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A New Method of Studying the Hybrid Effect in Bamboo Cotton blended yarns

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Abstract: *About tweenty years ago, the hybrid effects in blended yarns were investigated, and this was followed by a few publications on the hybrid effects in polyester cotton blended yarns. The results obtained from the work done showed that some of the analysis done was found to be imprecise and were not found to be correct. This paper reports an investigation of the prediction of blended yarn properties from the constituents by a hybrid model which has been formulated. Previous research workers used different methodologies which were fraught with many imprecisions. The methodology followed in the present investigation gives precisely the parameters, their interactions together with their significance levels. The interaction value can be simply obtained from quadratic regression model avoiding the use of equations given by various authors. No proper linear regression analysis was done on the data by the previous research workers and thus there were many imprecisions which were noticed. Five blends of yarns comprising of bamboo and cotton namely, 100% bamboo, 75% bamboo and 25% cotton, 50% bamboo and 50% cotton, 25% bamboo and 75% cotton and 100% cotton were produced and they were tested for tenacity, elongation, evenness, imperfections and friction. Both quadratic and linear regression analyses were performed. The linear regression analysis which was conducted meticulously unlike the previous authors showed that the values were significant. Interaction values were found to be significant for elongation, thin and thick places. It was found that tenacity of bamboo cotton/ blended yarns fell upto 75% bamboo and rose thereafter. Elongation of bamboo/cotton blended yarns was found to increase with increase in bamboo content. An improvement in U% and imperfections and friction was noticed with increase in bamboo content.*

Keywords: *Bamboo/Cotton, hybrid model, Interaction, linear regression.*

I. INTRODUCTION

Bamboo fiber, unlike viscose, is endowed with anti bacterial properties. A number of studies have been undertaken on bamboo and its blends with polyester, cotton and tencel. Whenever two fibers are blended, there is interaction effect due to inter fiber friction and surface effect. A positive hybrid effect means that the properties are above the prediction given by rule of mixtures while a negative hybrid effect means that the properties are below the prediction. In composites, a great deal of work has been done on the hybrid effect. Although a number of workers have dealt with the hybrid effect in blended yarns, still it is not clear as to which method should be followed in determining the interaction. Data provided by previous research workers lack in precision and not of use in calculating the interaction. Most of the workers have used the experimental values which are prone to random error. It is necessary to estimate the value of interaction by regression analysis and then to predict the properties of blended yarns. Although for the prediction of mechanical properties of blended yarns, the estimated values have been used, in respect of linear regressions it is noticed that the experimental values are used which have led to considerable imprecisions. In some of the previous studies, the experimental values have been considered to calculate the interaction as given by Pan etal (2000), Even in Pan's paper, the correct procedure for calculating the interaction is not given. Aghasian etal (2008) have taken logarithm of the experimental values and given the interaction. The data, which provide the interaction values in respect of various yarn properties by Aghasian etal (2008), are found to be incorrect.

The methodology used by Pan etal (5) Aghasian etal and Moghassem and Fakhiali is quite different. Pan etal (5) have used estimated value but their method of calculating interaction appears to be incorrect. Aghasian (etal) and Moghassem and Fakhrali have followed the same methodology for calculating interaction value which has been proposed by Pan etal (5). Chattopadhyay etal (1) have partially carried out the regression analysis for the data. While the quadratic regression model is found to be correct, linear regression model leaves much to be desired. Linear regression has not been carried out properly and a cursory look of the paper will show that they have considered the experimental values, and thus the work carried out is unsound. The essence of the work Aghasian etal and Moghassem and Fakhrali is that the experimental values are considered which are notorious for random errors. Neither of the procedures is generally correct and the correct procedure should be followed for calculating interaction.

The aim of present paper to offer a convenient, handy and efficient tool for calculating the interaction and also to predict the blended yarn strength made from two component fibers utilizing the computing techniques. The mathematical model for predicting the blended yarn strength is given, and the method of determining the various parameters such as tenacity, elongation, U%, thin, thick, neps and friction for the blended yarn is described. In particular, the method of calculating interaction has been simplified and the equations given by Pan etal (5) Aghasian etal (2) and Moghassem and Fakhrali (3) are not required.

Mixture Model

Scheffe (4) proposed a model for the prediction of mixture properties using linear and quadratic models Montgomery (6) has suggestions the following model.

$Y = \beta_i X_i + \beta_j X_j + \beta_{ij} X_i X_j$ ………… (1)

Recently Meloun and Militry (7) suggested the polynomial model which is given below.

$Y = \beta_0 + \beta_1 x + \beta_2 x^2 + e$ …………… (2)

$Y = \beta_1 X_1 + \beta_2 X_2$ is a linear ROM

Previous workers namely Moghassem and Fakhrali (3) and Aghasian etal (2) have not carried out regression analysis to get X_1, X_2 and / values.

The simple rule of mixture is given below.

$X_s = X_1 W_1 + X_2 W_2$ ………… (3)

Where X_i and W_i are the corresponding properties and the fraction respectively. If the interaction between components / is proposed, the simple model (ROM) is given by

$X_s = X_1 W_1 + X_2 W_2 + / W_1 W_2$ …… (4)

$X_s = X_1 W_1 + X_2 (1-W_1) + / W_1 (1-W_1)$ …….. (5)

$= X_1 W_1 + X_2 - X_2 W_1 + / W_1 - / W_1^2$ ..…. (6)

$X_s = X_1 W_1 + X_2 - X_2 W_1 + / W_1 - / W_1^2$ ……. (7)

$= X_2 + W_1 (X_1 - X_2 + /) - / W_1^2$ …… (8)

↓ ↓ ↓

A B C

Where / represents the interactions between two constituents. There are three cases based on the values of / ; for />0, interactions of constituents 1 and 2 will enhance the overall system property: /<0 represents a case where the interactions actually reduce the system property and /=0 means that the interactions do not exist.

It is simple to rearrange the equation (2) into quadratic regression model as shown below.

$X_s = A + BW_1 + CW^2$ ……..… (9)

Where $A = X_2$, $B = X_1 - X_2 + /$ and C= -/. Therefore the least squared algorithm should be used for identification of parameters A B C from experimentally determined values (X_{si},W_{li}) and then the parameters X_1 , X_2 and / should be calculated, The significance of parameters /or C is then indicators of importance of interaction which is generally used, Pan etal. (2000) have given the following equation which is over simplified because X_{50} is experimental value which is subject to random errors.

$I = 4X_{50}/ -2 (X_1+X_2)$ ………. (10)

$I = 4[X_{50}/ -0.5 (X_1+X_2)]$ ………. (11)

$I = 4[X_{50}/ -\langle X\rangle] = - 4\Delta X$ ……… (12)

Values of interaction obtained by using the above equations are redundant.

The parameters X and X_2 are not experimental values but estimators of X_s (W_1=1) and X_s (W_1 = 0).

The correct procedure is to estimate the values by regression and then to use them for prediction of properties.

II. MATERIALS AND METHODS

Table 1: Details of Fiber Properties

Fibers	Fibre length(mm)	Fiber Strength (g/tex)	Fiber Uniformity Index (%)	Fibre Moisture (%)	Fibre Elongation (%)
Cotton	27.7 mm	36.1	81.5	7.6	5.7
Bamboo	36 mm	35.2	91.4	6.4	15.0

Table 1 gives the properties of Bamboo and Cotton Fibers used.

Production of Yarn Samples

A series of five yarns comprising 100% bamboo, 100% cotton, 25% cotton and 75% bamboo, 50% bamboo and 50% cotton, 25% bamboo and 75% cotton was prepared. The fibres were blended at draw frame in the required proportion. A hank of 0.13 was kept in card and the drawframe sliver had a hank of 0.15. The roving produced had a hank 1.6 and the yarns were spun in ring frame of 40Ne (16.0 tex) using 733TPM.

Testing

Yarn count was determined as per ASTM-D 1907:2001 standard. Evenness of samples was measured by ASTM-D1425:1996.Twenty samples were taken randomly for count determination and the mean was calculated. For evenness, ten samples were tested in Uster tester and 4-SXR2 and mean values was taken. These parameters were tested as per Uster standard testing method. Uster Tensorapid 3V70 was used to test yarn samples with the testing speed of 5000 mm/min. Two hundred samples were tested and mean strength values in yarn were converted to cN/tex. Yarn hairiness was determined as per Uster standard testing method. Uster tester 4-SXR2.0 was used with the test speeds of 400m/min. Ten samples were tested and the mean value is reported Coefficient of friction was determined as per ASTMD_3108:2007.Lawson-Hemphill Tension-W instrument was used. Wrap angle and input tension were 180◦C and 20g respectively.

III. RESULT AND DISCUSSION

The various parameters and interaction and their level of significance were calculated using statistical software. The p values calculated show the level of significance. The linear regression analysis of the data has been carried out meticulously which has not been done by Chattopadhyay etal.(1).

Table 2: Mechanical and physical properties of bamboo cotton blended yarns

S. No	BLENDING RATIO	Tenacity	CV%	ELONGATION	CV%	U%	THIN	THICK	NEPS	FRICTION
1	COTTON-100	15.45	12.68	4.6	9.84	14.52	70	438	746	0.3
2	B/C – 25/75	14.58	18	5.1	15.39	13.2	52	210	580	O.25
3	B/C - 50/50	14.2	23.5	7.2	12.47	12.3	41	120	360	O.25
4	B/C – 75/25	10.64	18.78	10.2	19.35	11.2	20	82	230	O.25
5	BAMBOO-100	15.37	9.62	13.7	8.71	10.91	5	61	131	O.25

Table 2 shows the Mechanical and physical properties of bamboo cotton blended yarns.

Tables 3 and 4 show the quadratic and linear models together with their standard deviations and level of significance. Interaction values of parameters are shown in quadratic model. Most of the interactions are significant in quadratic model which imply that the level of interaction is high. Also most of interactions is negative which means that estimated values are all well below experimental values. It is apparent that the interaction values in respect of tenacity, U%, neps and friction are not significant. In the case of linear regression analysis, thick places, thin places and neps do not show any significance between different blends. The correlation coefficient obtained from quadratic ROM is found to be higher in comparison to linear ROM. However, with respect to tenacity, the values are low. It is also interesting to note that the quadratic model fits the experimental values very well (Figure 1).

Table 3: Quadratic regression model

Sl no	Testing	Quadratic Regression Equation	R^2	SD			Probability			Level of Significance		
		$Y=\beta_1X_1+\beta_2X_2-\beta_1\beta_2X_1X_2$		β_1	β_2	$\beta_1\beta_2$	β_1	β_2	$\beta_1\beta_2$	β_1	β_2	$\beta_1\beta_2$
1	Tenacity	$Y=14.373X_1+16.013X_2-9.165X_1X_2$	0.6336	2.0358	2.0358	9.2501	0.0195	0.0158	0.4262	S	S	NS
2	Elongation	$Y=13.805X_1+4.485X_2-7.885X_1X_2$	0.9989	0.2327	0.2327	1.0574	0.0003	0.0027	0.0175	S	S	S
3	U %	$Y=10.847X_1+14.535X_2-2.125X_1X_2$	0.9970	0.1534	0.1534	0.6972	0.0002	0.0001	0.0928	S	S	NS
4	Thick	$Y=72.371X_1+425.171X_2-532.571X_1X_2$	0.9921	25.7845	25.7845	117.1571	0.1070	0.0037	0.0451	NS	S	S
5	Thin	$Y=4.628X_1+69.428X_2+4.571X_1X_2$	0.9970	2.6332	2.6332	11.9646	0.2209	0.0014	0.7392	NS	S	S
6	Neps	$Y=125.40X_1+757.40X_2-256.0X_1X_2$	0.9974	24.0972	24.0972	109.4902	0.0350	0.0010	0.1443	S	S	NS
7	Friction	$Y=0.254X_1+0.294X_2-0.114X_1X_2$	0.9258	0.2943	0.2943	0.1143	0.0020	0.0015	0.1548	S	S	NS

Table 4: Linear regression model

Sl.no	Testing	Linear Regression Equation	R^2	SD		Probability		Level of Significance		*Note
		$Y=\beta_1X_1+\beta_2X_2$		β_1	β_2	β_1	β_2	β_1	β_2	
1	**Tenacity**	$Y=13.228X_1+14.868X_2$	0.3279	1.6705	1.6705	0.0042	0.0030	S	S	**S = Significant**
2	**Elongation**	$Y=12.82X_1+3.5X_2$	0.9691	0.8394	0.8394	0.0006	0.0251	S	S	**NS = Not Significant**
3	**U %**	$Y=10.582X_1+14.27X_2$	0.9828	0.2451	0.2451	0.0000	0.0000	S	S	
4	**Thick**	$Y=5.8X_1+358.6X_2$	0.9058	58.3308	58.3308	0.9271	0.0087	NS	S	
5	**Thin**	$Y=5.2X_1+70X_2$	0.9968	1.8330	1.8330	0.0658	0.0000	NS	S	
6	**Neps**	$Y=93.4X_1+725.4X_2$	0.9903	31.2896	31.2896	0.0584	0.0002	NS	S	
7	**Friction**	$Y=0.24X_1+0.28X_2$	0.7071	0.2800	0.2800	0.0004	0.0003	S	S	

The paper by Chattopadhyay etal (1) also is certainly not without faults In carrying out linear regression analysis, they have committed a mistake in that the experimental values are considered, Values of X_1, X_2 and interaction should be obtained by regression In the paper by Pan etal (5), there is no procedure given for calculating X_1 and X_2 although it is stated that X_{50} was obtained by estimation. The method of calculating interaction is unsound as noticed from their equations. In this study, the values of X_1, X_2 and / have been obtained by regression analysis in respect of bamboo cotton blended yarns.

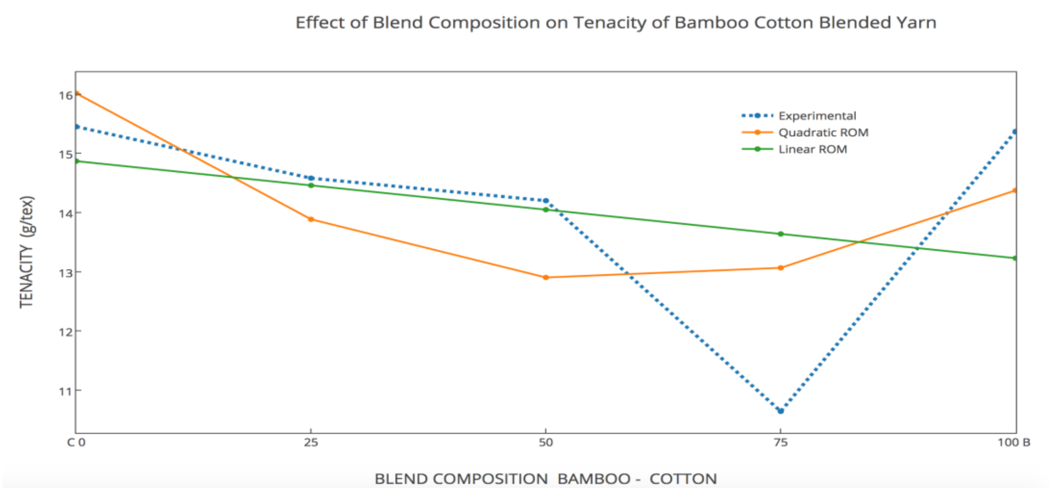

Figure 1: Relationship between blend composition and tenacity of bamboo cotton blended yarns

Figure 1 shows the effect of blend composition on tenacity of blended yarns It is noticed that the strength of yarns decrease upto 75% bamboo and then shows an increase. The quadratic and linear regression models fail to disclose this trend. It is clearly seen that the interaction is negative as the predicted values lie below the experimental values. It is also seen that the interaction value obtained is not significant. The correlation between blend composition, and tenacity, although is found to be higher than that of the correlation obtained by linear regression, is low. The trend followed by bamboo/cotton blend in terms of tenacity is more or less similar to polyester cotton blend. Values of X_1 and X_2 obtained by linear regression are found to be significant.

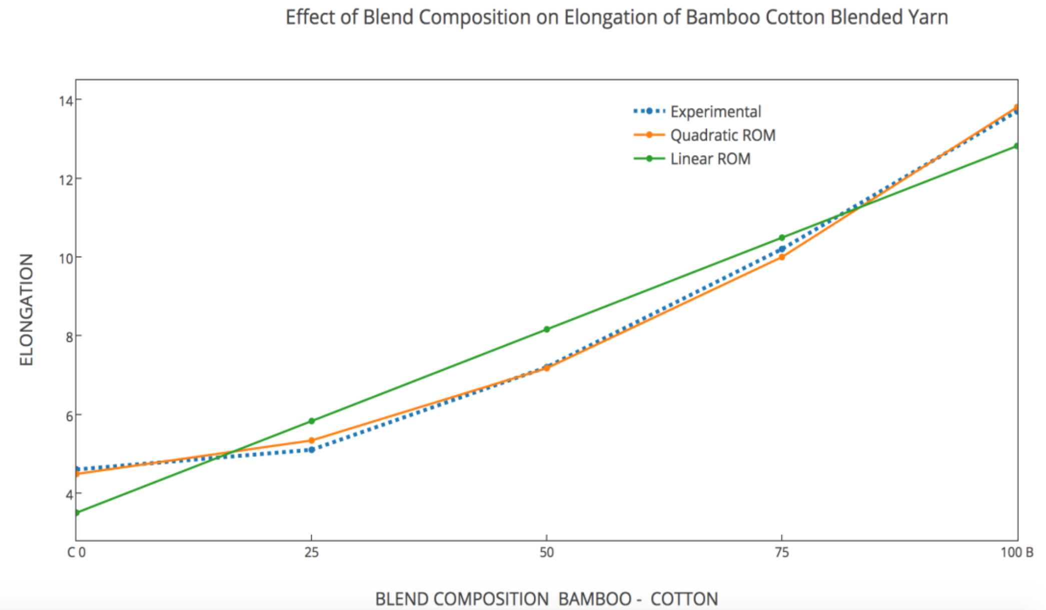

Figure 2: Relationship between blend composition and elongation of bamboo cotton blended yarns

Elongation is found to increase with increase in bamboo content. This is due to the higher elongation of bamboo fibers in comparsion to cotton. The interaction value is found to be negative and significant Correlation between blend compostion and elongation is found to be higher in both quadratic and linear regression models (Figure 2). This is evidence another to indicate the relationship between blend composition and elongation.

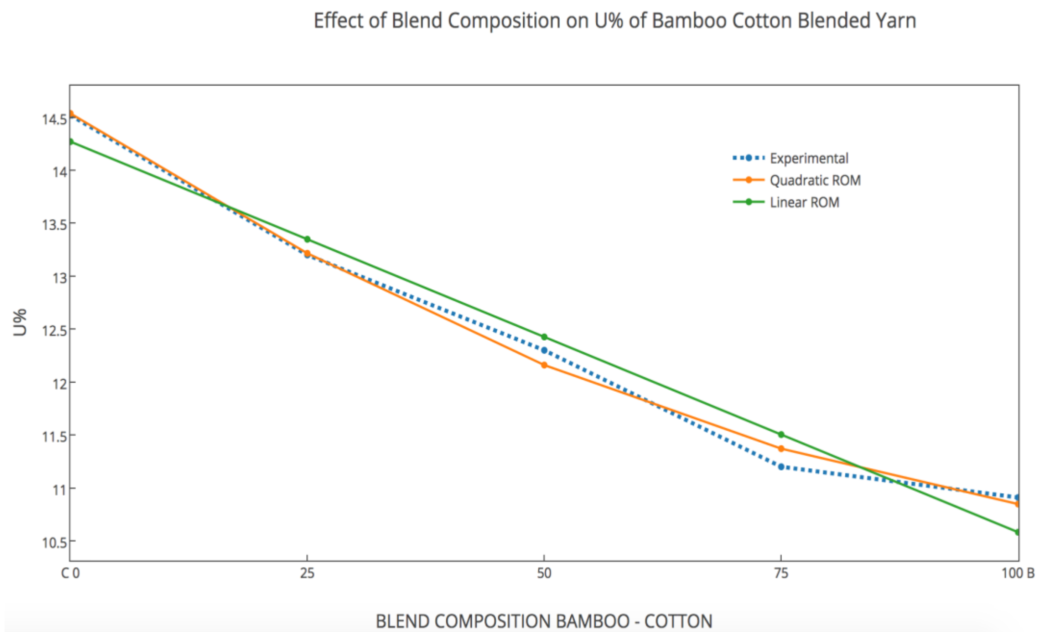

Figure 3: Relationship between blend composition and U% of bamboo cotton blended yarns

Evenness is found to improve with addition of bamboo in the blend. (Figure3) interaction value is found to be not significant and the predicted values obtained by both quadratic and linear models are found to be below the experimental values. The correlation between blend composition and U% is good in both the models.

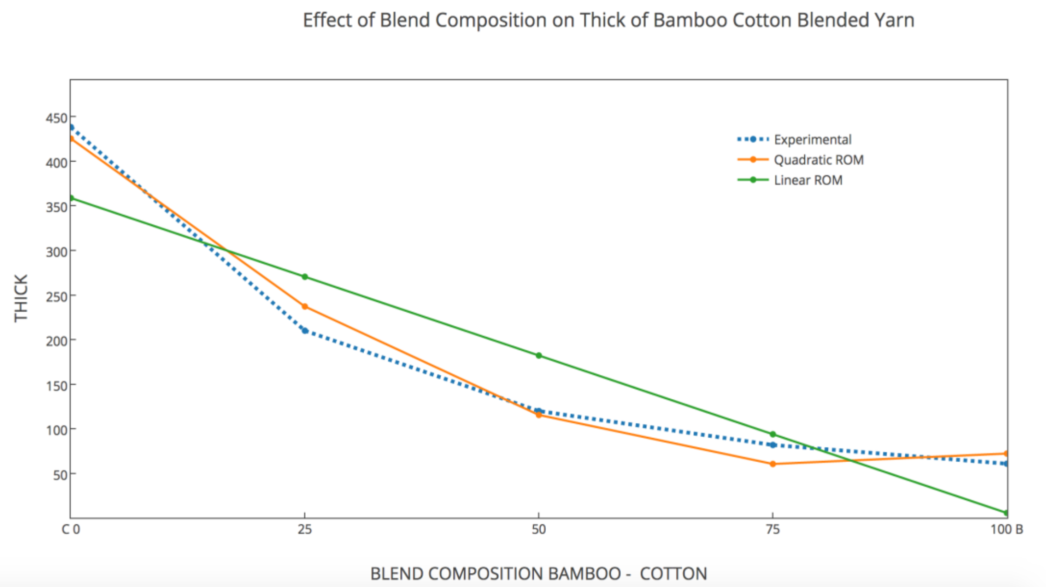

Figure 4: Relationship between blend composition and thick places of bamboo cotton blended yarns

As regards thick places, interaction is negative and found to be significant. The correlation in both the cases is found to be high. The quadratic and linear models agree with experimental values very well. (Figure4). The improvement in thick places is due to the better uniformity of bamboo fibres.

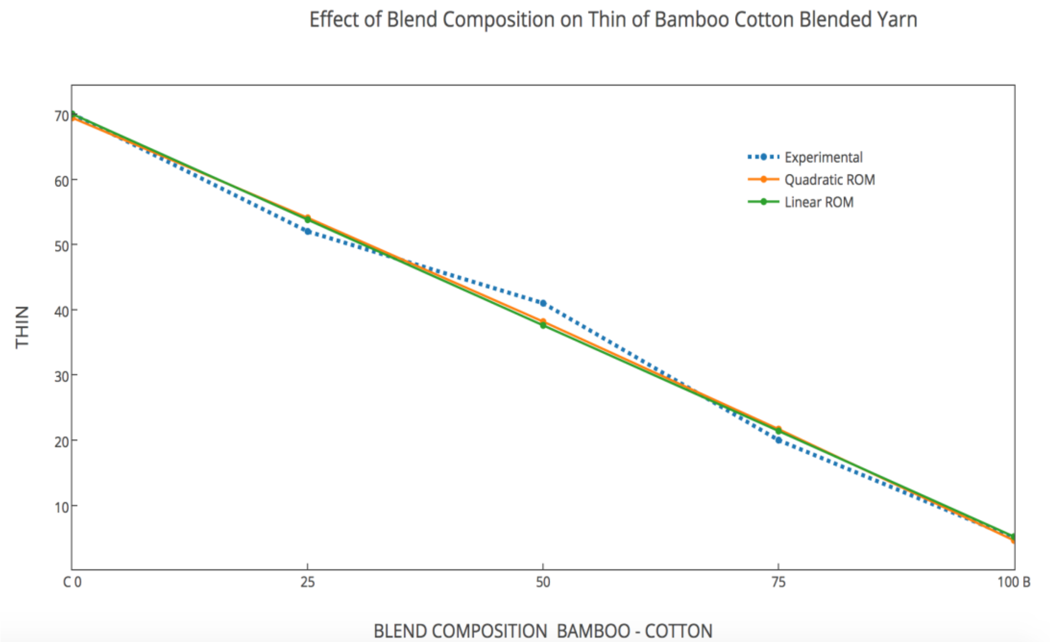

Figure 5: Relationship between blend composition and thin places of bamboo cotton blended yarns

As regards thin places (Figure 5) there is a significant improvement with the addition of bamboo fibers. Both the quadratic and linear models agree substantially with the experimental values. The correlation values are also found to be high and significant. The reduction in thin places is due to the better uniformity of bamboo fibers.

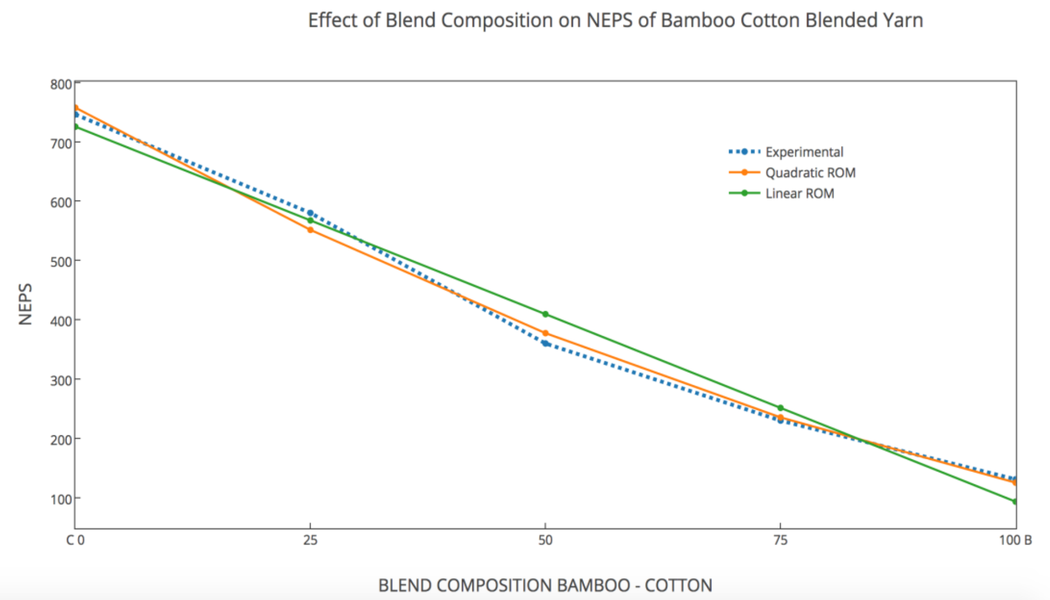

Figure 6: Relationship between blend composition and neps of bamboo cotton blended yarns

With regard to neps, there is a substantial reduction with the increase in bamboo content. This is due to the better uniformity of bamboo fibers, Cotton fibers are notorious for neps and thus 100% cotton yarn is more neppy. The interaction value is not significant and the correlation between blend composition and neps is good in both the causes (Figure 6).

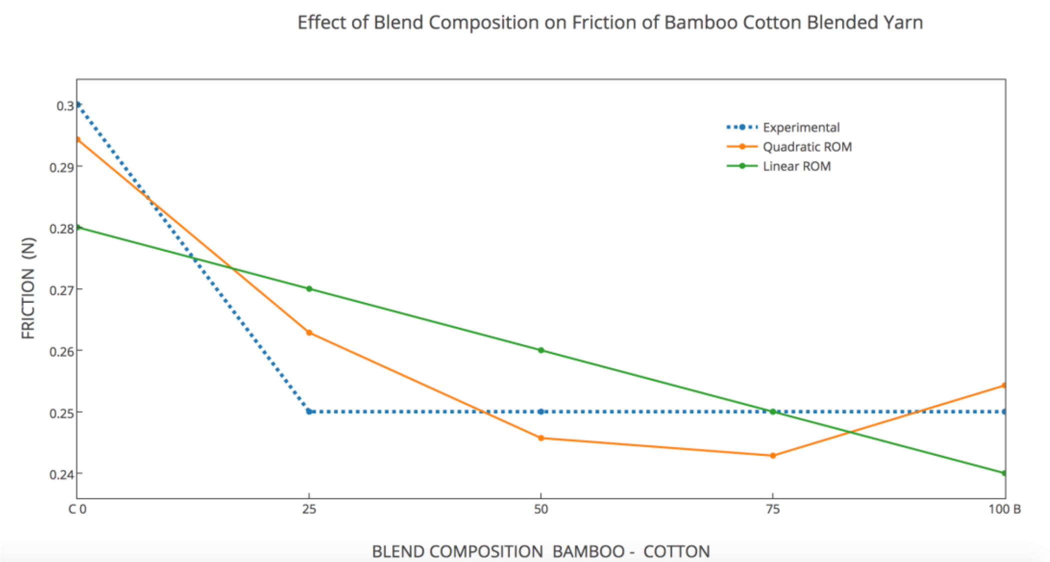

Figure 7: Relationship between blend composition and friction of bamboo cotton blended yarns

Figure 7 shows the relationship between blend composition and friction. The interaction is negative and is not found to be significant, Cotton shows a higher friction in comparison to bamboo With the increase in bamboo content, the friction shows a reduction, Quadratic interaction model is found to give a better fit with experimental values and is found to be superior compared to linear model.

IV CONCLUSION

The following conclusions can be drawn from the above study.

Interaction value can be calculated from the quadratic model than computing them from the formula provided by previous research workers. Values of interaction were found to be significant in respect of elongation, thin and thick places. Quadratic regression can be used for the prediction of the blended yarn strength and also to find out their significance. Linear regression model can also be used profitably to predict the strength values. The strength of bamboo/cotton fell upto 75% bamboo and rose thereafter Elongation of blended yarns increased with increase in bamboo content. Evenness, imperfections and friction showed improvements with increase in bamboo content. Some of the interactions were found to be significant.

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