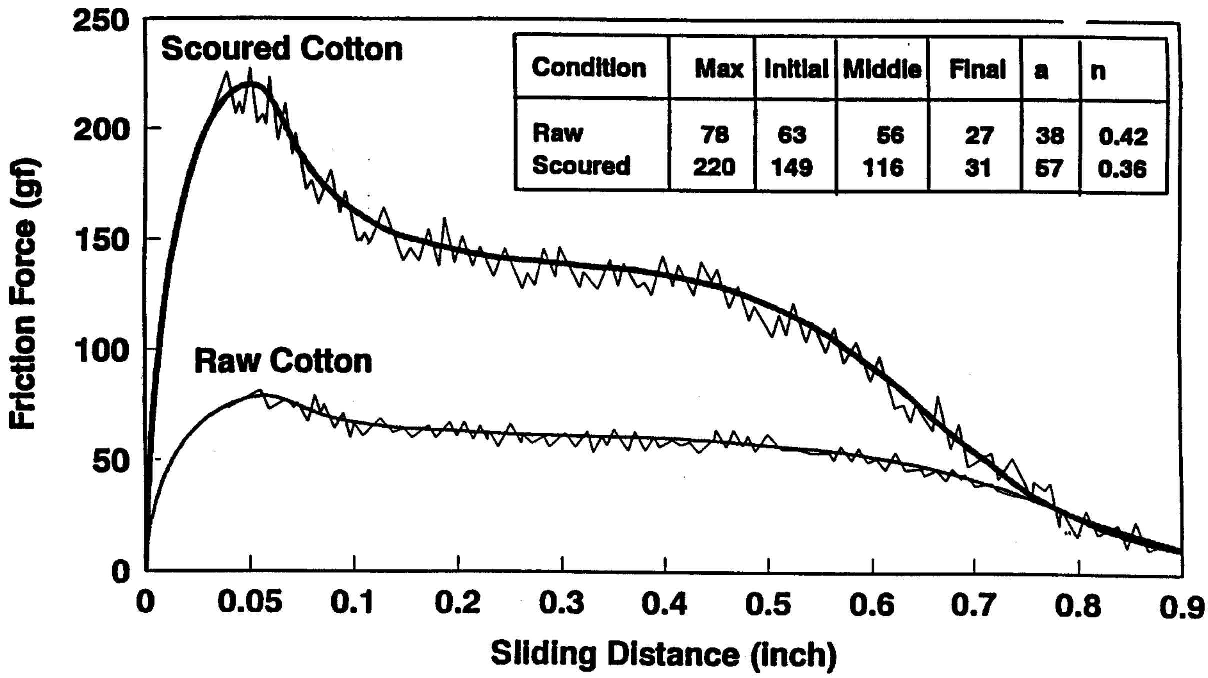
The capability of the Beard test in predicting the processability of wet-treated cottons was examined by testing cottons of different finish conditions which had been processed through carding. Figure 4 shows fiber/fiber maximum friction values of these cottons along with their processing performance [N = normal running, F = failure to run due to cylinder loading and a weak web]. As can be seen in this Figure, treated cottons which were processed normally also exhibited low friction levels, while those which failed to process exhibited high friction levels. The only exception was the cotton finished with BES/Sodium Acetate. This cotton processed normally despite its high friction level. Using the Beard test, it was found that cotton treated with this particular finish exhibited lower levels of friction at higher sliding speeds. Since BES is a liquid finish, these results call for further evaluation of the classical hydrodynamic lubrication theory.

Modification of the Auburn-Beard test is currently being made to allow better control of the driving system, wider range of sliding speed, and better computing capabilities for output parameters.

Detection and Analysis of the Acoustic Pulses from Fracture of a Bundle of Cotton Fibers

Normal Instron testing will measure the breaking strength and elongation of single fibers. If we could measure a breaking pulse for every fiber in a bundle of cotton we could determine single fiber strength statistics from the bundle test. Using a special audio instrument which was developed this year, it may be possible to determine breaking strength and elongation for individual fibers in a cotton bundle. On a very large bundle of cotton fiber it is impossible to compare the height of the acoustic pulse of every breaking fiber with the corresponding breaking strength and elongation. The Clemson group is, therefore, developing a dedicated instrument which can extract breaking strength and elongation of every fiber from complicated information of a breaking bundle of cotton fibers. A stepper motor and an elevator constitute the stretching mechanism of the instrument. The clamp holds about 200 cotton fibers. The signals from the load cell are fed to an amplifier whose amplification is 40 decibels. The signals, representing the change of strength, are then transmitted to the EISA-A2000 High-Speed Analog Board. The EISA-A2000 stores these data in memory-buffers. Data are stored at a rate of 250 ksamples/sec. The computer controls the speed of stretching fibers and records the elongation of every breaking fiber by means of Indexer and Drive. At the same time, a half inch diameter condenser microphone detects the acoustic pulses. The signals from the microphone are fed to a preamplifier. They are then transmitted to a band-pass filter in which the signals are filtered and amplified.

A soundproof box will be developed in which a low noise extension mechanism with an auto-pneumatic jig is installed. This is envisioned as an additional test station, parallel to the strength testing station currently in use on the HVI.



Condition	Max	Initial	Middle	Final	a	n
Raw	78	63	56	27	38	0.42
Scoured	220	149	116	31	57	0.36

Figure 3 Fiber/Fiber Friction Profiles of Raw and Scoured Cotton (Auburn Beard Friction Test)

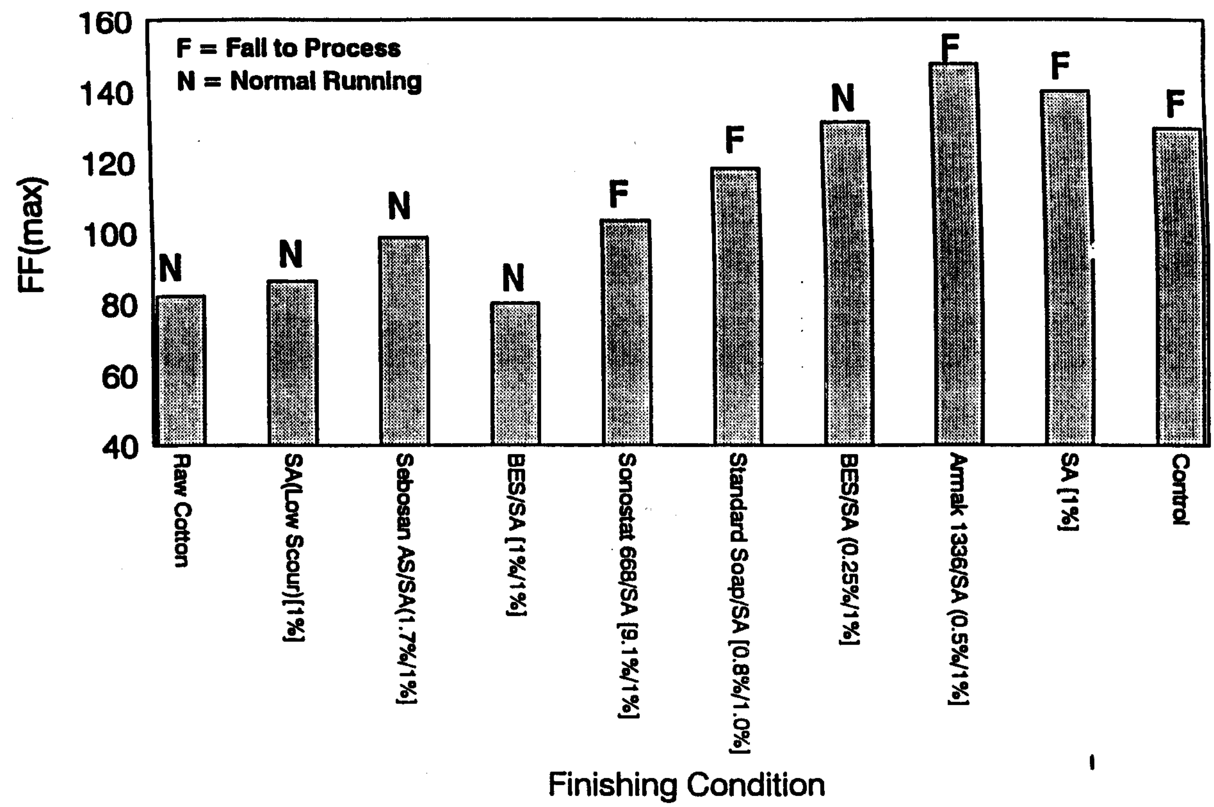


Figure 4 Interfiber Friction and Processing Performance For Finished Cottons

2. Cotton Fiber Selection

Algorithms for Cotton Fiber Selection (El Mogahzy, Auburn)

Results presented in previous progress reports showed that the two fiber selection algorithms developed by Auburn, namely; proportional-weight category picking (PWC), and optimum category picking (OPC), resulted in more uniform laydowns than the random method. Both between-laydown and within-laydown variances were kept under control using an optimum trade-off technique. Currently, we are implementing these techniques for selection involving a desirable yarn quality parameter. This approach requires fiber/yarn modeling techniques. In addition, a special emphasis is being made to improve the uniformity of the cotton mini-mix.

Optimal Blending for Improved Yarn/Fabric Strength (Suh/Koo, NCSU)

A 2,117-bale optimal blending experiment was completed in a 4-week period by processing three different types of cotton to produce 6/1 ring- spun yarns and weaving them into a denim fabric. The HVI data and lab test results on tensile properties of yarns and fabrics were analyzed to conclude that the HVI elongation data in their raw form are not useful as a criterion for bale selection.

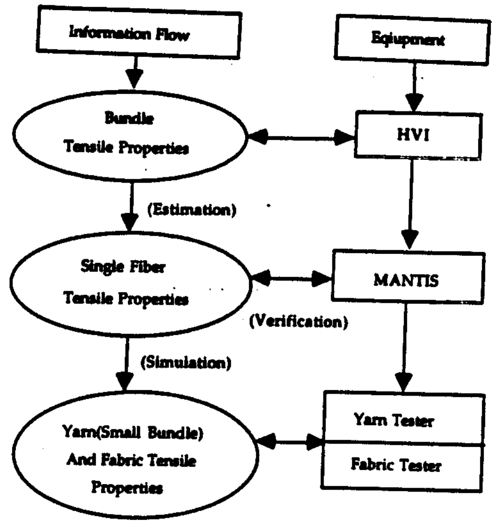
Based on a new model for estimating single fiber tensile properties from HVI bundle tensile data, the variance of breaking elongations was estimated for all fibers contained in each laydown. The schematics of the study design is given in Figure 5. The simulated bundle tensile properties from these converted tensile data were applied in analyzing the experimental data. The simulated tensile properties of small bundles (6/1 single yarn) together with HVI fiber length provided a useful method for optimizing the yarn and fabric strengths. MANTIS single fiber results were used for obtaining the single fiber tensile properties from the HVI bundle data.

Production data were obtained over a 1.5 year period. Thirty weeks of data were selected for analysis, the remainder being discarded because of missing values. A total of 29,145 bales were included in the test periods. Three single-fiber tensile properties were estimated from HVI test results and analyzed for their relationship with the tensile properties of the yarns and fabrics produced and tested during the corresponding periods. One important conclusion is that as the estimated standard deviation of the single fiber elongation decreases, the strength of yarn increases, confirming a research hypothesis. The regression analysis is shown in Figure 6.

3. Fiber/Machine Interaction

In this area, the main focus has been on the change in distributions of fiber characteristics as fibers flow from one process to another in the spinning line. Figures 7 and 8 show typical distributions for Micronaire, and fiber strength, respectively. Based on several trials conducted over time-increments of one hour, it was found that each fiber characteristic exhibits a unique distribution after each processing stage. This finding calls for modeling these distributions to be used as a tool in detecting abnormal fiber/machine interactive incidents.

Figure 6. Design of Single-Fiber Tensile Property Study



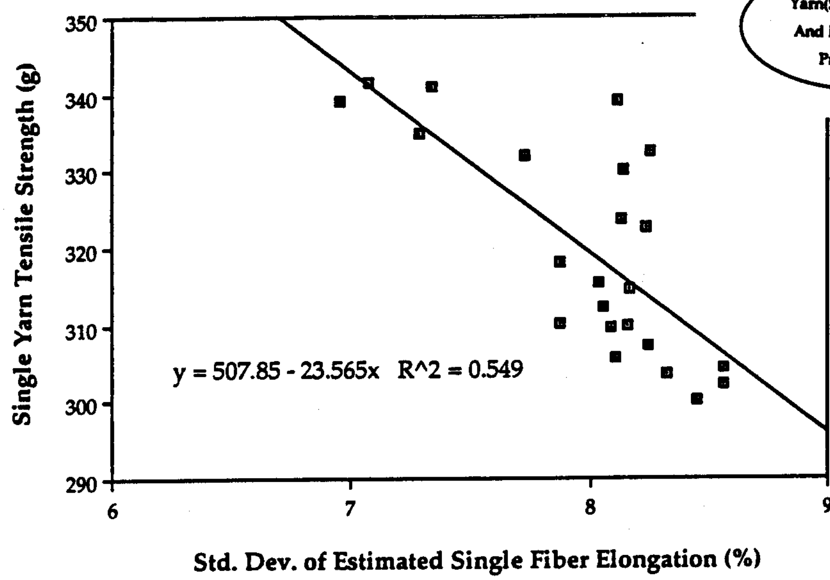


Figure 6. Effect of the Variation of Fiber Elongation on Yarn Tensile Strength

Process	Mean	C.V%
Bales:	4.27	14.54
Chute Feed:	4.21	2.64
Card:	4.15	2.38
Drawing 1:	4.17	1.75
Drawing 2:	4.25	3.05

Process	Blending Index (BI*)
Bales:	
Chute Feed:	96.7%
Card:	97.3%
Drawing 1:	98.6%
Drawing 2:	95.6%

$$* BI = \frac{100\,[C.V^2_{bales} - C.V^2_{process}]}{C.V^2_{Bales}}$$

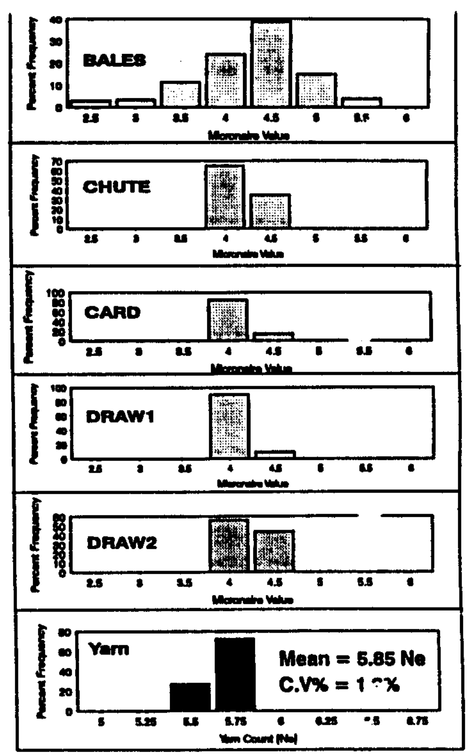


Figure 7. Variation of Micronaire at Each Stage of Processing

Process	Mean	C.V%
Bales:	28.1	8.1
Chute Feed:	28.5	4.1
Card:	30.5	4.4
Drawing 1:	33.5	3.0
Drawing 2:	37.2	3.5

Process	Blending Index (BI*)
Bales:	
Chute Feed:	75.0%
Card:	71.3%
Drawing 1:	86.5%
Drawing 2:	82.0%

$$* BI = 100 [C.V^2_{bales} - C.V^2_{process}] / C.V^2_{Bales}$$

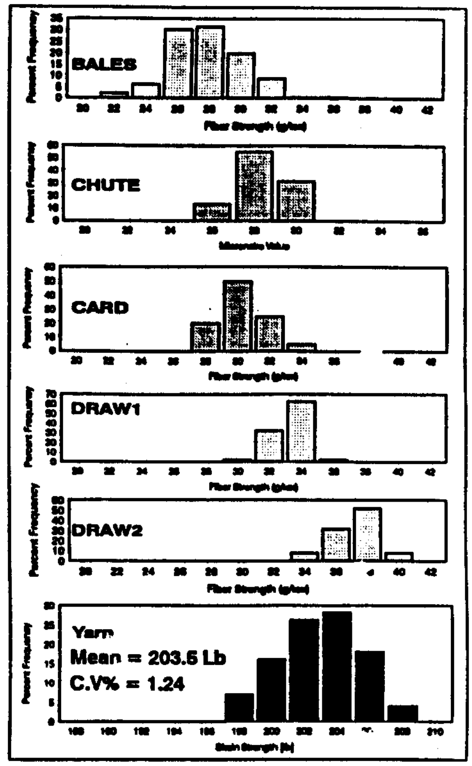


Figure 8. Variation of Fiber Strength at Each Stage of Processing

A study has been made (Oxenam/Aarnink, NCSU) of the possible applications of AFIS to determine fiber machine interactions by quantifying changes in fiber properties during processing. While much of the work has concentrated on a "large scale" industrial trial involving monitoring the sliver quality produced by a set of carding machines over a period of three months, a smaller, more fundamental study has been carried out in parallel. This latter study has investigated the effect of sample presentation and, has shown that both sliver weight and feed direction have an influence on the values obtained for different fiber properties. Data from the industrial trial are still being analyzed, but typical results are presented in Figures 9 and 10, which show the properties of fibers produced by five cards. The differences in the properties represent not only the differences between cards, but also reflect changes in raw material during the assessment period.

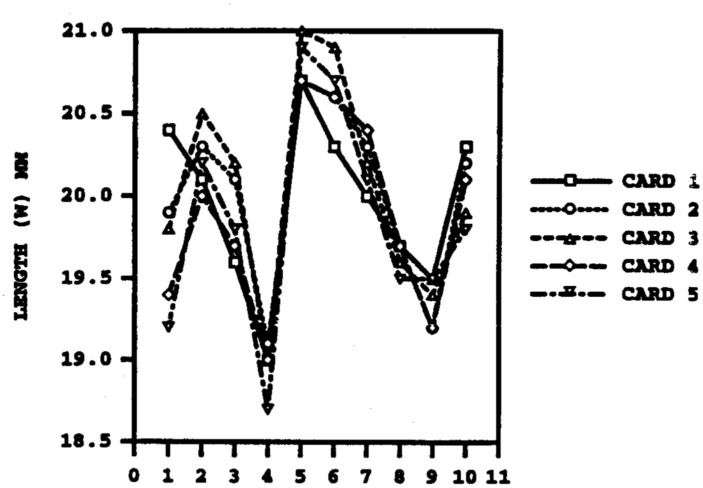


Figure 9. Variation of Card Sliver Fiber Length with Time

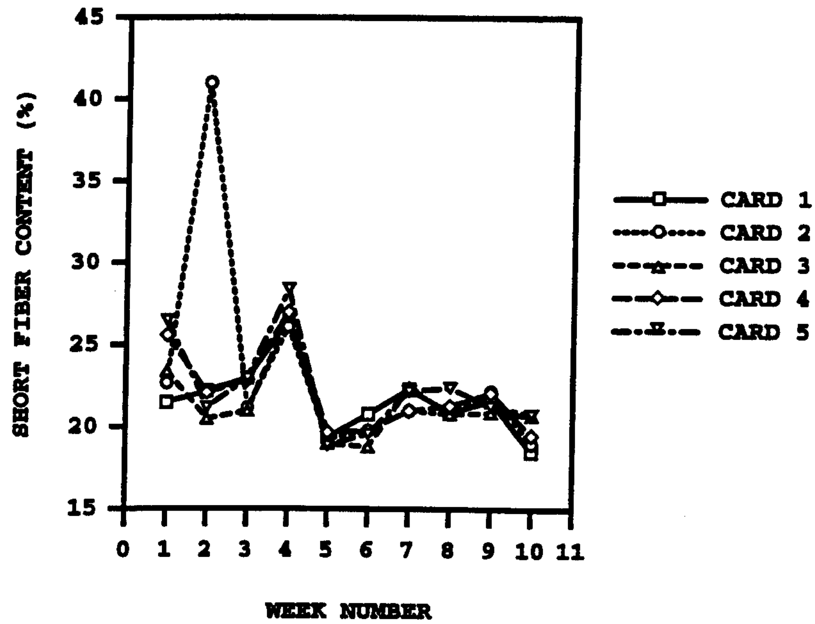


Figure 10 Variation of Card Sliver Short Fiber Content with Time

Evaluation of Yarn Quality Using Surface Analysis

A new method of evaluating yarn quality using a mechanical stylus surface analyzer (MSSA) has been developed. The MSSA was used to characterize yarn surface in order to obtain a surface parameter which might be predictive of subsequent yarn performance. Surface profiles of open-end and ring-spun yarns were collected for short test lengths. The data has been studied in the time and frequency domains. Energy analysis of the instrument signals have been performed. The energy corresponding to signals obtained from open-end yarns are higher than those of ring -spun yarns. The energies of the signals were compared to AFIS and HVI data, and with yarn results from the Uster III. Results were interesting and unique for open-end and ring-spun yarns. As shown in Figure 12, the low frequency range signal energies had a correlation coefficient of 0.59 with ring yarn hairiness and 0.40 with AFIS short fiber content. This suggests that the stylus was measuring either hairiness or some other ring-spun yarn structure related to hairiness. It also suggests that short fiber content could cause very short term irregularities in yarn structure that were measured by the MSSA.

The energy over all frequencies had correlation coefficients of 0.45 and 0.77 with the CV% of ring and open end yarns respectively. This is promising in terms of using MSSA to characterize fine differences in yarn structure between yarns made within a spinning system. Further, the total energy had a correlation of -0.73 with AFIS short fiber content.

Due to the promising results, the MSSA is being redesigned to test longer test lengths (about 10 yards. The objective is to use MSSA to produce a yarn quality index which allows prediction of the hand of knitted fabric. T-shirts from fifteen different cotton rotor yarns have been produced. All fifteen yarn samples have been tested on the Uster III, and the T shirts have been evaluated for hand. The correlations between the Uster III results and hand evaluations are shown in Table 1.

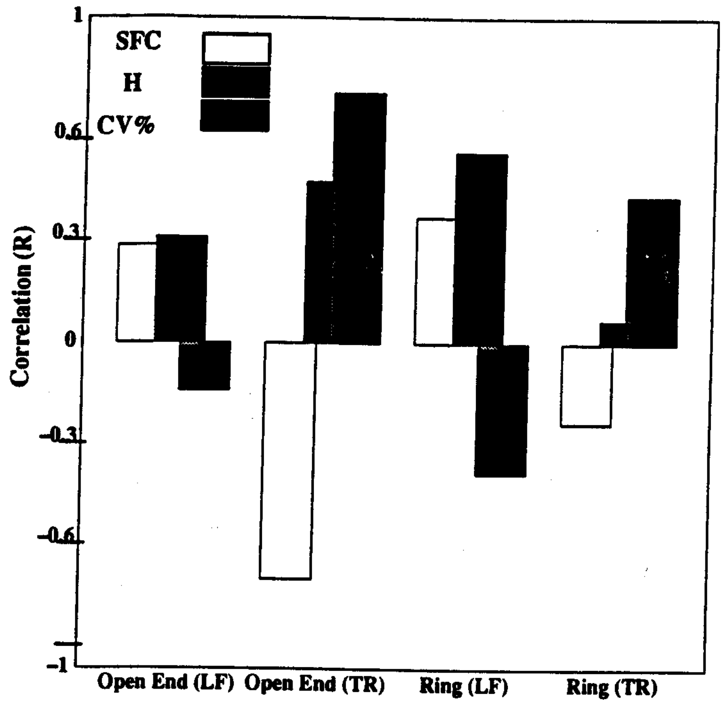


Figure 11. Correlation of Yarn Properties and Surface Profile Parameter (Energy Density Spectrum)

Table 1. Correlation Coefficient Between Hand Evaluation and Uster Parameters

Uster Parameters	Correlation Factor
CV%	-0.386
CV(10)	-0.42
index	-0.373
Th -30	-0.2862
Th-50	-0.299
thk +35	-0.3632
thk +50	-0.378
+200%	-0.2748
+280	-0.1918
Nec/120	-0.5475
m(Max, 10Y) %	-0.3796
m(Min, 10Y) %	0.4423
Sh(-)	0.1639
Sh (Y)	0.1837
h(Max, 1Y)	0.193
h(Min, 1Y)	0.0661

5. Expert System Development

An expert system "SELECTEX" is being demonstrated to industrial representatives. The program in its current state can provide the user with information about yarn count, spinning system, preparation, and fiber type for a given end-product. Fiber/yarn/fabric calculations are being developed. All ASTM testing methods [for fiber/yarn/fabric] as well as some other testing techniques have been incorporated in the program and are readily accessible. A Masters thesis was completed [Mr. Jarick Rager, June 1994] in which details of the "SELECTEX" program are presented.

6. Activities This Year

Publications **	Auburn [5], NCSU [6]
Presentations**	Auburn [3], NCSU [4]
Theses	Auburn [2], NCSU [1]
Students	Auburn [2], NCSU [3]
Industrial Contacts	Auburn [20], NCSU [15]
Academia Contacts	Auburn [8], NCSU [6]

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(1) "Yarn Quality Measurement, New Perspectives", J.P. Rust and Shahran Peykamian,Beltwide Cotton Conference, San Diego, January, 1994, Proceedings.

(2) "Contribution to the Theory of Cotton Fiber Selection and Blending", Yehia EL Mogahzy, Yasser Gowayed, Beltwide Cotton Conferences, San Diego, CA, January, 1994, Proceedings.

(3) "Improving Yarn and Fabric Strengths by HVI and Single Fiber Test Data" Moon Suh, Beltwide Cotton Conferences, San Diego, January, 1994, Proceedings (pp 1648 - 1652).

(4) Cotton Fiber Friction, Roy Broughton, and Yehia EL Mogahzy, Beltwide Cotton Conferences, San Diego, CA, January, 1994, Proceedings.

(5)"Contribution to the Theory of Cotton Fiber Selection and Blending", Yehia EL Mogahzy, Yasser Gowayed, Two-Part Paper accepted by Textile Research J., April 1994, in Press.

(6) " The Friction Profile of Cotton Fibers and its Utilization in the Nonwoven Process, Yehia EL Mogahzy, Roy Broughton, and Qin Wang, Two-Part Paper accepted by International Nonwoven Journal, INDA, July 1994, in Press.

(7) 'Optimization of Yarn and Fabric Tensile Properties by HVI Fiber Data", M. W. Suh, H. J. Koo Proceedings of the 23rd Textile Research Symposium, at Mount Fuji, Shizuoka Japan, (in press).

(8) " Maximization of Yarn and Fabric Strengths through HVI and Single Fiber Testing" , H. J> Koo, Masters Thesis, N. C. State University, December, 1993.

(9) "Softness Evaluation by Mechanical Stylus Scanning", J. P. Rust and T. L. Keadle, K. B. Allen, I Shalev, and L Barker, Textile Res J. March 1994.

(10) "Mechanical Stylus Surface Analysis Instrumentation for Soft Tissue Paper Products" , D. B. Allen, J. P. Rust, I. Shalev, and L. Barker , Tappi Nonwovens Conference, Greenlefe FL, February 1994, Proceedings.