Significance of Non-Conventional Properties in Assessing Yarn Parameters

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ABSTRACT

A range of cotton cultivars were grown during different crop years and locations in India. Four cotton cultivars were selected for fiber analysis and were spun in yarns of two different yarn counts with two different twist levels. The cotton fibers were analyzed by conventional instruments (HVI and FMT) and non-conventional parameters were also measured, e.g. wax content, number of reversals, convolution and orientation parameters. Statistical regression techniques were used to predict yarn parameters, first of all using only the conventional fiber parameters and then including the non-conventional parameters. An improvement in the prediction of yarn parameters can be obtained by including some of the non-conventional parameters in the equation. The quickly measured HVI and FMT parameters do not cover all factors influencing yarn quality in the assessment of yarn parameters.

Introduction

This research was performed in co-operation between the Department of Textiles, Universiteit Gent (Belgium) and the Indian Agricultural Research Institute of New Delhi (India).

Predicting yarn quality based on fiber properties is important for spinners and for growers. It gives spinners tools to assess yarn quality beforehand in order to satisfy the customer requirements, allows fiber and yarn properties to be kept in balance and enables growers to select cotton cultivars that give the best fiber and yarn quality. A lot of studies have been published on regressions between fiber and yarn parameters. Fiber strength, length and fineness are important factors contributing to yarn strength but because of several correlations between fiber properties, a lot of different models can be established Anon 1993; Anon, 1991; J.Y. Dréan, 1991; El Moghazi, 1992; Frydrych, 1991; Anon, 1990; Meredith *et al.*, 1991; Färber, 1992).

The problem with regression is that it is only valid for a certain yarn type, range of yarn counts, and fiber parameters. It is also difficult to have a representative data-set that is universal for all yarns. Furthermore, this technique is only useful for quite simple relations. More complex relations can be handled with Neural Networks (Sette *et al.*, 1997; Pynckels, 1997), although a huge amount of data (more than 100 measurements) is required for the training of the neural net. However, it is proved that a reliable prediction of yarn parameters can be obtained.

In this study, the significance of less conventional parameters for predicting the most important yarn parameters is evaluated by means of statistical regression.

Materials and methods

Four cotton varieties belonging to three species, *Gossypium hirsutum* (Bikaneri Narma and AC-738), *Gossypium arboreum* (Y-1) and *Gossypium bardadense* (Suvin), were grown at four locations (Coimbatore, Nagpur, New Delhi and Suvin) in India. However, because of practical problems, the whole data set was not completely available. HVI analyses were performed, for determination of: length (“LEN”), length uniformity (“UN”), strength (“STR”), elongation (“EL”), micronaire (“MIC”), colour (“RD”,”B”) and trash (“AREA”, “COUNT”). Maturity and fineness were measured on the Fineness Maturity Tester (“MAT”, “PM”, “FIN”). In addition, the following less conventional tests were performed:

- The wax content (“WAX”) was determined by extraction in chloroform.
- The number of reversals (“REVERS”) and the number of convolutions (“NO_CONV”) were counted optically.
- Orientation parameters (40% and 50% X-ray angles, average angle of orientation and the Hermans factor) were obtained by X-ray diffraction.

The cultivars were spun in two different yarn numbers (25 and 40 tex). The yarn strength and elongation at break of all spun yarns were tested on the fully automated dynamometer (Statimat). The regularity of the yarns was tested on the Uster Tester 1. The number of thin places, thick places and neps were counted, as well as the mass variation. Yarn count and yarn twist were checked with the conventional methods. A correlation analysis was performed on the fiber parameters.

To check the influence of the less conventional parameters on yarn parameters, a stepwise regression analysis was performed with the HVI and FMT parameters only on the one hand and all parameters including those that are less conventional on the other. The regression equations were calculated for the most

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important yarn parameters: yarn tenacity, yarn elongation and yarn regularity.

Results and discussion

The results of the stepwise regression taking into account the HVI and FMT parameters on the one hand and all parameters on the other hand, are shown below.

Yarn Tenacity (N/tex)

The following results were obtained:

HVI and FMT parameters

N = 26	B	t(21)	p-level
Intercpt	10.18	2.56	.018
STR	.65	6.14	.000
MIC	-.47	-1.05	.307
LEN	-16.27	-3.36	.003
COUNT	.20	2.63	.016

$R = 0.85$ $R^2 = 0.72$ Adjusted $R^2 = 0.67$
$F(4,21) = 13.56$ $p < .00001$ Std. Error of estimate = .96

ALL parameters

N = 20	B	t(14)	p-level
Intercpt	-1.82	-.57	.580
WAX	-5.84	-8.46	.000
BUN_STR	.28	7.00	.000
40%	.26	4.19	.001
REVERS	-.18	-2.16	.048

$R = 0.95$ $R^2 = 0.91$ Adjusted $R^2 = 0.88$
$F(5,14) = 37.09$ $p < .0000$ Std. Error of estimate = .61

Taking into account HVI and FMT-parameters, a regression equation is found with a correlation coefficient of 0.85. In literature, the largest contribution to yarn tenacity is to be found for strength, length and fineness. In this analysis, indeed length and strength are included, but instead of fineness, the count of trash particles and micronaire values seem to influence the yarn tenacity more than fineness.

By inserting all parameters in the regression analysis, an equation is found that includes fiber uniformity, wax content, bundle tenacity, the 40% X-ray angle and the number of reversals per cm. A prediction equation is obtained for yarn tenacity of which the correlation coefficient is obviously higher than with only HVI- and FMT-parameters. Also, the error of prediction is clearly lower when the non-conventional parameters are included.

Yarn Elongation (%)

The regression analysis gives the following results:

HVI and FMT parameters

N = 18	B	t(22)	p-level
Intercpt	15.95	5.92	.000
PM	-.06	-3.35	.003
LEN	-5.85	-2.37	.026

$R = 0.67$ $R^2 = 0.44$ Adjusted $R^2 = 0.40$
$F(2,23) = 9.16$ $p < .0012$ Std. Error of estimate = .65

ALL parameters

N = 18	B	t(11)	p-level
Intercpt	5.44	2.91	.010
NO_CONV	.06	3.46	.003
PM	-.04	-2.13	.048

$R = 0.75$ $R^2 = 0.56$ Adjusted $R^2 = 0.51$
$F(2,17) = 10.77$ $p < .00095$ Std. Error of estimate = .58

A forward stepwise regression with HVI and FMT parameters gives an equation with independent variables % mature fibers and fiber length. Clearly, the prediction of elongation is more difficult than the prediction of tenacity, giving only a correlation coefficient of 0.67.

For the regression analysis with all parameters the independent parameters, i.e. number of convolutions and % mature fibers were selected.

A prediction was obtained for yarn elongation with a correlation coefficient that is higher than with only HVI- and FMT-data. The estimation error is somewhat lower taking into account the non-conventional parameters.

Yarn Regularity (%)

The results of the regression analysis are mentioned hereafter.

HVI and FMT parameters

N = 26	B	t(20)	p-level
Intercpt	16.12	.55	.588
MIC	1.06	2.21	.038
UN	-.70	-2.43	.024
LEN	13.40	2.83	.010
RD	.47	2.95	.008
PM	.08	2.58	.018

$R = 0.86$ $R^2 = 0.74$ Adjusted $R^2 = 0.68$
$F(5,20) = 11.48$ $p < .00003$ Std. Error of estimate = .84

ALL parameters

N = 18	B	t(12)	p-level
Intercpt	-59.66	-4.19	.001
RD	.92	6.02	.000
PM	.10	3.75	.002
NO_CONV	-.10	-3.33	.005
REVERS	.35	2.45	.027

$R = 0.90$ $R^2 = 0.81$ Adjusted $R^2 = 0.75$
$F(4,15) = 15.51$ $p < .00003$ Std. Error of estimate = .74

Taking into account HVI and FMT parameters results in an equation with the following parameters: micronaire, uniformity, fiber length, reflectance and % mature fibers. Yarn regularity can be predicted with a correlation coefficient of 0.86 using HVI and FMT parameters.

When all parameters are included in the forward stepwise regression, an equation (R = 0.90) is obtained that includes the following parameters: the reflectance, % mature fibers, the number of convolutions and the number of reversals.

For yarn regularity, the improvement by inserting the less conventional parameters is not as high as for yarn tenacity. Also in this case, the error of prediction is lower with the selection of the less conventional parameters.

Conclusion

An important problem in predicting of yarn parameters by using statistical analysis is the correlations between fiber parameters since regression analysis assumes that all parameters in the equation are independent. As a consequence in this study, the correlation between parameters was taken into account. Lower correlation coefficients were obtained but the assumptions were satisfied, so the equations can be expected to be more reliable.

Although the twist coefficient has been taken into account as an independent variable, it is not selected by the forward stepwise regression because of the non-variability (only 2 different values) of this parameter. Yarn twist would make a large contribution to the yarn parameters if more yarn numbers and twists were included.

By using only the conventional parameters (HVI- and FMT-data) regression equations are found for yarn tenacity and yarn regularity with correlation coefficient higher than 0.85. The prediction of yarn elongation is more difficult ($R = 0.67$).

By inserting less conventional parameters, such as wax content, number of reversals, convolution data, and X-ray data, the correlation coefficients increase for all yarn parameters. Also a lower error of prediction is obtained for the models including the less conventional parameters. This result confirms that the use of HVI- and FMT-data only is not sufficient to predict yarn parameters. Unfortunately, these less conventional parameters are not as easy or quick to measure as HVI- and FMT-data. There is a need to find quicker and easier methods to determine these less conventional parameters.

These regression equations are based on a limited amount of data but nevertheless, they give are indicators as to which parameters are important in predicting yarn properties.

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Figure 1. Prediction of yarn tenacity (N/tex).

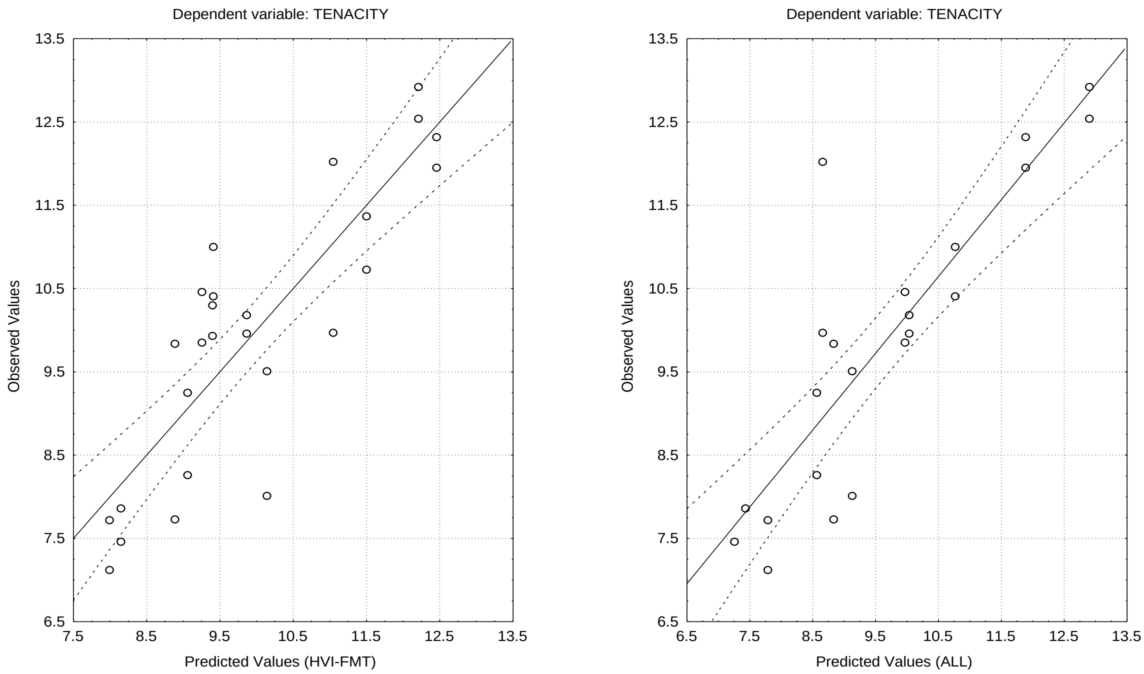

Figure 2. Prediction of yarn elongation.

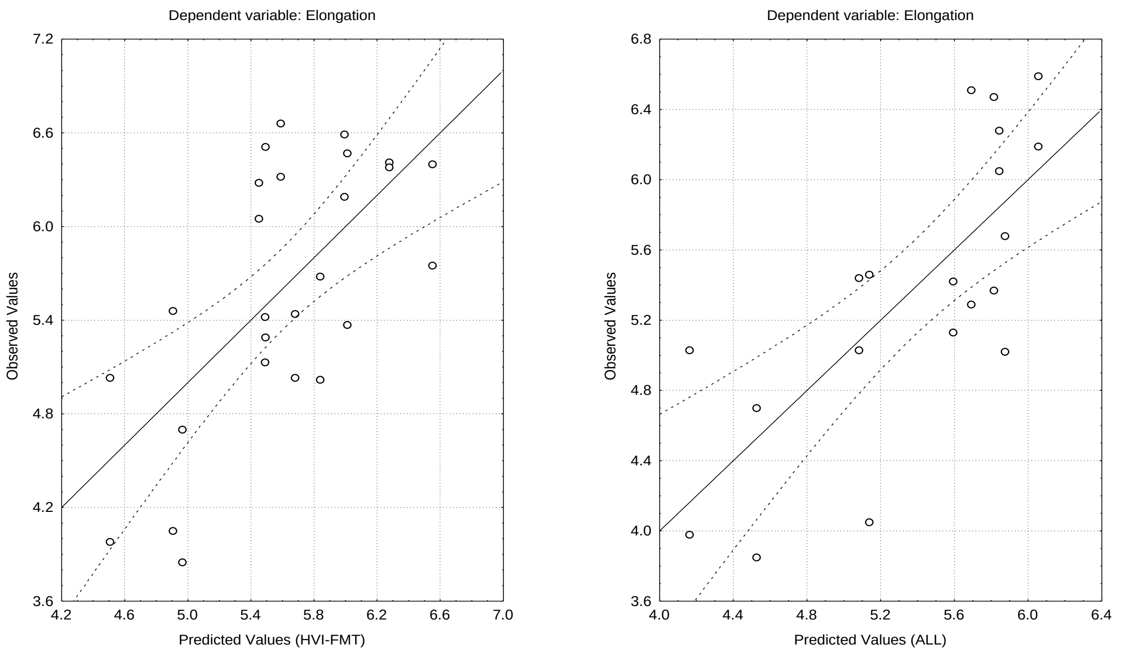

Figure 3. Prediction of yarn regularity.