Research Article

DEVELOPMENT OF BULKY SILK YARN IN WEB SILK REELING PROCESS

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ABSTRACT

CSTRI, CSB, Bengaluru has developed a concept of web silk reeling machine for imparting bulkiness during the raw silk the production using differential traverse mechanism. The process variables viz., differential rotary traverse mechanism speed, reel speed and number of cocoons significantly influences the both reeling and quality characteristics of bulky raw silk and imparts desired bulkiness in the raw silk viz., diameter (bulkiness), productivity average size, size deviation and tenacity of bulky raw silk. The analysis of results also indicate that 3:1 combination between rotary traverse speed and reel speed produces good quality web structured bulky raw silk. The yarn produced using this machine was three times bulkier than the yarn produced from same number of cocoons in regular silk reeling machine. The silk fabrics produced using bulky raw silk in weft has shown better properties in terms of tensile and tear strength, crimp percentgae, abrasion resistance and drape co-efficient, which in turn result in better comfort properties.

INTRODUCTION

Silk is naturally spun by silkworm in the form of cocoons. These cocoons are combined in the process of reeling to obtain raw silk in the continuous filament form (Sonwalkar, 1993). The characteristics of raw silk like softness, luster, durability, elegance, smooth texture and mechanical strength have made it the acceptable to human for many centuries (Tribhuvan Singh *et al*., 2011). The comfort properties of silk fabrics are slightly lower than that of cotton yarn / fabrics. Always there is demand for making silk more bulky so that raw silk can have better comfort properties. Efforts made to impart bulkiness in raw silk have resulted in production of heavier denier (Dupion) raw silk having strand like structure (Subhas Naik *et al*., 2003). Other possible methods of imparting bulkiness to the silk filament yarn viz., mechanical texturizing, air texturizing and chemical texturizing methods are being tried by various researchers (Ramachandran, 2001). In view of real demand for bulky raw silk, CSTRI has taken up fabrication of bulky raw silk producing machine with differential rotary traverse mechanism.

CSTRI bulky raw silk reeling machine

The concept of the development of bulky raw silk reeling machine was derived from a part of the brushing mechanism of Automatic silk reeling machine. Generally mulberry raw silk was produced by combining 8 ~ 10 cocoon filaments in reeling machine on vertical axis. In the CSTRI bulky raw silk reeling machine, the cocoon filaments are collected on the horizontal axis using the differential traverse mechanism developed by CSTRI. The mechanism has two types of motion, one on its axis and another perpendicular to the axis. When the rotary traverse mechanism rotates it takes the cocoon filaments around itself and simultaneously moves then forward, thus arranging the cocoon filaments in zigzag manner. The resultant yarn produced from the bulky raw silk reeling machine have web like structure and are more bulkier than the raw silk produced from the same number of cocoons in existing reeling machines. The concepts of the vertical and horizontal silk reeling techniques are shown in Fig. 1.

When the cocoon filaments reach the end of the rotary traverse mechanism, they are accumulated and pulled gently by the reel and wrapped in them via thread guide and croissure pulley. During the passage from the rotary traverse mechanism to reel the web silk gets dried to some extent and steam pipes provided behind the reels dry them further. The accumulated silk filaments can have anywhere between 50 ~ 100 cocoons during reeling and can be altered depending upon bulkiness required. Based on the bulkiness of the silk being produced the speed of rotary traverse mechanism as well as the reel should be altered so the bulky raw silk can be produced uniformly. Any quality of the cocoons can be reeled on this bulky raw silk reeling machine to produce required quality of bulky raw silk. The bulky raw silk can be further twisted before using them for

fabric production. The proto type model bulky raw silk reeling machine is shown in Fig. 2.

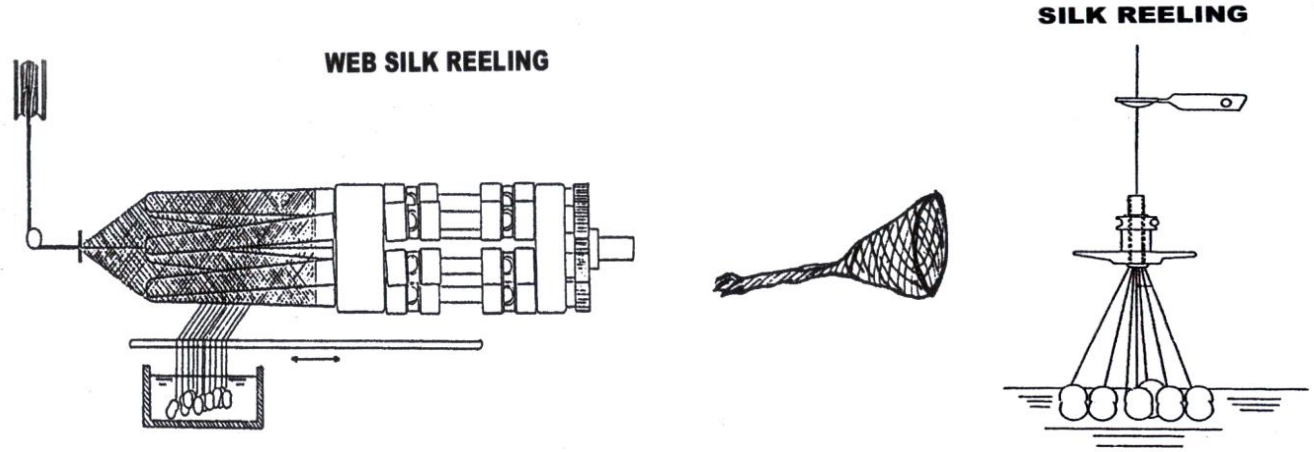

Fig. 1. The concept of bulky raw silk (Web Silk) reeling machine with differential rotary traverse mechanism compared to regular silk reeling technology

Fig. 2. The proto type model bulky raw silk reeling machine developed by CSTRI

MATERIALS AND METHODS

An experiment was designed using Box and Benken method to standardize the rotary traverse mechanism speed, reel speed and number of cocoons to be maintained while reeling. Reeling studies were conducted using inferior quality multibivoltine lots and web structured bulky raw silk was produced as per the design of the experiment. Using the standard reeling techniques developed by CSTRI (Somashekar and Kawakami, 2003; Lakshmipathaiah *et al.*, 2000), the multi-bivoltine cocoons were hot air dried in Batch type hot air drier, cooked in Two pan cooking equipment following the temperature profile of 50°- 90°- 65°- 95°- 95° to 80°C for 7 minutes and reeled on bulky raw silk reeling machine. Different combinations of rotary traverse mechanism speed, reel speed and number of cocoons to be reeled for the production of bulky raw silk have been selected using the factorial design as shown in Table 1.

Table 1. Experimental methodology used in the study

Std Order	Run Order	Rotary mechanism Speed (rpm)	Reel speed (rpm)	No of cocoons reeled per end
18	1	85	30	80
5	2	76	24	92
6	3	94	24	92
7	4	76	36	92
19	5	85	30	80
13	6	85	30	60
2	7	94	24	68
20	8	85	30	80
10	9	100	30	80
11	10	85	20	80
4	11	94	36	68
9	12	70	30	80
3	13	76	36	68
1	14	76	24	68
12	15	85	40	80
17	16	85	30	80
15	17	85	30	80
8	18	94	36	92
14	19	85	30	100
16	20	85	30	80

Table 2. Average reeling performance results of Bulky raw silk produced

Run Order	Diameter Yarn (mm)	Production Per end per day (g)	Renditta	Waste % on Silk weight
1	0.337	146.7	10.2	25.3
2	0.380	132.9	10.5	24.4
3	0.317	133.2	10.2	17.4
4	0.357	156.0	9.6	20.1
5	0.300	149.3	10.0	20.3
6	0.287	114.8	9.4	19.6
7	0.333	96.8	9.7	20.8
8	0.373	156.0	9.6	18.6
9	0.337	152.0	9.8	21.7
10	0.327	91.9	10.1	20.5
11	0.350	145.2	9.9	21.2
12	0.413	133.9	10.0	20.3
13	0.317	112.9	9.1	18.1
14	0.317	94.4	9.9	24.9
15	0.350	162.7	9.8	19.0
16	0.317	157.3	9.5	20.1
17	0.343	154.7	9.7	19.7
18	0.307	167.6	10.2	22.5
19	0.303	176.8	9.6	19.0
20	0.353	144.0	10.4	25.6

Table 3. Average quality characteristics of Bulky raw silk produced

Run Order	Average size (Denier)	Size deviation	Maximum Size deviation	Tenacity (g/d)	Elongation (%)
1	198	21.6	33.7	2.9	15.9
2	237	32.7	57.3	2.8	21.7
3	236	22.8	35.8	2.7	17.6
4	178	18.9	28.0	3.9	14.7
5	179	22.9	33.3	3.9	17.6
6	162	16.7	28.4	3.1	15.4
7	166	19.3	31.1	3.8	21.5
8	173	22.9	39.5	3.7	23.8
9	176	20.4	30.3	3.4	17.9
10	161	16.9	24.1	4.0	14.4
11	150	24.6	36.8	3.7	20.4
12	212	24.6	38.6	4.5	17.5
13	140	14.5	25.9	4.0	18.9
14	146	22.7	37.0	4.1	20.1
15	206	37.4	56.2	3.4	17.8
16	199	24.7	41.1	3.6	20.1
17	190	27.9	41.5	3.6	18.1
18	251	37.4	45.6	3.6	17.9
19	237	28.8	41.7	2.8	19.8
20	200	30.4	40.5	3.3	19.0

Fig. 3. Photograph showing the comparison between web structured bulky raw silk and heavy denier silk reeled from same number of cocoons

The reeling characteristics of bulky raw silk viz., productivity, renditta, waste % on silk weight and diameter of bulky raw silk and the quality characteristics viz., average size, standard deviation, maximum size deviation, tenacity and elongation were observed for different combinations of bulky raw silk produced. The data were analyzed statistically using response surface experimental design. To relate the variables with the response a multiple regression was fitted representing a quadratic polynomial function.

$$Y = b_0 + \sum^{3} i = 1\, b_i x_i + \sum^{3} i = 1\, b_{ii} x_i^{2} + \sum^{3} i = 1\, b_{ij} x_i x_j + \sum$$

$$i < j ; j < k$$

Where,

y is the response of the dependent variable,

X_i, X_j are the process variables and

b_o, b_i, b_{ii}, b_{ij} are the coefficient of the regression equations.

Table 4. Regression equations and coefficients of reeling and quality characteristics of bulky raw silk

Characteristics	Regression equations	Regression coefficient (R^2)	P Value	ANOVA P value
Diameter	– 0.3963 – 0.0164*RTS – 0.001*RS + 0.0365 Cocoons + 0.0002*RTS^2 + 0.000*RS^2 - 0.0001* Cocoons^2 + 0.001*RTS*RS – 0.0002* RTS*cocoons + 0.000*RS*Cocoons	75.3	0.003**	0.006**
Production / end / day (g)	– 935.7 + 9.8*RTS + 3.4*RS + 8.4 Cocoons + 0.1*RTS^2 – 0.3*RS^2 – 0.0001*Cocoons^2 + 0.1*RTS*RS – 0.0001*RTS*cocoons – 0.0001* RS*Cocoons	95.7	0.022*	0.001**
Renditta	14.7269 – 0.1516*RTS – 0.4328*RS + 0.1932* Cocoons + 0.0003*RTS^2 + 0.0012*RS^2 – 0.0008*Cocoons^2 + 0.0045*RTS*RS – 0.0004* RTS*cocoons – 0.0005*RS*Cocoons	60.7	0.733	0.129
Waste % on silk weight	99.13 – 0.973*RTS – 3.783*RS + 0.589* Cocoons + 0.001*RTS^2 – 0.011*RS^2 – 0.004*Cocoons^2 + 0.039*RTS*RS – 0.004* RTS*cocoons + 0.013*RS*Cocoons	49.2	0.082	0.117
Average size	654.056 – 9.271*RTS – 4.186*RS – 3.213* Cocoons + 0.007*RTS^2 – 0.090*RS^2 + 0.017*Cocoons^2 + 0.151*RTS*RS + 0.049* RTS*cocoons – 0.039*RS*Cocoons	71.6	0.766	0.062
Size deviation	165.455 – 1.151*RTS – 9.782*RS + 0.846* Cocoons – 0.011*RTS^2 + 0.021*RS^2 – 0.006*Cocoons^2 + 0.099*RTS*RS + 0.002* RTS*cocoons + 0.007*RS*Cocoons	67.5	0.040*	0.105
Maximum size deviation	80.81 – 0.67*RTS – 10.24*RS + 3.11* Cocoons – 0.01*RTS^2 + 0.02*RS^2 – 0.01*Cocoons^2 + 0.13*RTS*RS – 0.01* RTS*cocoons – 0.02*RS*Cocoons	53.6	0.166	0.356
Tenacity	23.2605 – 0.3867*RTS – 0.3955*RS + 0.0547* Cocoons + 0.0021*RTS^2 + 0.0022*RS^2 – 0.0013*Cocoons^2 – 0.0005*RTS*RS + 0.0002* RTS*cocoons + 0.0039*RS*Cocoons	67.3	0.158	0.123
Elongation	– 9.424 – 0.038*RTS + 0.143*RS + 0.700* Cocoons – 0.001*RTS^2 – 0.017*RS^2 – 0.001*Cocoons^2 + 0.017*RTS*RS – 0.004* RTS*cocoons – 0.008*RS*Cocoons	16.4	0.610	0.755

RTS – Rotary traverse speed, RS – Reel speed, Cocoons – No of cocoons reeled

RESULTS AND DISCUSSION

The reeling results and quality of web structured bulky raw silk results are given in Tables 2 and 3. The regression equations and coefficients for both reeling and quality characteristics are given in Table. 4.

Table 5. Characteristics of fabrics produced from bulky raw silk and heavy denier silk as weft.

Characteristics	Bulky raw Silk	Heavy denier Silk
Fabric mass (g/m^2)	76.4	78.6
Fabric Thickness (mm)	0.18	0.18
Ends / inch	120	104
Picks / inch	100	94
Yarn count (denier) Warp	33.4	32.5
Yarn count (denier) Weft	135.1	177.7
Cover Factor Warp	9.5	8.1
Cover Factor Weft	15.9	17.1
Cover Factor Fabric	20.0	20.3
Crimp (%) Warp	10.20	8
Crimp (%) Weft	0.50	1.2
Twist (TPM/Direction/Ply) Warp	889/S/2	921/S/2
Twist (TPM/Direction/Ply) Weft	269/S/1	240/S/1
Tensile strength Warp (lbf)	61.1	50.7
Tensile strength Weft (lbf)	124.7	169.9
Elongation Warp (%)	26.0	26.1
Elongation Weft (%)	17.6	17.1
Tearing strength Warp (g)	1043.2	1190
Tearing strength Weft (g)	3366.4	Tears in warp direction
Crease recovery angle Warp	72	73.4
Crease recovery angle Weft	89	96.8
Crease recovery angle Total	161	170.2
Flexural rigidity Warp (mg x cm)	52	35.6
Flexural rigidity Weft (mg x cm)	453	430
Flexural rigidity Overall (mg x cm)	154	124
Abrasion resistance (Cycles)	2317	1740
Bursting strength (Kg/cm^2)	13.5	14.2
Specific handle force	656.6	1890.4
Drape co-efficient (%)	63.1	53
Air permeability (m^3/ m^2/min)	6.4	6.3

Influence of reeling characteristics on the production of bulky raw silk

The correlation analysis was performed to reveal correlation pattern between reeling characteristics on the production of bulky raw silk. Among the characteristics the diameter of the bulky raw silk, production, renditta and waste % on silk weight are significantly influenced by the process variables viz., differential rotary traverse mechanism speed, reel speed and number of cocoons used for the production of bulky raw silk (Table 2). From the results it could be observed that increase in the rotary traverse speed and reel speed decreases the diameter of bulky raw silk. Further increase in both traverse mechanism speed and reel speed increases the production of bulky raw silk (Tsuboi *et al.,* 1989).

The relationship between diameter of bulky raw silk and productivity are significantly influenced by the process variables as could be seen from high regression coefficients (R^2) (Table 4). The decrease in renditta is linked to the improvement in productivity (Sericulture manual-silk reeling industry, http://bieap.gov.in). The higher values of renditta are due to utilization of inferior quality cocoons in the process of bulky raw silk production (Debisis Chatopadhya *et al.,* 2017). Similarly the renditta is positively correlated with silk waste generation. It is obvious that waste decreases while renditta decreases (Mahadevaiah *et al.,* 2015). The results also indicate that 3:1 combination between rotary traverse speed and reel speed produces good quality web structured bulky raw silk.

Influence of quality characteristics on the production of bulky raw silk

It could be observed from the Table 3 that the quality characteristics viz., average size, size deviation, maximum size deviation tenacity and elongation of the bulky raw silk are significantly influenced by the process variables viz., differential rotary traverse mechanism speed, reel speed and number of cocoons used for the production of bulky raw silk (Table 3). From the results, it could be observed that increase in the rotary traverse speed and reel speed increases the average size (denier) and size deviation of bulky raw silk (Subhas Naik, 2012). The relationship between quality characteristics viz., average size, size deviation and tenacity are significantly influenced by the process variables as could be seen from high regression coefficients (R^2) (Table 4) (Tsuboi *et al.,* 1989). Thus the results indicate that for the production of web structured bulky raw silk, all the three parameters viz., speed of the rotary traverse mechanism, reel speed and number of cocoons reeled play a vital role. The comparison between the bulky raw silk and raw silk reeled with same number of cocoons is shown in Fig. 3.

Production of bulky raw silk fabric

For comparing the fabric quality parameters, fabrics were developed on power loom using bivoltine raw silk as warp and web structured bulky raw silk and hevy denier raw silk as weft produced using same number of cocoons. The fabris were analyszd for their characteristics and the results of the bulky raw silk fabrics were compared with heavy denier silk fabric. From the results given in Table 5, it could be observed that bulky raw silk fabric has shown better properties in terms of tensile and tear strength, crimp percentgae, abrasion resistance and drape co-efficient while most of the other fabric properties are similar to heavy

denier silk fabric. It could also be observed that bulky raw silk has certain unique characteristics and the same can be exploited in the development of new varieties of fabrics for both export and domestic markets.

CONCLUSION

It is inferred from the above study that web structured bulky raw silk could be produced using the differential rotary traverse mechanism incorporated in the CSTRI developed proto type reeling machine. The process variables viz., differential rotary traverse mechanism speed, reel speed and number of cocoons significantly influences the both reeling and quality characteristics of bulky raw silk and imparts desired bulkiness in the raw silk. The fabric produced using bulky raw silk also shown unique characteristics. Thus bulky raw silk can be used for producing sarees, dress materials and knitted fabrics with better bulkiness, which in turn will have better comfort properties. CSTRI has taken up development of prototype model into commercial model bulky raw silk reeling machine.

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