A Study of Spinning Persian Silk Waste/Cotton Blends on Rotor Spinning System

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Abstract

In this study, processing of cutting and de-gumming of silk waste samples were carried and silk waste sliver was prepared. Silk waste and cotton slivers were blended at three different blend ratios (65/35, 50/50 and 35/65) and silk waste/cotton blended as well as cotton and silk rotor spun yarns were produced. The physical and mechanical properties of the produced yarns including liner density, tensile strength, evenness, imperfection, hairiness, frictional and abrasion resistance were studied.
Our finding shows that by increasing the silk fiber blend ratio, the yarn elongation and abrasion resistance significantly increased. However, silk fiber blend ratio has no significant influence on yarn imperfection, frictional and evenness properties. It also shown that tensile strength of silk waste/cotton blended rotor spun yarn at 50% silk fiber blend ratio is significantly higher than those of 100% cotton as well as two other blended yarns. Utilizing Hamburger theory also confirmed this finding. Thus, silk waste rotor spun yarn has the highest tensile strength compared with other yarn samples. On the other hand, the results indicate that by the increase of silk blend ratio, slight reduction of yarn linear density and yarn hairiness deterioration occurred.

Keywords: Silk waste, rotor spinning, cotton fiber, de-gumming, blended yarn, Hamburger theory.

1. Introduction

In staple fiber yarn processing, blending is accomplished for a number of reasons, including uniformity, technical and engineering, functional and aesthetic and economic [1-9]. A most comprehensive study of this can be found elsewhere [10]. Silk fibre is known for its strength, fineness, luster and elasticity [11]. To obtain desirable characteristics of blended fibre products, silk waste fibres may be blended with cotton fibres in the cotton spinning system to give comfort, strength and elegance in blended yarn.

There are several research works studied Throstle-spun-silk/raw-silk core-spun yarn as well as double-core twin spun silk yarns and fabrics properties [12-16]. In recent years, there are some interests on silk waste fibre blends with cotton, wool and polyester fibres [17-23]. In particular, Lo and Cheng [18] investigated silk waste/polyester blended DREF-spun yarns. Kumar *et al*.,[19] studied the feasibility of spinning pure silk as well as silk waste-polyester on ring spinning cotton system. In a recent study, Chollakup *et al.*, [23] investigated physical properties and fibre arrangement of blended silk waste/cotton yarns in cotton ring micro-spinning system. Concerning the higher speed of rotor spinning compared with ring spinning system, the rotor spinning system is however more economical than ring spinning [24]. Therefore, the objective of the current research work is to investigate the feasibility study of spinning Persian silk waste/cotton blends on rotor spinning system.

In this study, processing of cutting and de-gumming of silk waste samples were carried and silk waste sliver was prepared. Silk waste and cotton slivers were blended at three different blend ratio (65/35, 50/50 and 35/65) and silk waste/cotton blended as well as cotton and silk rotor spun yarns were produced. The physical and mechanical properties of the produced yarns including liner density, tensile strength, evenness, imperfection, hairiness, frictional and abrasion resistance were studied.

2. Experimental

2.1 Materials

Persian silk in hank form was procured. The hanks of Persian silk were then cut to a length of 40 mm staple by using a gutting machine designed for cutting the paper. Degumming was carried out by boiling off in soap solution under the following conditions:

Sodium carbonate	5 g/litre.
Ultravon GPN	10 g/litre.
Silvatol FL	10 g/litrte.
L.R	30:1
Time	90 min.
Temperature	90°C.

After degumming, the fibres were washed in soft warm and then in cold water and dried at room temperature for 24 hours. In order to facilitate the processing of silk fibre in spinning, additives agents as softener was also used with following specifications:

SAPAMINE OC	300% (in fibre weight)
ACETIC ACID	0.50% (in fibre weight)
L.R	30:1
Temperature	40°C.
Time	20 min.

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It was observed that the produced silk fibre was partially entangled. The silk fibre was then pre-opened by using a special opener (Larosche). The material was allowed to be conditioned for 24 hours. In addition, in order to prevent from static electricity in silk fibre, an anti- static solution (ZEROSTAT C) at 20 g/litre concentration was prepared and then sprayed over fibres at 10% fibre weight.

The cotton fibres used in this research was a mixture of different Iranian cotton fibres (Ghom-SM, Ghom-GM, Eshtehard-SGM). The physical properties of silk and cotton fibres used in this study are measured as follows: Effective length and short fibre content of cotton and silk fibres were measured using "Comb Sorter" method [25-26]. Single fibre tensile strength of silk fibre was measured using Fafegraph apparatus. The gauge length and cross-head speed were adjusted at 1 cm and 1000 mm/min values. Cotton fibre bundle strength was measured using Pressley method [25-26]. Silk fibre fineness was measured using Vibromat method [26-27]. The dead weight was 70 mg. To evaluate cotton fibre fineness, Micronaire method was used [25-26]. Table 1 shows the mean values of cotton and silk fibre specifications.

Table 1 Raw material specifications

Material	Fineness (dtex)	Tensile Strength (cN/tex)	Short fibre content (%)	Effective Length (mm)
Silk waste fibre	1.42	45.09	13.16	44
Cotton fibre	1.51	27.6	11.54	29

2.2 Spinning Processing

The prepared staple silk fibers were fed into a conventional bale opener and then through a chute-feed system, fed and processed on a Crosrol MK4 Card and 100% silk fiber sliver with liner density of 5 ktex produced. Cotton fibers were also fed into a conventional bale opener and then through a chute-feed system, a Kirschner beater and a step-cleaner, fed and processed on a Crosrol MK4 Card and 100% cotton fiber sliver with liner density of 5 ktex produced. In order to produce 65/35 silk/cotton sliver, the blended fibers were prepared as sandwich blending procedure and then followed the same procedure as for 100% silk fiber and a 65/35 silk/cotton carded sliver with a linear density of 5 ktex was produced. However, 50/50 and 35/65 silk/cotton slivers were blended using the draw-frame principle. Table 2 shows the production procedures in spinning preparation stage. The drawn slivers were processed on a rotor spinning machine (Schlafhorst) to produce yarn of 30 Ne. (20 tex) with twist level of 850 TPM. The Rotor spinning machine specifications are listed in Table 3.

Table 2: Spinning preparation specifications

	Carding Process		*Draw-Frame Process*			
Sliver Type	Linear Density of Carded Sliver (Ktex)	Production speed (m/min)	Draw-frame Linear Density (Ktex)	Production speed (m/min)	Draft	Doubling
Pure silk sliver	5	40	4.2	350	7.1	6
Pure cotton sliver	5	40	4.2	350	7.1	6
65/35 silk/cotton sliver	5	40	4.2	350	7.1	6
50/50 silk/cotton sliver	5	40	4.2	350	7.1	6
35/65 silk/cotton sliver	5	40	4.2	350	7.1	6

Table 3: Spinning machine specifications

Spinning Machine Parameter	Specifications
Rotor type	T40
Take-up nozzle	Steel-4 Grooves
Opener Type	For Synthetic fibre, B171DN
Yarn Linear Speed	67.8 m/min
Sliver Feed Speed	0.36 m/min
Draft	178.2
Rotor Speed	60000 rpm
Opener Speed	8500 rpm
Yarn Twist	850 TPM

2.3 Yarn tests

The physical properties of produced yarns including liner density, tensile strength, evenness, imperfection, hairiness, frictional and abrasion resistance were investigated.

The yarn count was measured using standard test methods [25-26]. Yarn strength and breaking elongation values were determined on an Instron tensile tester (yarn gauge length was 150 mm and cross-head speed was 200 mm/min). The yarn evenness measurement was obtained on Uster Evenness Tester 3.

To measure yarn hairiness, we used a Zweigle G565 hairiness tester. The S3 values (number of hairs with a length greater than or equal to 3 mm) were measured over a length of 100 m of yarn at 60m/min, and 5 tests were conducted for each yarn. Yarn frictional properties were measured using a Shirley yarn frictional tester. The test speed was 60 m/min and 5 tests were conducted for each yarn. The yarn abrasion resistance was investigated by using a Shirley yarn abrasion tester. A standard abradant (P2500) was usued and 5 tests were conducted for each yarn sample. All tests were conducted under the standard laboratory conditions (22 ± 2°c and 65 ± 2% r.h.). The average test result of yarn properties is shown in Table 4. The experimental results of yarn physical properties were statistically analyzed using ANOVA and Multiple Range Test methods.

Table 4 Physical properties of silk/cotton blended rotor-spun yarns for different silk fibre blend ratio
(The CV% values are indicated in brackets)

Silk fibre Blend Ratio (%)	0	35	50	65	100
Yarn Count (tex)	22.58 (1)	21.95 (1.59)	21.13 (3.92	21.15 (2.08)	19.57 (9.65)
Yarn Tenacity (cN/tex)	10.37 (10.7)	9.95 (12.42)	11.13 (11.23)	10.19 (12.36)	13.19 (9.86)
Elongation (%)	4.72 (9.14)	6.68 (10.71)	7.24 (10.65)	7.46 (7.23)	10.02 (7.54)
Evenness (CV_m%)	11.37 (2.11)	11.73 (1.28)	11.74 (2.89)	10.95 (2.56)	12.02 (6.58)
Neps (280%)	1 (81)	0.5 (116)	0.75 (66.6)	0.75 (126.6)	1 (82)
Thick Places(50%)	0.5 (116)	2 (91)	1 (82)	0.75 (128)	1 (82)
Hairiness (S3 Value/ m)	5.6 (9.28)	8.86 (15.68)	9.2 (8.69)	10.72 (10.35)	9 (2.66)
Yarn Coefficient of Friction (μ)	0.06 (0)	0.07 (0)	0.064 (8.55)	0.07 (0)	0.054 (16.56)
Yarn Abrasion Resistance	12.4 (13.47)	19.6 (36.88)	51 (4.39)	52.2 (10.34)	69.2 (13.45)

3. Prediction of Tensile Properties of Silk Waste/Cotton Blended Rotor Spun Yarns

Tensile properties of silk waste /cotton blended rotor spun yarns were predicted using Hamburger theory [27-28]. In this study, the cotton component is less extensible than silk component. Figure 1 shows a typical tensile strength curve of silk and cotton rotor spun yarns.

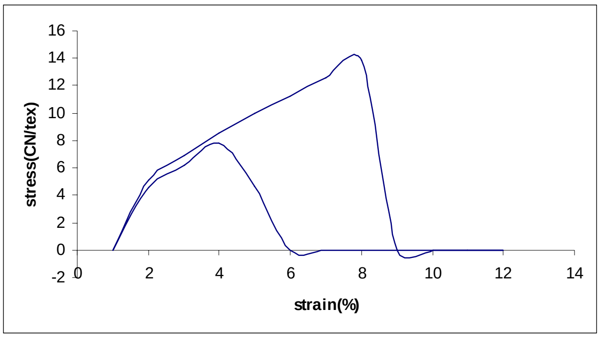

Fig. 1 A typical tensile strength curve of silk and cotton rotor spun yarns

To derive the tensile strength equation of blended silk/cotton rotor spun yarns, the following assumptions and calculations were considered:
a = cotton fiber proportion (%)
b = Silk fiber proportion (%)
S_c = Cotton yarn tenacity (cN/tex)
S_s = Silk yarn tenacity (cN/tex)
S_{cs} = Silk component tenacity at the time of cotton component breakage (cN/tex).
P_1 = Blended yarn tenacity at the time of cotton component breakage (cN/tex).
P_2 = Blended yarn tenacity at the time of silk component breakage (cN/tex).

$$p_1 = aS_c + bS_{cs} \qquad (1)$$

$$p_2 = bS_s \qquad (2)$$

$$a + b = 1 \qquad (3)$$

4. Results and Discussion

Physical properties of silk/cotton blended rotor-spun yarns for different silk fiber blend ratio are stated in Table 4. The effects of silk fibre blend ratio on physical properties of silk/cotton blended rotor-spun yarns are also plotted in Figures 2 to 8.

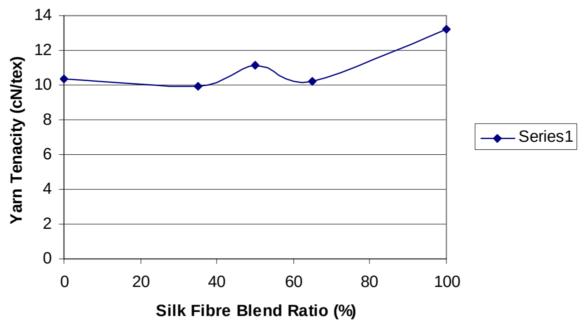

Fig. 2 Effect of silk fibre blend ratio on yarn tenacity of silk/cotton blended rotor-spun yarns.

It is shown that tensile strength of silk waste/cotton blended rotor spun yarn at 50% silk fiber blend ratio is significantly higher than those of 100% cotton as well as two other blended yarns (Figure 2). Thus, silk waste rotor spun yarn has the highest tensile strength compared with other yarn samples. The increase in tenacity of silk rotor-spun yarn is presumably due to higher tensile strength as well as effective length of silk fiber compared with cotton fiber. The predicted result of silk/cotton rotor-spun blended yarn is compared in Figure 3. It is shown that at 50% and 65% silk fiber blend ratio, the predicted results are less than experimental values. It is also indicted that by using Hamburger theory the blended silk/cotton yarn tensile strength behavior is predictable.

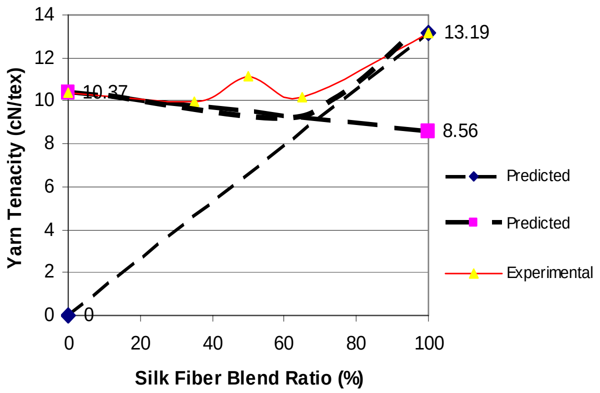

Fig. 3 Yarn tenacity of silk/cotton blended rotor-spun yarns (Predicted and Experimental Results).

The results of experiment showed that by increasing the silk fiber blend ratio, the yarn elongation (Figure 4) and abrasion resistance (Figure 5) significantly increased. This result is attributed to the higher tensile strength and elongation of silk fiber compared with cotton fiber.

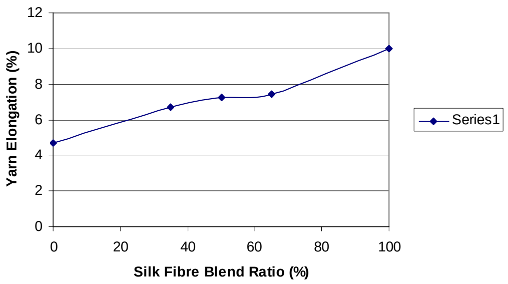

Fig. 4 Effect of silk fibre blend ratio on yarn elongation of silk/cotton blended rotor-spun yarns.

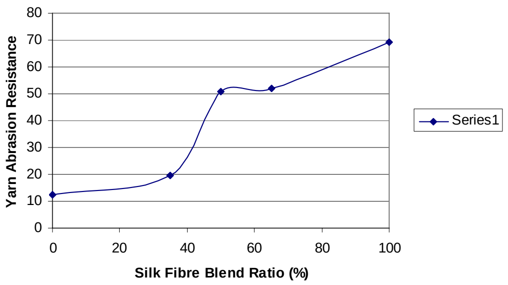

Fig. 5 Effect of silk fibre blend ratio on yarn abrasion resistance of silk/cotton blended rotor-spun yarns.

However, silk fiber blend ratio has no significant influence on yarn imperfection (Table 4), frictional (Table 4) and evenness properties (Figure 6). The results indicates that by the increase of silk the silk blend ratio, slight reduction of yarn linear density (Figure 7) and yarn hairiness (Figure 8) deterioration occurred. It is deduced that the higher short fiber content as well as higher effective length of silk fibre compared with cotton fiber results to a slightly significant increase in yarn hairiness. It should be also notified that silk fiber used in this research is finer than cotton fibre. This results to an increase in the number of fiber ends in yarn surface and thus increases of yarn hairiness. It is also implicated that opener roller of rotor spinning machine has some effects on silk fiber length which in turn results to a decrease of yarn linear density.

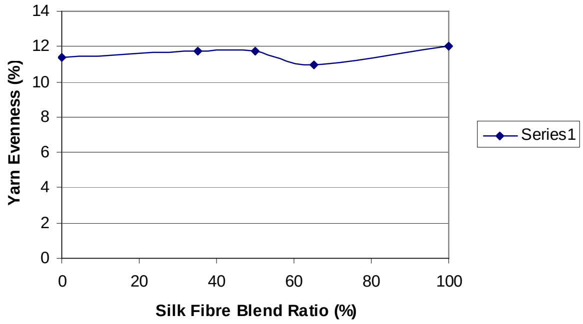

Fig. 6: Effect of silk fibre blend ratio on yarn evenness of silk/cotton blended rotor-spun yarns.

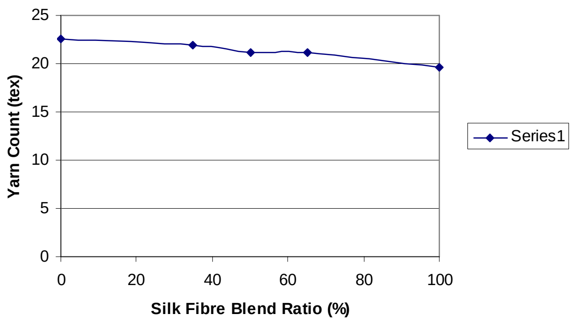

Fig. 7: Effect of silk fibre blend ratio on yarn count of silk/cotton blended rotor-spun yarns.

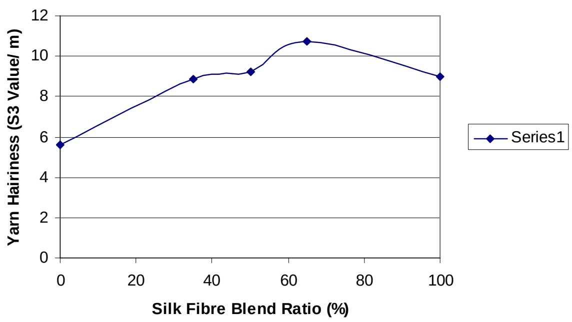

Fig. 8: Effect of silk fibre blend ratio on yarn hairiness of silk/cotton blended rotor-spun yarns.

5. Conclusion

In this work, processing of cutting and de-gumming of silk waste samples were carried and silk waste sliver was prepared. Silk waste and cotton slivers were blended at three different blend ratio (65/35, 50/50 and 35/65) and silk waste/cotton blended as well as cotton and silk rotor spun yarns were produced. The physical and mechanical properties of the produced yarns including liner density, tensile strength, evenness, imperfection, hairiness, frictional and abrasion resistance were studied.

The results indicate that by increasing the silk fiber blend ratio, the yarn elongation and abrasion resistance significantly increased. However, silk fiber blend ratio has no significant influence on yarn imperfection, frictional and evenness properties. It also shown that tensile strength of silk waste/cotton blended rotor spun yarn at 50% silk fiber blend ratio is significantly higher than those of 100% cotton as well as two other blended yarns. Thus, silk waste rotor spun yarn has the highest tensile strength compared with other yarn samples. The result of this research suggests that the tensile strength of silk waste/cotton blended rotor-spun yarns is predictable using Hamburger theory. The hairiness and yarn linear density of silk waste/cotton blended rotor spun yarns deteriorated slightly with increase of silk fiber content. Further studies are needed to investigate the structural properties of silk/cotton rotor-spun yarns and the physical and mechanical properties of fabrics made from these yarns.

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