PREDICTION OF YARN TENSILE PROPERTIES BASED ON HVI TESTING OF 36 U. S. UPLAND COTTONS

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Abstract

Thirty six U. S. Upland cottons from 1995 crop were processed into 30/1 Ne ring-spun carded yarns. The Mantis® single fiber tensile properties before and after carding, HVI properties, AFIS® fiber length, and yarn tenacities were analyzed to evaluate the relationship between fiber and yarn properties and effects of carding. The study has shown that HVI bundle strength, micronaire, single fiber strength, standard deviation of single fiber elongation and fiber length are all found to be significant contributing factors to yarn tenacities. The single fiber tensile properties, tested after carding, were shown to be even better for predicting the resulting yarn tenacities.

Introduction

In manufacturing a spun yarn, it is necessary to have procedures on optimal selection of the component fibers and processing conditions in order to optimize the yarn properties. The purpose of this research was to study the relationships between cotton fiber properties and the resulting spun yarn tenacities, and single out the most important factor affecting yarn tenacities.

In addition, this study was aimed at improving the utilization of HVI test results in cotton fiber processing based on the single fiber properties obtained by Mantis® and AFIS®.

Experimental Study on Cotton Fiber and Yarn Properties

From thirty six cotton samples, 30/1 Ne ring-spun yarns were produced by using a laboratory spinning machine at the USDA-ARS SRRC Lab. The cottons were tested for the single fiber tensile properties, length, and short fiber contents using Mantis® and AFIS®, and for the bundle tensile properties using a Spinlab HVI. The fiber data were compared against the resulting yarn properties in order to examine the relationships between the fiber and yarn properties.

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MANTIS® Single Fiber Database Before and After Carding

A large amount of data on the single fiber tensile properties were acquired through Mantis® testing. These samples consisted of 36 bales of major varieties of U. S. Upland cottons from 1995 crop. The samples were drawn from both the raw cotton stocks (bales) and the card slivers. Table 1 shows the origins of the 36 cottons. A total of 28,800 single fiber, 400 tests on each for both bale and sliver samples, were performed on the 36 cottons.

The effects of carding on single fiber tensile properties are shown in Figures 1 ~ 5. The single fiber strength and elongation are shown to be not significantly changed after carding. On the other hand, the single fiber crimp and the variances of single fiber elongation and crimp are shown to have decreased after carding.

HVI Bundle Tensile Properties

The 36 U. S. cottons, as obtained from the bales, were tested for 9 different HVI properties using Spinlab HVI.

AFIS® Fiber Length and Short Fiber Contents

From each of the 36 cottons, a 0.7 gram sample was taken randomly from the bale and aligned gently by hand and then processed into a sliver using a special device. Each sample contained well over 10,000 fibers. The slivers were tested for fiber length and short fiber contents using AFIS®.

Production of 30/1 Ne Ring Spun Carded Yarns

For each of the 30/1 Ne ring-spun carded yarns produced from the 36 different cottons, the tensile properties were tested 100 times, 20 times per bobbin for 5 bobbins, using the standard test method. This data were analyzed with respect to the fiber properties.

Relationship between Fiber and Yarn Properties

Simple regression analyses were run using SAS® system in order to evaluate the relationships between fiber properties and yarn tenacities. The R^2 and p values between each fiber property and yarn yanacity are given in Table 2. The single fiber strength, standard deviation of single fiber elongation, HVI strength, micronaire and AFIS® fiber length all have shown significant correlations with the yarn tenacity.

In Figure 6, the HVI strengths are shown to have a strong positive correlation with yarn tenacities, whereas the HVI micronaires show a weaker negative correlation with yarn tenacities in Figure 7.

Figures 8 ~ 9 show the relationships between standard deviation of single fiber elongation and the yarn tenacities. The standard deviations of single fiber elongations, measured both before and after carding, show negative correlations with yarn tenacities. The correlation with the yarn tenacities are shown to be higher with the standard deviation of single fiber elongations estimated after carding.

The yarn tenacities were found to have no significant correlations with single fiber elongation, crimp and standard deviation of crimp.

Figure 10 shows the relationships between fiber lengths and yarn tenacities. The AFIS® fiber lengths are shown to be positively correlated with yarn tenacities.

Prediction of Yarn Tenacity

Regression analyses were run using SAS® system in order to evaluate the effects of fiber properties on yarn tenacity. The average for each fiber property and the average yarn tenacity were obtained for each cotton to make up the data points for regression analyses. Multiple regression analyses were made using only those fiber properties showing significant simple correlations with the yarn tenacity as predictor variables. Following this method, single fiber length, strength, standard deviation of elongation, and HVI bundle strength and micronaire remained as candidates for the predictor (X) variables.

Two sets of multiple regression analyses were run by applying two distinct sets of independent variables; Model I based on single fiber data only (length, micronaire, strength, S. D. of elongation) from bale and sliver (after carding) samples excluding HVI strength, and Model II by including HVI strength in place of single fiber strength. The results are summarized in Tables 3 and 4 and Figures 11 ~ 14.

The results based on Model I (Table 3 and Figures 11 and 12) show that fiber length, strength, micronaire and standard deviation of single fiber elongation were the most significant predictor variables before and after carding. It is clearly shown from the table and the figures that R^2 values become higher with fiber properties measured after carding indicating that single fiber strength and standard deviation of single fiber elongation measured after carding are more relevant to yarn tenacity.

The results based on Model II (Table 4 and Figures 13 and 14) show that HVI bundle strength, micronaire and standard deviation of single fiber elongation were the most significant predictor variables. The R^2 values are shown to be even higher for Model II where HVI strengths are used. It is most important to note that significant effects of the standard deviation of single fiber breaking elongation are present in both Model I and Model II.
While there have been many reports on the effects of fiber length, micronaire and strength on yarn tensile properties, this study has shown the importance of fiber elongations, especially in terms of their variance in optimizing yarn tensile properties.

Conclusions

The fiber length, HVI bundle strength, micronaire, single fiber strength and standard deviations of single fiber elongation were all found to be significant contributing factors to yarn tensile strengths based on the 36 major varieties of cotton samples tested.

The single fiber strength and standard deviation of single fiber elongation, taken after carding, were shown to be better predictor variables for determining the tensile strengths of the resulting yarns.

The HVI bundle strength was found to be an important factor for predicting the tensile properties of the resulting yarns.

The standard deviation of single fiber elongation is a key factor for maximizing the tensile properties of the resulting spun yarns.

The fiber strength and breaking elongation are not significantly altered by carding whereas the fiber crimps and variances of fiber breaking elongation are shown to be reduced by carding.

Table 1. Varieties and Origins of 36 US Cottons

Cotton Type	Cultivar	Origin
1	DPL 5415	Delta
2	MD 51 ne	MS
3	DPL 4-910-2-2	Delta
4	CA 3084	TX
5	Prema	CA
6	EW 8718-001-101	
7	Maxxa	CA
8	HS 26	TX
9	CAB-CS	TX
10	B 7465	CA
11	SP 93-274	PC
12	DPL 50	Delta
13	TX G3-27	TX
14	STV 474	Delta
15	KC 311	East
16	DPL 5432	AZ
17	Acala 1517-95	NM
18	SP 6-49	PC
19	HQ 95-6	TX
20	GC 95-MS-1	MS
21	SG 501	Delta
22	C-225	CA
23	PD 93057	PD
24	SP 125-401	PC
25	SP 92-219	PC
26	MD 5678 ne	Delta
27	HS 46	MS
28	LA 887	MS
29	El Dorado	CA
30	PD 3-14	PD
31	SP 4-22	PC
32	DPL 0227	MS
33	HX 1220	MS
34	SG 125	Delta
35	Coker 320	East
36	PD 93056	PD

Table 2. Summary of Correlation between Fiber Properties and Yarn Tenacity (R^2 and p values)

	Yarn Tenacity
Single Fiber Strength from Bale vs.	$R^2 = 0.083$ ($p = 0.0787$)
Single Fiber Strength after Carding vs.	$R^2 = 0.084$ ($p = 0.0857$)
S. D. of Single Fiber Elongation from Bale vs.	$R^2 = 0.181$ ($p = 0.0098$)
S. D. of Single Fiber Elongation after Carding vs.	$R^2 = 0.322$ ($p = 0.0003$)
HVI Strength vs.	$R^2 = 0.819$ ($p = 0.0001$)
Micronaire vs.	$R^2 = 0.274$ ($p = 0.0011$)
AFIS® Fiber Length vs.	$R^2 = 0.268$ ($p = 0.0012$)

Table 3. Results of Multiple Regression Analyses (Model I)

Process	Equations	Prob. > |t|	R^2
Bale	$YTS = 9.13 + 20.79 X_1 - 3.92 X_2 + 1.60 X_3 - 0.99 X_4$	X_1: 0.0250 X_2: 0.0001 X_3: 0.0057 X_4: 0.0460	0.72 (p = 0.0001)
After Carding (Sliver)	$YTS = 7.28 + 19.98 X_1 - 4.18 X_2 + 2.51 X_3^* - 1.51 X_4^*$	X_1: 0.0020 X_2: 0.0001 X_3^*: 0.0001 X_4^*: 0.0012	0.84 (p = 0.0001)

Table 4. Results of Multiple Regression Analyses (Model II)

Process	Equations	Prob. > |t|	R^2
Bale	$YTS = 5.55 - 1.07 X_2 - 0.71 X_4 + 0.59 X_5$	X_2: 0.0112 X_4: 0.0258 X_5: 0.0001	0.88 (p = 0.0001)
After Carding (Sliver)	$YTS = 7.42 - 0.80 X_2 - 1.31 X_4^* + 0.57 X_5$	X_2: 0.0311 X_4^*: 0.0003 X_5: 0.0001	0.91 (p = 0.0001)

Notes: YTS = Yarn Tenacity
X_1 = Fiber Length
X_2 = Micronaire
X_3 = Single Fiber Strength from Bale
X_3^* = Single Fiber Strength after Carding
X_4 = S. D. of Single Fiber Elongation from Bale
X_4^* = S. D. of Single Fiber Elongation after Carding
X_5 = HVI Bundle Strength

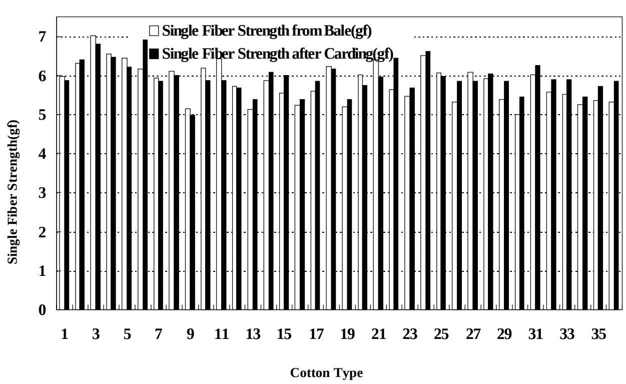


Figure 1. Effects of Carding on Mantis® Single Fiber Strengths

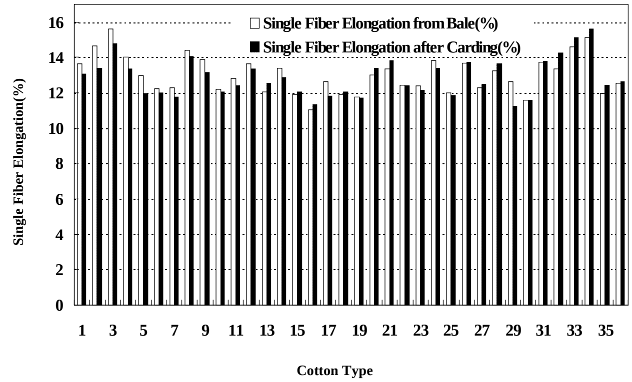


Figure 2. Effects of Carding on Mantis® Single Fiber Elongations

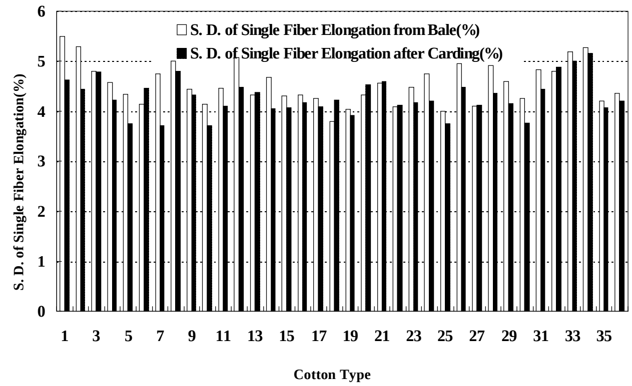


Figure 3. Effects of Carding on S. D. of Mantis® Single Fiber Elongations

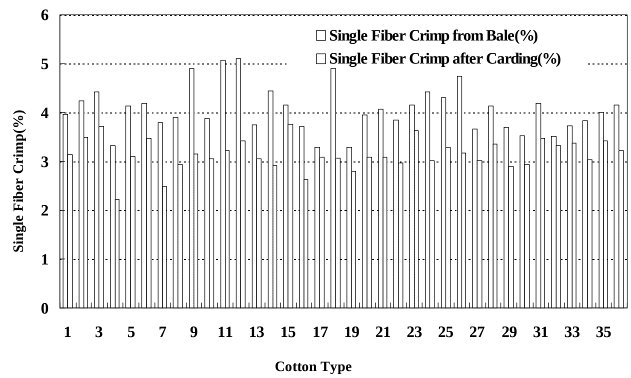


Figure 4. Effects of Carding on Mantis® Single Fiber Crimps

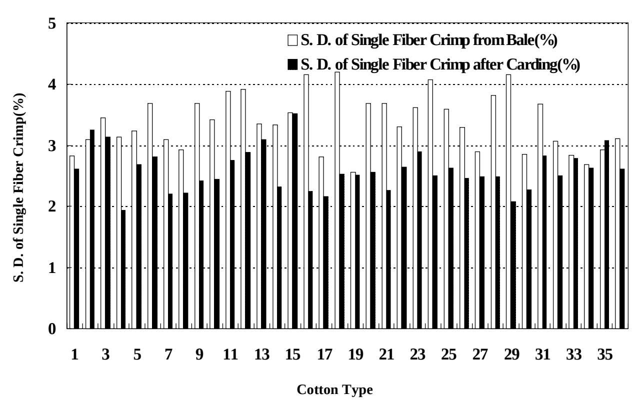


Figure 5. Effects of Carding on S. D. of Mantis® Single Fiber Crimps

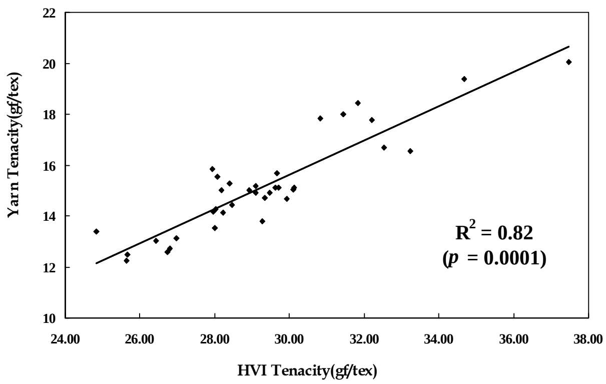
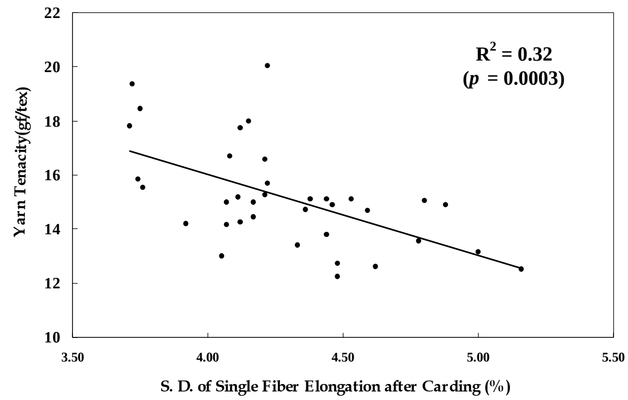


Figure 6. HVI Strength vs. Yarn Tenacity



igure 9. S. D. of Mantis® Single Fiber Elongations after Carding vs. Yarn Tenacity

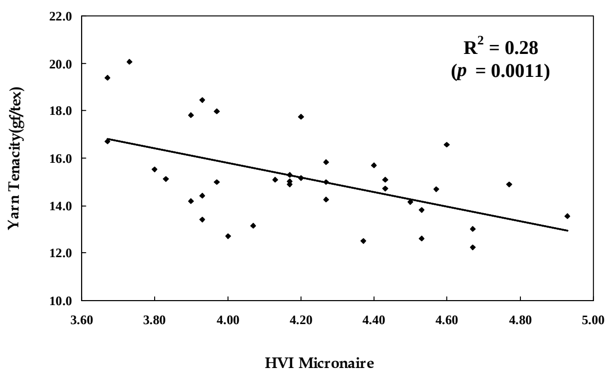


Figure 7. HVI Micronaire vs. Yarn Tenacity

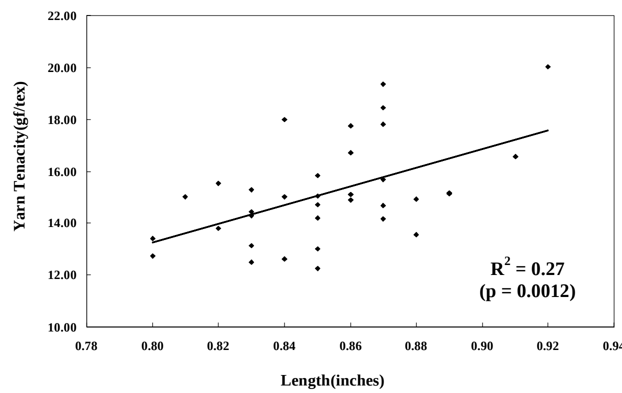


Figure 10. AFIS® Fiber Length vs. Yarn Tenacity

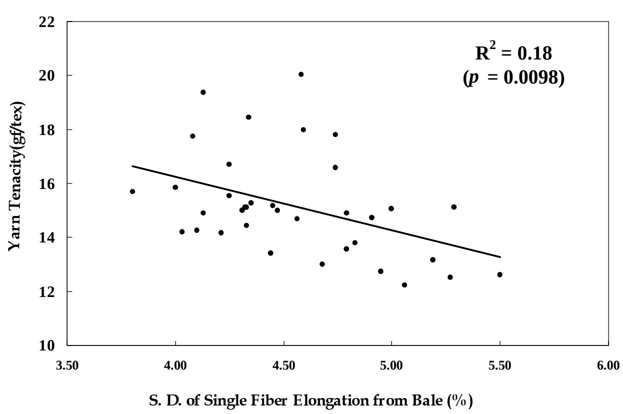


Figure 8. S. D. of Mantis® Single Fiber Elongations from Bale vs. Yarn Tenacity

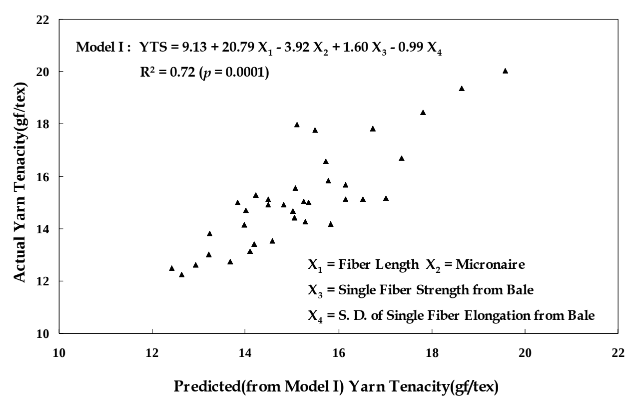


Figure 11. Predicted and Actual Yarn Tenacities - Model I with Bale Data

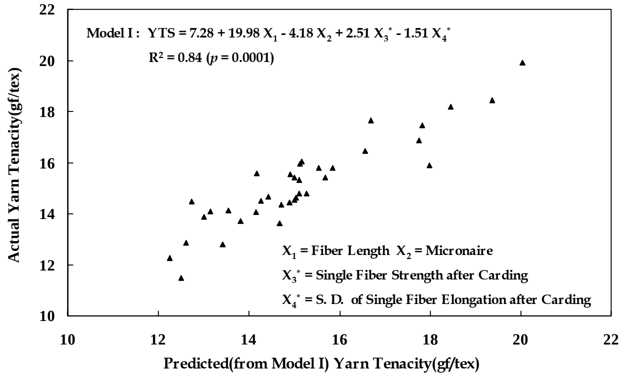


Figure 12. Predicted and Actual Yarn Tenacities - Model I with Sliver Data

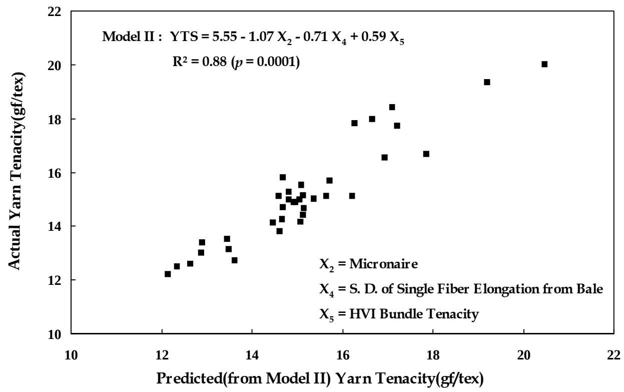


Figure 13. Predicted and Actual Yarn Tenacities - Model II with Bale Data

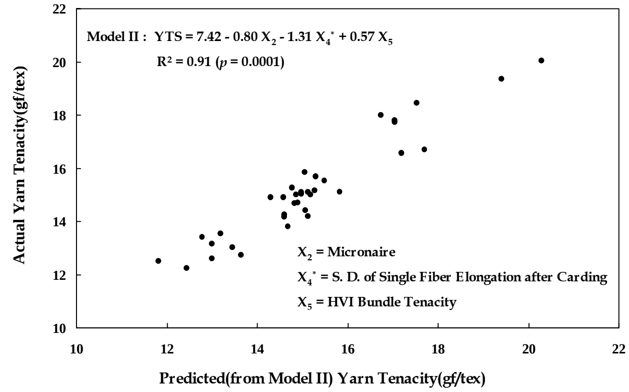


Figure 14. Predicted and Actual Yarn Tenacities - Model II with Sliver Data