Studies on tensile properties of eri/acrylic blended yarn

Prabir Kumar Choudhuri¹, Prabal Kumar Majumdar² & Bijon Sarkar³
¹Visva-Bharati University, Silpa Sadana, Sriniketan 731 236, India
²Government College of Engineering and Textile Technology, Serampore 712 201, India
³Production Engineering Department, Jadavpur University, Kolkata 700 032, India

Received 11 September 2011; revised received and accepted 11 January 2012

Eri/acrylic blended yarn has been prepared at different blend ratio in ring spinning system following draw-frame blending technique. The Box and Behnken design for three variables and three levels has been used to study the influence of count of the yarn spun (Ne), twist multiplier and proportion of eri fibre in the blends on some important tensile properties of the yarns produced. The chosen level of variables remaining within the industrially acceptable limits shows that fibre parameters and yarn parameters are the determining factors to influence yarn tensile properties.

Keywords: Acrylic, Blending, Eri silk, Helix angle, Tensile properties

1 Introduction

The textile fibres are inhomogeneous in their characteristics. This is inevitable owing to the different cultivation conditions of natural fibres and the different production conditions for manmade fibres which are partly deliberate to influence the properties of end product and the process. Fibre blending is a common practice in the textile industry for a long time, stimulated to a great degree by the availability of an ever increasing number of manmade fibres. Blending is chiefly performed to achieve desired characteristics of the product which cannot be realized using one fibre type alone, compensate variations in fibre characteristics and hold down raw material cost.

Many research works have been conducted on blending of manmade and natural fibres having two or more types of fibre to produce yarn. Acrylic fibres possessing all necessary characteristics along with its indigenous nature of bulkiness occupy a remarkable position in blending with others to produce yarns like acrylic/cotton, acrylic/polyester, acrylic/wool, and acrylic/viscose for apparels. The studies on blending of acrylic with mulberry silk waste are also reported. On the other hand, eri fibre has long been used to produce yarn on hand spinning system. However, machine spinning of eri fibre in commercial scale has started very recently. Though eri fibres possess all necessary characteristics and offer tremendous blending possibilities with other fibres, literature hardly reports any study on its blending with acrylic fibre to produce yarn.

In the present work, an attempt has been made to blend eri with acrylic fibre in draw frame stage, intended to manufacture eri/acrylic blended yarn on a ring spinning system following Box and Behnken design of experiment for three variables and three levels and to study its tensile properties. The Box and Behnken design of experiment has been popularly used by some researchers to study the effects of variables on responses during spinning process. The factors exclusively selected in the present study are count of the yarn spun (Ne), twist multiplier and % of eri in blends as they influence the quality of the yarn produced.

2 Materials and Methods

2.1 Materials

Acrylic and eri silk cut staple as detailed in Table 1 have been used for the study. The acrylic and exi fibres were procured from Bardhman Acrylic Ltd, Bharuch, Gujarat; and Tamulpur, Anchalik Gramdan Sangh, Assam respectively.

Eri silk was collected in the form of card sliver of 0.167 hank (3.53 ktex) and the acrylic fibres in identical form (0.167 hank) were obtained from mill processed through Trumac Blowroom line and NSE Card.

2.2 Preparation of Sample

Taking eri and acrylic card sliver as starting material, blending was carried out in LMW make
DO/6 Draw-frame with 6-ends up. By feeding two eri sliver with four acrylic sliver, three eri sliver with three acrylic sliver and four eri sliver with two acrylic sliver separately, three sample of eri/acrylic blended breaker draw-frame sliver in the blend ratio of 33:67, 50:50 and 67:33 were obtained. These were again drawn through a LMW make DO/6 draw-frame with 6-ends up to get finisher drawframe sliver.

The finisher draw-frame slivers so produced were processed separately in a speed-frame (make LMW, model LF 1400A) to produce roving. Draft was adjusted to produce roving of 1.8 Ne (0.328 ktex) with 0.8 TM for each blends so that the ring-frame permits to give required draft to produce yarns of 20 S Ne, 40 S Ne and 60 S Ne from respective type of roving.

In order to prepare the yarn samples, the Box and Behnken model on design of experiment for three variables and three levels was followed. The actual levels of variables are given in Table 2. The design matrix was generated using MINITAB 13 (Table 3).

Respective rovings were fed to a miniature ring-frame (make Trytex) with PK 225 drafting system and 10,500 rpm spindle speed separately as per the sequence in design matrix and maintaining the variable combinations (uncoded level) therein to produce 15 yarn samples. Draft and twist were altered suitably to produce these yarn samples.

2.3 Testing of Samples

Count of the yarn samples in cotton system (Ne) was measured following standard method ASTM D 1907-01. Leas of skeins measuring 120 yd were prepared by wrap reel and weighed on an electronic balance. The count of yarn in cotton system (Ne) was observed. Thirty (30) tests were conducted for each sample and average was taken.

Yarn twist was measured by untwist-retwist method on ‘Eureka single yarn twist tester’ following standard method ASTM D 1422-99 using a tension of 1.5gf/tex. A specimen length of 10 inch was used and twist per inch (tpi) was calculated. Thirty (30) tests were conducted for each sample and average was taken.

Tensile characteristics of eri and acrylic fibres were measured following standard test method ASTM D 3822-01 using Instron tensile testing machine (Model 3366) at a strain rate of 5 mm/min. The gauge length was kept at 10 mm and load cell used was 5 N for all the samples. Fifty (50) tests were conducted for each sample and average was taken.

Tensile characteristics of all the yarns made of eri and acrylic fibres were also studied following standard test method IS:1671-1977 using Instron tensile testing machine (Model 3366) at a strain rate of 100 mm/min. The gauge length was kept at 200 mm and load cell used was 500 N for all the samples. Fifty (50) tests were conducted for each sample and average was taken.

3 Results and Discussion

3.1 Particulars of Fibre Properties

The properties of eri and acrylic fibres used in this experiment are presented in Table 1 which reveals that the closeness in their fineness values offers better compatibility in blending between them. The representative stress-strain curves of eri and acrylic fibres are shown in Fig. 1, wherein it may be observed that the curves follow a typical shape leading to possibilities in blending between them.

Tensile characteristics of all the yarns made of eri and acrylic fibres were also studied following standard test method IS:1671-1977 using Instron tensile testing machine (Model 3366) at a strain rate of 100 mm/min. The gauge length was kept at 200 mm and load cell used was 500 N for all the samples. Fifty (50) tests were conducted for each sample and average was taken.

3.2 Evaluation of Tensile Properties of Blended Yarns

In order to evaluate the relationship between the controlled experimental factors like count (Ne), TM and eri% in blends and the different tensile properties, the response surface methodology, an empirical modeling technique, has been used.

In a system involving three significant independent variables \(X_1, X_2, X_3\), the mathematical relationship of the response on these variables can be approximated.
by the following quadratic (second degree) polynomial equation:

\[ Y = C_0 + C_1 X_1 + C_2 X_2 + C_3 X_3 + C_{12} X_1 X_2 + C_{13} X_1 X_3 + C_{23} X_2 X_3 + C_{11} X_1^2 + C_{22} X_2^2 + C_{33} X_3^2 \]  \hspace{1cm} \text{... (1)}

where \( Y \) is the predicted yield; \( C_0 \) the constant; \( C_1, C_2 \) & \( C_3 \), the linear coefficients; \( C_{12}, C_{13} \) & \( C_{23} \), the cross product coefficients and \( C_{11}, C_{22} \) & \( C_{33} \), the quadratic coefficients.

Depending upon the selection of terms like only linear, linear + square, linear + interaction in Eq. (1), the above mathematical model can be reduced into following three separate equations:

\[ Y = C_0 + C_1 X_1 + C_2 X_2 + C_3 X_3 \]  \hspace{1cm} \text{... (2)}

[considering the linear terms only]

\[ Y = C_0 + C_1 X_1 + C_2 X_2 + C_3 X_3 + C_{11} X_1^2 + C_{22} X_2^2 + C_{33} X_3^2 \]  \hspace{1cm} \text{... (3)}

[considering the linear + square terms only]

\[ Y = C_0 + C_1 X_1 + C_2 X_2 + C_3 X_3 + C_{12} X_1 X_2 + C_{13} X_1 X_3 + C_{23} X_2 X_3 + C_{11} X_1^2 + C_{22} X_2^2 + C_{33} X_3^2 \]  \hspace{1cm} \text{... (4)}

[considering the linear + interaction terms only]

Multiple regression analysis in addition to ANOVA using MINITAB 13 software is done to obtain the coefficients based on best \( R^2 \) (adj) value obtained among above four equations.

The regression equations are evaluated through backward elimination method in which the factors are excluded based on the \( p \)-values of co-efficient of respective factors at the level of 95%. Using the experimental results of all 15 yarn samples as presented in Table 3, the regression equations for different responses are developed (Table 4). The given \( R^2 \% \) (adj) value corresponding to each equation...
depicts the strength of relationship between factors and response.

The contour diagram and response surface plot for different responses are also drawn in order to visualize the influence of variables on response.

### 3.2.1 Tenacity

It is observed from the response surface equation (Table 4) and Figs 2 a-c that for all counts of yarns the tenacity reduces with the increase in eri% in the blend which may be due to presence of more number of weaker fibres. It is also observed that the tenacity reduces as the yarn count changes from medium to finer for all blends, which may be due to presence of less number of fibres generating less cohesive force. Also, when there are few fibres in the yarn cross-section, the proportion of contacts with low pressure is proportionally much greater than the situation where there are much greater number of fibres in yarn cross-section, having few fibres in yarn becomes a source of weakness. This is again confirmed from the Fig. 2b that with the increase in eri% and fineness of the yarn the tenacity falls. However, the variation in twist within the experimental domain shows very little influence, which is revealed from Figs 2a & c and from the predicted regression equation. When eri% in the blend increases the requirement of twist becomes marginally higher to achieve a particular tenacity value, may be
due to the demand of higher twist to generate better cohesive force as evidenced from Fig. 2a.

3.2.2 Elongation-at-break

It can be observed from Table 4 and Figs 3a-c that for all counts of yarns the breaking elongation (%) decreases with increase in eri% in the blend and decrease in TM. This may be due to less extensibility of eri fibre as compared to acrylic. Higher average helix angle of the fibres with higher twist may be the reason of higher elongation.

It is also observed that at a given TM the breaking elongation (%) increases with the increase in coarseness of yarn. This may be due to interaction of more number of fibres while longitudinal straining delaying the failure of yarn.

3.2.3 Initial Modulus

Figure 4a shows the influence of eri% and TM on initial modulus of eri/acrylic blended yarn. Initial modulus increases with increase in twist. At higher twist the fibres remain already in strained state and hence as soon as the yarn deformation starts under tensile loading the constituent fibres start straining immediately, thus influencing yarn initial modulus. Figures 4a-c also depict that for coarser yarn higher
initial modulus is obtained at higher eri% in combination with higher TM, but as the count becomes finer the better modulus is obtained with the combination of lower twist and lower eri%. For coarser yarn with higher eri content, due to high twist the higher number of eri fibres attain more strained state earlier than acrylic fibres owing to their lower breaking extension, thus responding immediately to the yarn deformation which finally influences initial modulus. But as the count becomes finer the total number of fibres becomes less. At lower eri content the proportion of acrylic fibres having higher modulus value requiring lesser twist becomes more and their presence influences the yarn initial modulus.

### 3.2.4 Specific Work of Rupture

It can be observed from Table 4 and Figs 5a-c that for all counts of yarns the sp. work of rupture decreases with the increase in eri% in the blends, which may be due to lesser specific work of rupture value of eri fibre as compared to acrylic. It is also observed from Fig. 5c that at all levels of TM as the count becomes finer the sp. work of rupture of yarn decreases due to lesser tenacity and elongation of finer yarns as also explained in sections 3.2.1 and 3.2.2, the effect becomes more...
prominent with increase in eri content. However the TM has very marginal influence on sp. work of rupture.

4 Conclusion

It is possible to spin eri/acrylic blended yarn at different blend ratios in ring spinning system without difficulty.

4.1 Tenacity of the blended yarn reduces with the increase in proportion of eri fibre in the blend, which is comparatively weaker as compared to acrylic. Tenacity also reduces with fineness of yarn as less number of fibres generates less cohesive force. Twist level within the experimental zone shows not much significant effect on tenacity.

4.2 Breaking elongation reduces with the increase in eri fibre having lower extensibility than acrylic and decrease in twist lowering average helix angle. Breaking elongation increases with the increase in coarseness of the yarn due to interaction of more number of fibres delaying the failure of yarn during longitudinal straining. This is aggravated at lower level of twist in the yarn.

4.3 For initial modulus, low $R^2$ value shows poor degree of association between response and variables. However, initial modulus increases with the increase in twist, because in strained state fibres start responding immediately to the yarn deformation under tensile loading thus influencing yarn initial modulus.

Fig. 5—(a) Effect of TM and eri% in the blend on sp. work of rupture of yarn at constant yarn count of 40 S Ne, (b) Effect of count and eri% in the blend on sp. work of rupture of yarn at constant TM of 4.0, and (c) Effect of count and TM on sp. work of rupture of yarn at a constant eri% in blends of 50
4.4 Specific work of rupture decreases with the increase in eri content having lower specific work of rupture value as compared to acrylic. It decreases as the count becomes finer due to lesser tenacity and elongation of finer yarns.

Acknowledgement
The authors wish to acknowledge Dr. Arup Ranjan Mukherjee, Head, Statistical Quality Control and Operation Research, Indian Statistical Institute, Kolkata for his help during Statistical interpretation of data.

References