International Journal of Research in Engineering, Science and Management
Volume 4, Issue 5, May 2021
https://www.ijresm.com | ISSN (Online): 2581-5792

Optimization of Cotton Compact Yarn Product by Fibre Properties

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***Abstract*: The Compact spinning system, which has begun to gain an important place in textile industry, appreciate to its desired yarn characteristics, was developed in the early 2000s. Less hairy & higher tensile strength than normal ring spinning can be produced with this system. In this study, bulk production data over a period of 6 months collected from a spinning mill with different yarn counts (Ne 22 – Ne 120) in the existing condition and no special sample process is used. With this work, it was aimed to develop estimation equations which can help to lead the industrialists and technician to predicate the yarn parameter simply by fibre parameter. It is believed that having prior knowledge of the yarn without increasing costs of additional raw materials, labor and energy may increase the competitiveness of the yarn producer.**

***Keywords*: AFIS, Compact, Combed, Cotton fibre, Elongation, HVI, Imperfection, Knitting, Neps, Regression, RKM, Spinning, Textile, Unevenness, Weaving, Yarn.**

1. Objectives

1. Predicting and evaluating yarn quality parameters
2. Optimizing the production parameters
3. Optimizing the mixing parameters
4. Cost optimization
5. Saleable waste optimization

2. Introduction

Compact spinning is the new era additional retrofit equipment added in the ring spinning machine by several manufactures. The cotton fibre is the scarce resource available in many countries and produced as a seasonal agricultural product. This fibre gives comfort in wear ability and environment friendly during disposal. Most of the yarn manufacturers are interested to produce synthetic made fibre due to low cost and lesser variation between fibres and to achieve the consistent yarn quality. In many spinning mills are reluctant to utilize the available facility of compact spinning techniques due to non-reaping of best quality with optimum cost. The worldwide statistics shows around 3 million spindles are running with compact spinning and still many are producing yarn with conventional system due to unaware of the real benefit of optimizing compact yarn production system with available cotton fibre.

The optimum yarn quality requirement is the primary demand of customer to meet out required fabric quality and performance in the process.

By predicting and optimizing the parameters, we can minimize the raw material consumption by getting higher yarn recovery which is paramount effort to utilize the cotton fibre resources.

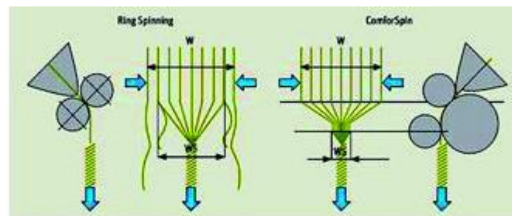

Fig. 1. Conventional ring spinning vs. the Com for Spin principle

3. Literature Review

The Cotton is still one of the most important fibres, with its high consumption rate, despite its share of the global fibre market decrement. It is a global raw material traded in fibre, yarn, fabric or finished goods form. HVI and AFIS instruments are commonly used for evaluating the quality of cotton fibres in a bale. HVI was designed to measure fibre properties from a bundle of fibres, while the AFIS instrument was created to measure single fibre. Typical HVI measurements include fibre length, length uniformity, bundle tenacity, elongation, micronaire, colour, and trash content, while the AFIS instrument measures length, fineness, maturity, circularity, short fibre content, immature fibre content, nep/g and percentage of dust and trash. There is a high correlation between the quality of raw materials and the final products. A high quality of cotton provides a high quality of yarn, neglecting the process conditions.

For the spinner, the presence of excessive amounts of short fiber in the input mix can result in production inefficiencies and losses in textile quality (D. Thibodeaux 2003). Behery (1993) described how short fibers behave during textile processing: during cotton spinning, the fiber strands are thinned or drafted by passing between pairs of drafting rolls that are spaced at distances that allow most fibers to pass through without bridging the gap between the rollers, which would result in breaking of the fibers. Short fibers are allowed to float between the drafting rollers where they can bunch up or thin out causing thick and/or thin imperfections in the yarn with accompanying

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diminished strength. Over the years, several researchers have studied problems arising in cotton spinning resulting from the presence of short fibers.

The Uster News Bulletin implied that the nep value is the most important parameter for cotton fibre quality, which is additionally used for judging ginning, carding and combing quality, and even fabric quality

Cotton fibers exhibit variation in their measured physical properties. In the past, these properties were measured and differentiated by cotton classers and later by High Volume Instrumentation (HVI™). However, the generated results are complex and multifaceted to the point that selection of optimum cotton fibers for a textile mills end product is a constant challenge and customarily more of an art than a science (Dr. Jonn Foulk 2007).

Evolving workable prediction formulae to relate fibre properties to yam quality has been an interesting field of work for several research workers for more than three decades author Lord developed an integrated index using basic fibre properties to predict the spinning performance. Subramaniam et al. put forward a fibre quality index by which Bogdan's intrinsic strength parameter of cotton can be predicted. In addition to this, they also identified two constants, which, once evaluated for a given spinning set-up, would enable the lea strength to be predicted by estimating first the intrinsic strength parameter and then the lea strength from Bogdan's equation. This procedure was modified by Dhawan and Subrarnaniam to further improve the accuracy of prediction.

SITRA developed an empirical relationship" between important fibre properties and yam CSP in 1968. However, in the last decade there has been a spectacular improvement in the technological performance of spinning machinery. This resulted from a number of factors such as improved opening and effective separation of heavy particles in modem blow room lines, better carding and efficient fibre control during drafting in modem preparatory and spinning machinery. Apart from the technological improvements, indigenous cottons have also undergone significant qualitative changes during the same period.

The quality of final yarn is largely influenced (up to 80%) by the characteristics of raw cotton (Abhijit Majumdar 2005). However, the level to which various fibre properties influence yarn quality is diverse, and also changes depending on the yarn manufacturing technology

The development of fibre testing instruments such as the High Volume Instrument (HVI) and the Advanced Fibre Information System (AFIS) has revolutionised the concept of fibre testing. With the HVI it is pragmatically possible to determine most of the quality characteristics of a cotton bale within two minutes. Based on the HVI results, composite indexes such as the fibre quality index (FQI) and spinning consistency index (SCI) can be used to determine the technological value of cotton; this can play a pivotal role in an engineered fibre selection programme.

A. Existing Prediction of Fibres vs. Yarn Parameters

1) Traditional models to determine the technological values of cotton

a) Fibre quality index (FQI)

This is probably the most widely used method to determine the technological value of cotton. The main reason for its popularity may be attributed to the simplicity of the equation used. Several variants of the FQI model are available and the following form of FQI proposed by the South Indian Textile Research Association. Fibre Quality and Yarn CSP is well known formula that when given cotton is spun to different counts using the same twist multipliers for all the yarns, cottons giving strong yarns not only tend to fall off in strength less rapidly but also show high initial values, i.e. high intercept on the Y-axis. Weak yarns have relatively high fall in strength with low intercept values. The analysis of data in the study showed that in long and extra-long-staple cottons (> 28 mm), the drop in CSP for a unit increase in count is 0.5%, whereas in short and medium staple cottons the fall in strength is 0.8%. The slope of the regression line relating count and CSP was, however, practically the same for all the cottons studied

$$FQI = \frac{LURSM}{F} \tag{1}$$

where *L* is 2.5% span length, *UR* is the uniformity ratio, *FS* is the fibre bundle tenacity, *M* is the maturity coefficient, and *F* is the fibre fineness (micronaire).

Many type of regression analysis was carried out using the test results of the yarns produced by HVI fiber properties which were measured before the production (Memik Bunyamin 2018). It was investigated whether the properties of the yarns can be estimated before production by using specified fiber properties. As a result of the analysis, the derived equations were used to estimate only tensile strength and unevenness values of the yarns.

Compact spinning system was developed with modifications made to the drafting zone of ring spinning system and the aim of this was to eliminate the spinning triangle. Fiber properties need to be known, as yarn producer have to adjust some machine parameters according to them besides quality of raw material. According to spinning system, some fiber properties become more important in terms of spinning quality. Fiber length is crucial in ring and airjet spinning while fiber strength has more importance in open-end spinning system (E. F. Hequet). HVI and AFIS systems are devices developed by Uster, which are used for determination of fiber properties. In fiber standardization, the HVI device has a great importance. Before this device; fiber properties such as strength, elongation and fineness were measured with Pressley tester, Stelometer and micronaire (G. T. Tyagi 2010). After the development of the device, it became possible to obtain more detailed information about fiber in one device and to standardize it accordingly. With current technology, the device can test properties such as fiber fineness, length, strength, elongation, lightness, yellowness, trash and nep number (G. T. Tyagi 2010). Some of these features were also used in our study. Producers make a number of production experiments while developing new products or improving existing products. These experiments cause additional raw material, energy and labor costs. Estimation takes place at this point. By using the features of the inputs used in production, it is possible to estimate the results with statistical methods. There are studies in the literature where these methods are used for the textile industry. Some of these studies focus on estimation of yarn strength, breaking extension, unevenness, hairiness and IPI faults as well as fabric properties. Üreyen and Kadoglu used regression analysis for estimation of ring spun yarns' tensile strength, breaking elongation, unevenness and hairiness values by using HVI and AFIS fiber properties. Faulkner et al also investigated the effects of fiber properties (used HVI and AFIS test results) to ring-spun yarn properties by using regression analysis. Üreyen and Gürkan used regression analysis and artificial neural network, in order to predict hairiness and unevenness values of ring-spun yarns. Furferi and Gelli used artificial neural network for predicting tensile strength of ring-spun yarns produced from different fibers by using fiber properties. Bedez Üte and Kadoglu used regression analysis to estimate tensile strength and unevenness of siro-spun yarns by using HVI and AFIS properties of the fibers used in productions. Uzumcu and Kadoglu used HVI fiber values for predicting IPI fault values of compact-spun yarns. Gurkan Unal used artificial neural network and response surface methods for evaluating the effects fiber properties on spliced yarn characteristics. For predicting the pilling tendencies of cotton interlock knitted fabrics, Kayseri used both regression analysis and artificial neural network methods in their studies. Sari and Oglakcioglu also used regression analysis in their study about pressure characteristics of medical stockings. Not only for cotton yarns, cotton waste containing yarn properties were also tried to be explained by using correlation with fiber properties by Telli and Babaarslan. Positive results were obtained in most of these studies where various methods such as regression analysis and artificial neural networks were used for estimation. In this study, it was investigated that how fiber properties effect yarn properties and if it is possible to determine yarn properties before production, in case of using compact spinning system. For this purpose, yarns were produced by compact spinning system using rovings produced from different blends. Data gathered from previous studies about predicting yarn properties indicated that various types of analysis were performed for properties of coarse yarns produced with ring, rotor, siro and vortex spinning systems.

However, practical applications are almost impossible because of the complexities of the models. They are usually based on certain assumptions and their success is determined by the feasibility of these assumptions. In recent years some researchers have shown an interest in the use of artificial neural networks (ANN) to predict yarn characteristics. This analytical system is also useful for discovering relationships between variables. AFIS (Advanced Fibre Information System) instrument is used for the measurement of individual fibres. The AFIS test provides detailed information regarding important fibre properties including fibre diameter, neps, trash, dust counts and several length parameters. AFIS is one of the instruments of choice for cotton spinning industry specialists since it provides them with both average fibre values and distributions. Although it is of great importance, very little research can be found related to the estimation of yarn properties by using AFIS test results. Chanselma et al. used AFIS test results to predict yarn evenness and imperfections and Zhu and Ethridge to predict yarn hairiness. The main aim of this investigation was to determine the relationship between ring yarn properties and the fibre measurements obtained by the AFIS instruments and to design appropriate models for predicting yarn properties.

During yarn spinning, textile experts commonly controls a series of parameters like the fiber strength, the fiber length, the twist yarn, the yarn count, and the fineness. More in detail a very important parameter that technicians want to control is the yarn strength. This is defined as the breaking force of a spinning yarn, and it is commonly measured in cN. On the basis of their skill, the expert operators are capable of giving a qualitative, raw prediction of the yarn strength; unfortunately, the empirical estimation of the actual value of the yarn strength is not straightforward. The assessment of such parameter is essential for obtaining high quality of the yarn (Rocco Furferi 2010). Accordingly, in the last two decades, the modeling of yarn properties has become one of the most important and decisive tasks in the textile research field. A considerable number of predictive models have been implemented to evaluate some yarn properties like strength, elongation, evenness, and hairiness. The relationship between fiber properties and yarn properties has been the focal point of several works. Many studies in literature have shown that the relationship between yarn strength and fiber properties is nonlinear. Accordingly, mathematical models based on the fundamental mechanics of woven fabrics often fail to reach satisfactory results. Some studies have been performed so far for modeling the yarn strength using linear regression. The main limitation of these studies is related to the need of defining a predefined linear model. In order to model a nonlinear relationship between input and output it is possible to devise an Artificial Intelligence-based approach. For this reason, the problem of yarn properties prediction has been faced by some researchers by employing some knowledge-based approaches like artificial neural networks (ANNs) and neuro-fuzzy models. Ramesh et al., Zhu and Ethridge, Guha et al., and Majumdar et al. have successfully used the artificial neural network (ANN) and neuralfuzzy methods to predict various properties of spun yarns. The fabric strength was modeled by Zeydan using neural networks and Taguchi methodologies. Support vector machines (SVMs), based on statistical learning theory, have been developed by Yang and Xiang for predicting yarn properties. The investigation indicates that in the small data sets and real-life production, SVM models are capable of maintaining the stability of predictive accuracy.

A comparison between physical and artificial neural network methods has been presented recently. The results show that the ANN model yields a very accurate prediction with relatively few data points. Moreover, it is proved that the parameters of the raw material that significantly influence the basic quality parameters of the yarns are length, strength, and fineness of fibers. The effect of yarn count and of twist yarn in the final yarn strength is also well established. The reliability and goodness of results, in comparison with linear regression models, prove that the present work may be considered a practical method for assessing the yarn strength. The developed system does not require technicians to produce a yarn and to measure its strength. The experts have only to test the rovings in order to assess some fiber properties. This operation is normally done before producing the yarn. Accordingly, by means of the devised model, the experience of the technicians is merged together with a simple approach in order to give an accurate prediction of the yarn strength.

Compact yarns have great value for producers and its importance grow day by day. Its higher tenacity, lower unevenness and lower hairiness –if required- are some of the reasons this yarn type gains importance. Yarn production of compact spinning systems basically similar to the conventional ring spinning system. Hence a simple mathematical model is required to fulfill the effective utilization of cotton fibres.

4. Materials and Methods

A. Materials

The aim of the investigation is to find out the impact of the new spinning technology, i.e. the compact spinning system on the yarn quality parameters as compared to those of yarns spun on the conventional ring spinning system in current use in the spinning industry.

In addition to spinning technique, machine parameters, operation stages, processing conditions and the physical characteristics of fibre determine its processing behaviour, production efficiency and final yarn and fabric quality.

The following materials were used in the present investigations;

Stage: 1

1) Cotton parameters

The cotton parameter of 10 combination of mixing variety with different type of cotton selected to evaluate the role in the spinning yarn preparation. Main parameter of length, strength, uniformity index, micronaire and short fibre index are taken from HVI tested parameters.

2) Yarn parameter

Yarn counts of 15 types are taken with above 10 combination of cotton variety with standard process parameter for each count is considered.

3) Process parameter

The cotton variety chosen for 10 combinations is processed with standard parameter like speed, feed hank, delivery hank, setting of rollers, waste percentage from blow room to yarn stage.

4) Environment condition

While collecting data for the investigation, the standard atmosphere range is maintained by continuous monitoring.

B. Methods

The following testers are used for testing the feed material and process materials;

1. HVI tester for cotton testing
2. AFIS tester for process material testing
3. Count checking by weighing scale
4. Wrap reel
5. LEA tester
6. Uster Tester 3 and 5
7. Uster Tensorapid
8. Uster Tensojet
9. Classimat test on Uster Quantum

5. Results and Discussion

The following main yarn parameters estimation equation with statistical analysis result is given in detail for four categories;

1. Yarn lea strength
2. Single yarn strength (RKM)
3. Yarn neps/km (Imperfection)
4. Yarn Unevenness %

A. Category - I

1) Combed Compact Weaving yarn: Prediction of Lea strength in pounds

Table 1
Weaving yarn lea strength regression statistics with ANOVA table

Regression Statistics	
Multiple R	0.977
R Square	0.955
Adjusted R Square	0.955
Standard Error	4.665
Observations	140

4.1.1.2 ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	63490	63490	2917.3	1.05585E-94
Residual	138	3003.3	21.763		
Total	139	66493			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-8.795	1.333	-6.600	0.000	-11.430	-6.160
X Variable 1	0.032	0.001	54.012	0.000	0.031	0.033

Formula:

Y = 0.03 * X – 8.8

Lea strength in lbs = 0.03 * (no. of fibres in the yarn X fibre strength in grams/tex) – 8.8

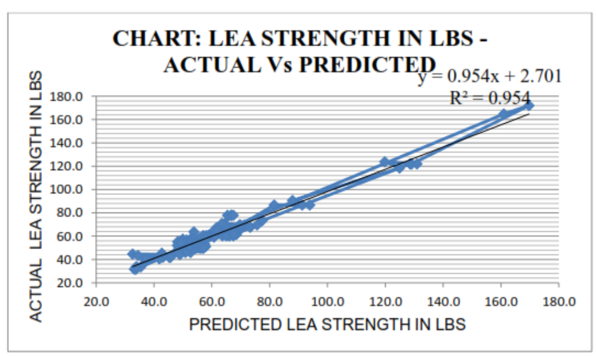

Fig. 1. Weaving yarn lea strength actual vs. predicted

In the model, the linear regression line, the multiple R & goodness of fit in the model is very close to the predicted value.

2) Combed Compact Knitting yarn: Prediction of Lea strength in pounds

Table 2
Knitting yarn lea strength regression statistics with ANOVA

Regression Statistics	
Multiple R	0.958
R Square	0.918
Adjusted R Square	0.916
Standard Error	7.206
Observations	45

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	24969.56	24969.558	480.87	5.71E-25
Residual	43	2232.813	51.925887		
Total	44	27202.37			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-2.289	3.129	-0.732	0.468	-8.598	4.020
X Variable 1	0.026	0.001	21.929	0.000	0.023	0.028

Formula:

$Y = 0.03 * X - 2.3$

Lea strength in lbs = 0.03 * (no. of fibres in the yarn X fibre strength in grams/tex) – 2.3

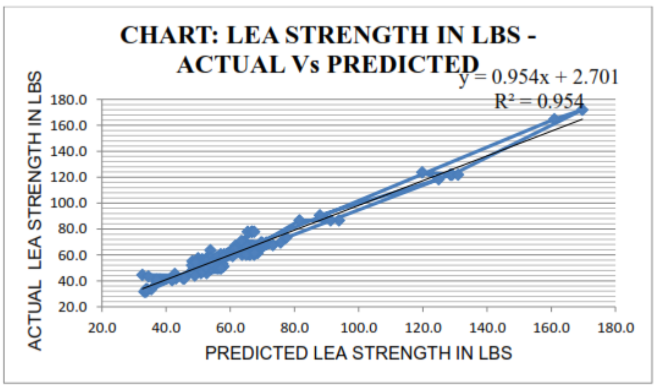

Fig. 2. Knitting yarn lea strength actual vs. predicted

In the model, the linear regression line, the multiple R & goodness of fit in the model is very close to the predicted value.

3) Combed Compact Weaving yarn: Prediction of yarn RKM in grams/tex

Table 3
Weaving yarn RKM regression statistics with ANOVA table

Regression Statistics	
Multiple R	0.899
R Square	0.808
Adjusted R Square	0.805
Standard Error	1.560
Observations	141

4.2.1.2 ANOVA

	Df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1413.685	706.843	290.388	3.52E-50
Residual	138	335.911	2.434		
Total	140	1749.596			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-2.906	1.306	-2.225	0.028	-5.489	-0.323
X Variable 1	0.014	0.006	2.169	0.032	0.001	0.027
X Variable 2	0.706	0.031	22.898	0.000	0.645	0.767

Formula:

$Y = 0.014 * X1 + 0.706 * X2 - 2.9$

Single yarn strength RKM = 0.014 * (no. of fibres in the yarn) + 0.706 * fibre strength in grams/tex – 2.9

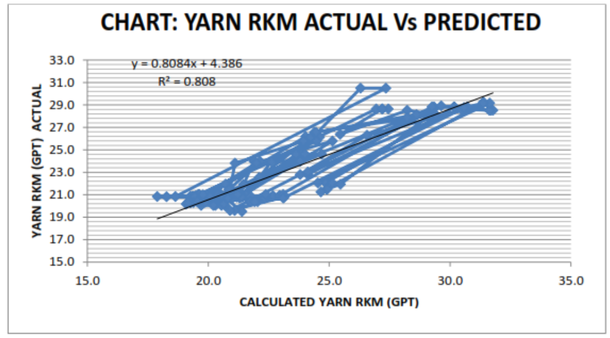

Fig. 3. Weaving yarn RKM actual vs. predicted

In the model, the linear regression line, the multiple R & goodness of fit in the model is very close to the predicted value.

4) Combed Compact Knitting yarn: Prediction of yarn RKM in grams/tex

Table 4
Weaving yarn RKM regression statistics with ANOVA table

Regression Statistics	
Multiple R	0.843
R Square	0.711
Adjusted R Square	0.704
Standard Error	1.231
Observations	91

4.2.2.2 ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	327.902	163.951	108.244	1.91E-24
Residual	88	133.288	1.515		
Total	90	461.191			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	3.077	1.304	2.359	0.021	0.484	5.669
X Variable 1	0.011	0.007	1.595	0.114	-0.003	0.025
X Variable 2	0.512	0.035	14.713	0.000	0.443	0.581

Formula:

$Y = 0.011 * X1 + 0.512 * X2 + 3.077$

Single yarn strength RKM = 0.011 * (no. of fibres in the yarn) + 0.512 * fibre strength in grams/tex + 3.077

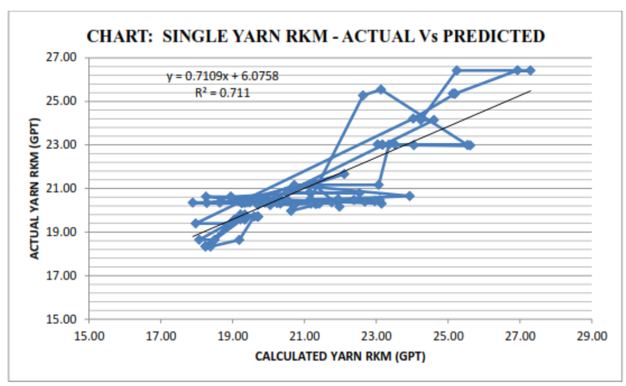

Fig. 4. Knitting yarn RKM actual vs. predicted

5) Combed Compact Weaving yarn: Prediction of yarn neps/km

Table 5
Weaving yarn neps/km regression statistics with ANOVA table

Regression Statistics	
Multiple R	0.768
R Square	0.589
Adjusted R Square	0.571
Standard Error	28.390
Observations	141

4.3.2.2 ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	6	154816.5	25802.75	32.01359	1.1E-23
Residual	134	108003.2	805.9937		
Total	140	262819.7			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	96.50	83.93	1.149	0.252	-69.492	262.494
X Variable 1	1.16	0.55	2.124	0.0354	0.0801	2.2456
X Variable 2	-24.55	111.68	-0.219	0.8263	-245.43	196.340
X Variable 3	1.95	0.166	11.754	2.31E-2	1.620	2.276
X Variable 4	-31.57	11.42	-2.763	0.00652	-54.156	-8.975
X Variable 5	16.39	3.08	5.319	4.25E-0	10.297	22.488
X Variable 6	-4.60	1.78	-2.592	0.0106	-8.114	-1.090

Formula:

Y = - 1.16 * X1 - 24.55 * X2 + 1.95 * X3 – 31.57 * X4 +16.39 * X5 - 4.6* X6 + 96.5

Yarn neps / km = - (1.16 * fibre neps count/g) - (24.55 * fibre neps size in micron) + (1.95* Actual count in Ne) – (31.57 * Micronaire) + (16.39 * HVI fibre SFI) – (4.6 * AFIS mean length) + 96.5

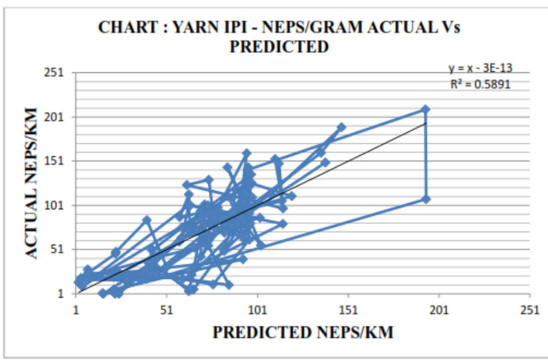

Fig. 5. Weaving yarn neps/km actual vs. predicted

In the model, the linear regression line, the multiple R & goodness of fit in the model is very close to the predicted value.

6) Combed Compact Knitting yarn: Prediction of yarn neps/km

Table 6
Knitting yarn neps/km regression statistics with ANOVA table

Regression Statistics	
Multiple R	0.746
R Square	0.557
Adjusted R Square	0.527
Standard Error	26.056
Observations	96

4.3.1.2 ANOVA

	Df	*SS*	*MS*	*F*	*Significance F*
Regression	6	76032.0	12672.0	18.7	0.0
Residual	89	60423.2	678.9		
Total	95	136455.2			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-91.6	110.0	-0.8	0.4	-310.1	126.9
X Variable 1	-0.7	0.6	-1.1	0.3	-1.9	0.5
X Variable 2	242.2	147.9	1.6	0.1	-51.7	536.0
X Variable 3	1.7	0.2	8.3	0.0	1.3	2.1
X Variable 4	-19.1	12.7	-1.5	0.1	-44.3	6.1
X Variable 5	14.3	3.0	4.7	0.0	8.3	20.3
X Variable 6	-3.2	2.0	-1.6	0.1	-7.1	0.7

Formula:

Y = - 0.7 * X1 + 242.2 * X2 + 1.7 * X3 – 19.1 * X4 +14.3 * X5 - 3.2* X6 – 91.6

Yarn neps / km = - (0.7 * fibre neps cnt/g) + (242.2 * fibre neps size in micron) + (1.7* Actual count in Ne) – (19.1 * Micronaire) + (14.3 * HVI fibre SFI) – (13.2 * AFIS mean length) – 91.6

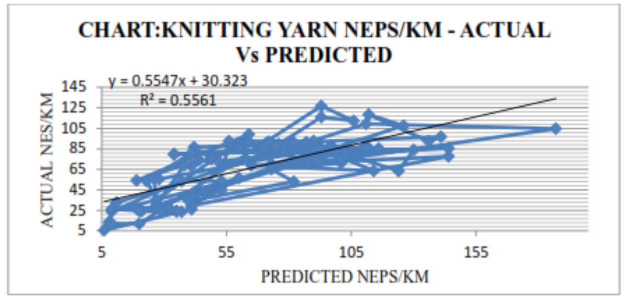

Fig. 6. Weaving yarn neps/km actual vs. predicted

In the model, the linear regression line, the multiple R & goodness of fit in the model is very close to the predicted value.

7) Combed Compact Weaving yarn: Prediction of yarn U%

Table 7
Weaving yarn Unevenness % regression statistics with ANOVA table

Regression Statistics	
Multiple R	0.753
R Square	0.567
Adjusted R Square	0.564
Standard Error	0.559
Observations	141

4.4.2.2 ANOVA

	Df	*SS*	*MS*	*F*	*Significance F*
Regression	1	56.766	56.766	181.98	4.89E-27
Residual	139	43.358	0.3119		
Total	140	100.125			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	5.777	0.335	17.233	2.56E-36	5.114	6.4399
X Variable 1	0.425	0.0315	13.490	4.89E-27	0.363	0.4875

Formula:

Y = 0.425 * X + 5.777
Yarn U% = 0.425 * ((100/sqrt(no. of fibres)/1.25) + 5.777

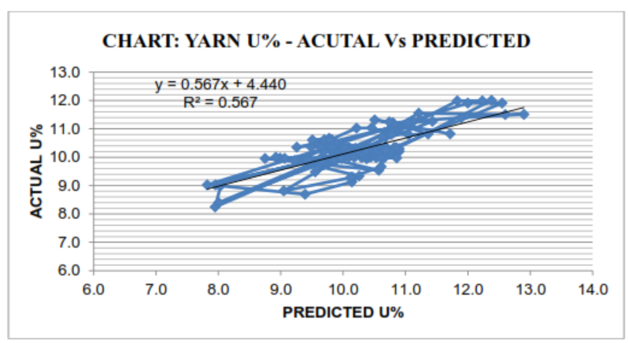

Fig. 7. Weaving yarn U% actual vs. predicted

In the model, the linear regression line, the multiple R & goodness of fit in the model is very close to the predicted value.

8) Combed Compact Knitting yarn: Prediction of yarn U%

Table 4
Knitting yarn Unevenness % regression statistics with ANOVA table

Regression Statistics	
Multiple R	0.895
R Square	0.802
Adjusted R Square	0.799
Standard Error	0.340
Observations	91

4.4.1.2 ANOVA

	Df	*SS*	*MS*	*F*	*Significance F*
Regression	1	41.602	41.602	359.658	5.13E-33
Residual	89	10.295	0.116		
Total	90	51.897			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	4.995	0.278	17.982	0.000	4.443	5.547
X Variable 1	0.513	0.027	18.965	0.000	0.460	0.567

Formula:

Y = 0.513 * X + 4.995

Yarn U% = 0.513 * ((100/sqrt(no. of fibres)/1.25) + 4.995

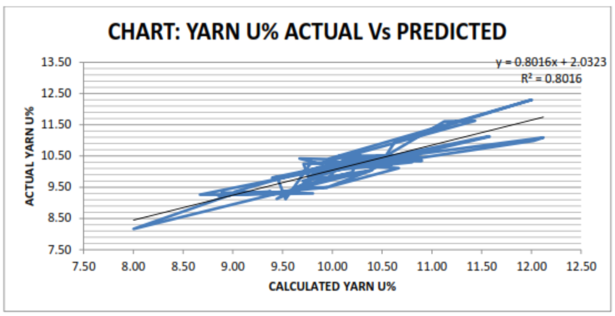

Fig. 8. Weaving yarn neps/km actual vs. predicted

In the model, the linear regression line, the multiple R & goodness of fit in the model is very close to the predicted value.

6. Summary and Conclusion

The value of CSP is the main parameter vastly used in the spinning industry at all levels and the simplest correlation for combed compact spinning lea strength value in pound is fit in the straight line i.e. Multiple R = 0.977 & 0.958 weaving & knitting yarn respectively. The adjusted R is very close to value 1 like multiple R i.e. 0.955 & 0.916 for weaving and knitting yarn respectively.

Similarly, single yarn strength measured in RKM is having straight fit with multiple R value of 0.90 and 0.84. The adjusted R is 0.80 & 0.70 for weaving and knitting yarn respectively. The difference of 0.1 values in adjusted R for knitting yarn may due to the role of twist i.e. soft.

The yarn neps level one of the major criteria for fabric appearance in combed compact regression R value is 0.746 & 0.767 respectively for knitting and weaving yarn is also having close linear regression but not like lea strength and RKM value. The yarn unevenness % is another criterion is having good correlation, R value for knitting yarn is 0.895 & weaving yarn is 0.753.

7. Further Scope of Study

The data collected on the basis of daily production of a spinning mill is mainly taken to match with the industry use for major parameters. If we collect data from all over the national on random sampling basis over a period of one year in each spinning mill especially for compact yarn will prove the best industry norm for each spinner.

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