High Efficiency Covering Technology for Covered Yarns Production: Controlling the Spandex Yarn Draw Ratio

Pei Feng[1,2], Dashuang Liu[1], Chongchang Yang[1,2]

1. College of Mechanical Engineering, Donghua University, Shanghai, 201620, China
2. Engineering Research Center of Advanced Textile Machinery, Ministry of Education, Shanghai，201620, China

Corresponding author: Chongchang Yang; Email: ycc@dhu.edu.cn;

Abstract: A new covered yarn system is proposed in this manuscript by controlling the tension of the spandex elastic yarn drawing.. By analyzing the relationship between the draw ratio and yarn tension, it has been verified that the new tension controlled drawing system is feasible and results in yarns with superior quality and process stability.

Keywords: Tension Controlled; Elastic Fiber; Draw Ratio; Spandex Covered Yarns

Introduction

Spandex Covered Yarns consist of bare spandex as the core material wrapped with various yarns and fibers. In the covering process, the spandex is drawn at a constant ratio, fed through a hollow spindle and covered with a covering yarn from a flanged bobbin [1,2]. Its properties, particularly elongation, elasticity and appearance, depend on the draft parameters, revolution speed and the covering yarn selection [3]. The critical factors responsible for various properties of spandex covered yarns are the pre-draft of spandex and core spun yarn twist multiplier, which should be used in reasonable way to match the purpose of the fabrics [4].

Drawing roller is the most critical part of drawing system which controls the equipment performance and product quality in the textile machinery. The drawing system also has great influence on the quality of semi-finished products, evenness of the yarn and the appearance of finished products. Development of drawing device of modern textile machinery has reached a considerable degree of maturity. Standardization of drawing equipment as well as precision of drawing effects are the directions towards which all drawing devices are being developed [5-7]. High quality yarn can be obtained by matching the drawing process through optimization of the critical drawing equipment [8].

Usually, for drawing of general and elastic yarns, roller drawing based drawing system is used, whereas, the drawing system of traditional covered yarn machine uses the speed ratio of two rollers for the drawing of elastic yarn [9-13]. The spandex unwinds actively by leading out of the feeder roller and entering the pre-drawing roller and finally, it goes into the hollow spindle. Smooth unwinding of spandex is controlled by the speed ratio of feeding roller to pre-drawing roller. The spandex is drawn due to the speed ratio of pre-drawing roller and doffing roller. Spandex is covered by hollow spindle driven outer wrapping fiber during which it is drawn 8-14 times.

Earlier, a new covering technology for producing covered yarns was proposed [14-15]. Herein, a new method for controlling the drawing ratio of spandex yarn is proposed. In this method, the draw ratio can be controlled easily and the performance of the spandex yarn can also be protected during unwinding. The method will open new fields for the elastic yarn drawing ratio and will also provide the direction for traditional machine modification.

Methods

Experimental setup

In order to solve the problems associated with the existing elastic yarn drawing technology, a new drawing device with controlled tension has been proposed. This method controls the draw ratio of the elastic yarn by adjusting the tension of spandex. The mechanism is shown in Figure 1. The tension is controlled by using tension control device, and drawing roller of the traditional covered yarn machine develops the required power. The working steps can be described as follows:

i) Unwinding of spandex is passive;
ii) Tension control device manages its tension;
iii) Drawing roller provides the covering power to drive the spandex moving forward;
iv) After passing the tension control device, turning covering yarn (polyamide) covers core yarn (spandex).

For this process, tension control is the most important thing. Controlled tension which is more stable compared to before can lead to better product. In comparison to the traditional drawing technology, this method has the following advantages: decrease of power dissipation, reduction of the space of roller, and elimination of roller's noise. Nevertheless, the product quality must be maintained.

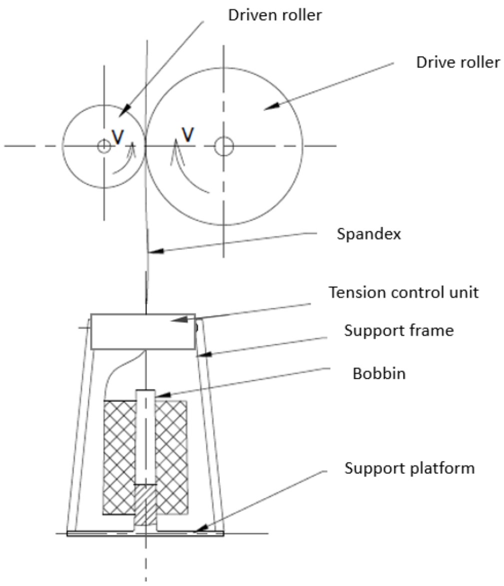

Figure 1. Schematic of the new elastic yarn drawing diagram

Feeding quantity determines the drawing deformation and the tension variation of spandex. The quality of covered yarn including structural stability, resilience and uniformity is influenced by tension. The draw ratio of the elastic yarn can be controlled by adjusting the feeding speed of spandex and the winding velocity of covered yarn [10].

Factors affecting the spandex drawing tension

It has been found that drawing tension is driven largely by spandex's specification, drawing ratio and drawing linear velocity. In order to find out the critical element among these three, an orthogonal experiment was carried out.

As shown in Table 1, there are 4 types of spandex used in this study: 15 dtex spandex, 20 dtex spandex, 30 dtex spandex and 40 dtex spandex. To maintain the quality of yarn, the drawing ratio is generally controlled from 2 to 4 [16-19]. So, four values of the drawing ratio were selected: 2.65, 2.85, 3.08 and 3.24. Meanwhile, if the drawing is too fast, the machine cannot work as well and hence the effect of tension will be poor. Therefore, 4 levels of drawing linear velocity are employed: 19 m/min, 21 m/min, 23 m/min and 25 m/min.

Table.1 The determination of factor levels

Levels	Factor		
	A	B	C
	Spandex Specification	Draw Ratio	Draw Linear Velocity (m/min)
1	15 dtex	2.22	10
2	20 dtex	2.9	20
3	30 dtex	3.62	30
4	40 dtex	4.18	40

As shown in Table.2, in one experiment three different values of factors can be set in an experiment corresponding to single row. Together, there are 16 experiments, with the results are shown in the last column.

Table.2 The factors and levels graph

Text Number	Factors			Results
	Spandex Specification	Draw Ratio	Draw Linear Velocity (m/min)	Tension (cN)
1	A1	B1	C1	1.33
2	A1	B2	C2	2.66
3	A1	B3	C3	5.18
4	A1	B4	C4	7.94
5	A2	B1	C2	1.67
6	A2	B2	C3	3.28
7	A2	B3	C4	6.67
8	A2	B4	C1	9.27
9	A3	B1	C3	3.77
10	A3	B2	C4	6.66
11	A3	B3	C1	10.92
12	A3	B4	C2	16.71
13	A4	B1	C4	3.89
14	A4	B2	C1	7.69
15	A4	B3	C2	16.43
16	A4	B4	C3	29.36

According to the test results from Table.2, the average values and ranges between the evaluation index can be obtained based on the tension values (Table 3) with k1, k2, k3 and k4 are the average values of corresponding levels. Ranges are the differences between maximum and minimum of each level; the values denote the extent of variation in the factors' evaluation indexes. The larger the range, the stronger the effect of evaluation index will be. Also, this factor is more important. Conversely, the factor is less important [20].

Table.3 The evaluation index average value and range based on tension

Evaluation index average value and range	Tension value (cN)		
	Spandex Specification	Draw Ratio	Draw Linear Velocity (m/min)
k1	4.28	2.67	7.3
k2	5.22	5.07	9.37
k3	9.52	9.8	10.4
k4	14.34	15.82	6.29
R	10.07	13.16	4.11

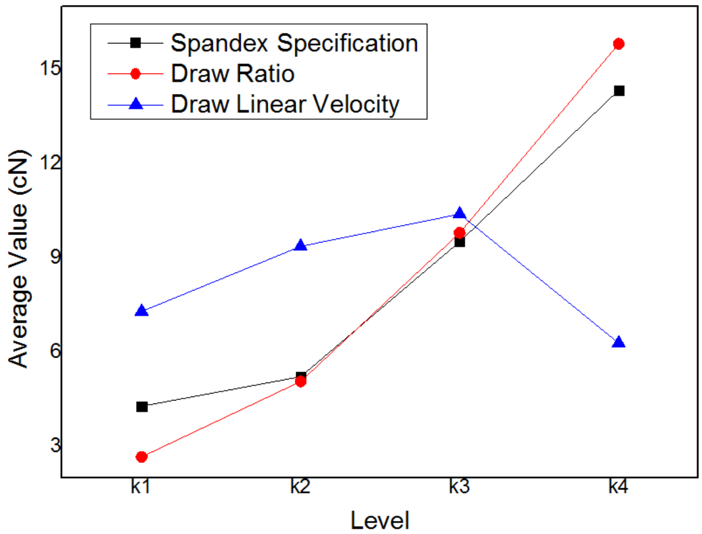

Figure 2. Relation between the factors and tension

In addition, Figure 2. the relationship between the factors and tension effects is shown. Draw ratio is found to be the most important factor for tension. Spandex's specification is the second one followed by drawing linear velocity. Thus, from the given Fig. it can be inferred that the draw ratio should be considered as priority for covered yarns' production.

Results and Discussions

Change of Spandex Tension with Draw ratio

Table.4 Relationship between draw ratio and tension

Drawing Ratio	Tension of 30 dtex (cN)	Tension of 40 dtex (cN)
2.22	3.17	3.74
2.32	3.44	3.97

2.41	4.39	4.38
2.52	4.48	4.95
2.63	5.38	5.55
2.76	5.97	6.28
2.90	6.50	7.42
3.05	7.60	8.47
3.22	8.34	10.23
3.40	9.68	11.99
3.62	11.02	15.31
3.87	13.39	20.00
4.15	16.49	25.72
4.45	21.13	34.67
4.80	27.63	—

Relationship between draw ratio and tension is presented in Table.4. The tension values of spandex 30 dtex and 40 dtex were measured and recorded by the dynamic monitoring densitometer under drawing linear velocity of 22 m/min.

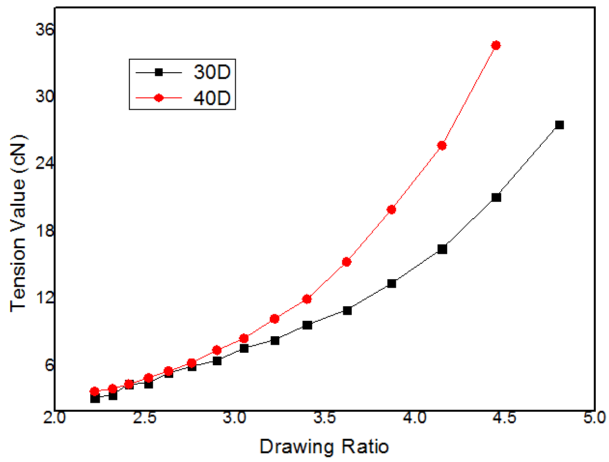

Figure 3. The tension value of spandex with various draw ratios

Figure 3 shows that tension increases with increase in drawing ratio and within the range for drawing ratio of 2.0 ~3.5, the increase of tension is linear. After exceeding a certain value, tension increases rapidly for both the different Spandex types. The possible reason may be that the spandex is strained in the process.

The stability of different tension control device

For this drawing technology based on tension control for elastic yarn, the major task is to choose the appropriate tension control device as the control of tension must be accurate and robust. Hence, 3 different kinds of tension control devices were introduced to test their stability under identical conditions. Then, the tension in the device was measured and compared with the traditional one. The test conditions were determined according to Figure 3. The spandex specification used in the experiment was 30 dtex with drawing ratio of 3.05. The drawing linear velocity is 22 m/min and the tension values of the control devices were set to 7.6 cN.

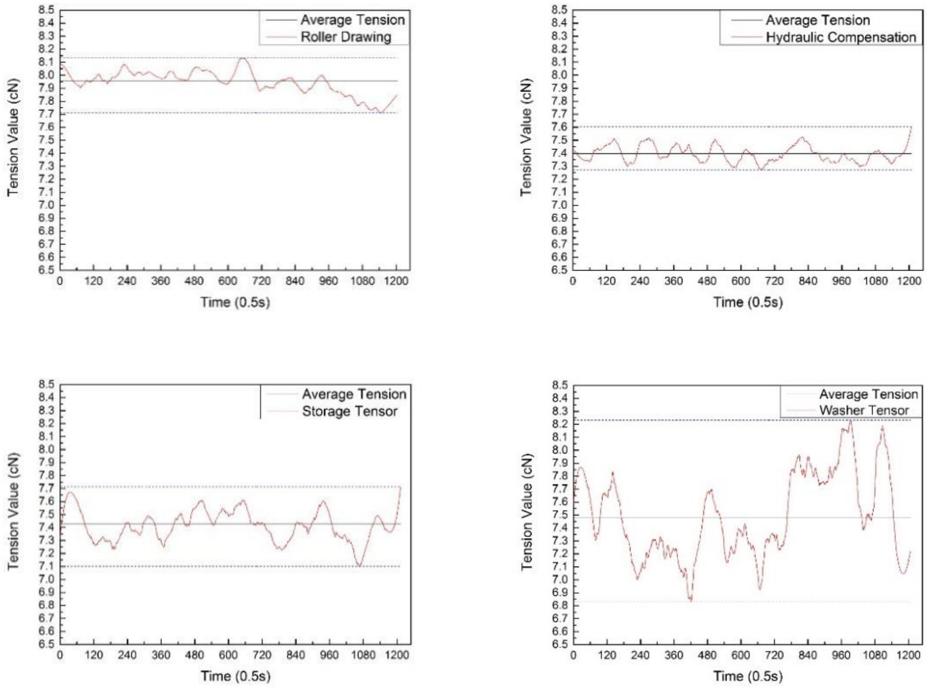

Figure 4. The stability of four kinds of tension control devices

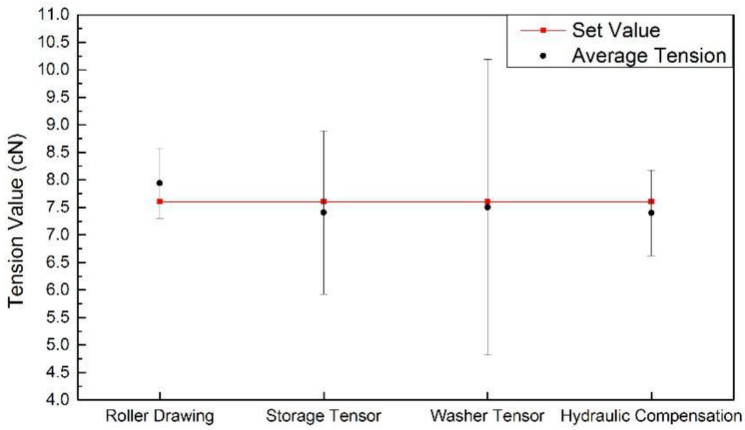

Figure 5. The control accuracy of the four kinds of tension control devices

According to Figure 4 and Figure 5, the range of fluctuations in tension by roller drawing device was about 0.45 cN with the average being 7.95 cN. Roller drawing device controls the drafting ratio by adjusting the feeding speed of spandex and the winding velocity of the covered yarn. So, it necessarily doesn't always have the same tension value in every experiment. For storage tension control devices, the range of the tension value was 0.61 cN with the mean value being 7.44 cN. It shows that this kind of control device has high accuracy. But it also can't achieve continuous adjustment because of its discontinuous control way. For washer tension control devices, the range of the tension value was 1.42 cN with the mean value being 7.49 cN. It can be seen that the tension value has bigger swings. As a result, the washer tension control device doesn't fit for the new elastic yarn drafting technology. For the last one of hydraulic tension-controlled device, the range of the tension value was 0.30 cN, and the mean value was 7.40 cN. The tension value has the smallest variation, and accordingly the stability was the highest.

Feasibility validation of elastic yarn drawing technology based on the tension control

In the process of Spandex covered yarn production, quality of the covering yarn is related to factors such as linear density, spandex drawing ratio and twist. In the coating production process, the merits of covered yarn tensile properties, linear density, draw ratio and covering to twist are closely connected [21-24].

In the traditional spandex drawing technology, draw ratio is directly controlled by varying the speed ratio of feeding roller and drawing roller, whereas, in the tension controlled spandex drawing technology draw ratio is indirectly controlled by controlling the tension between spandex. In order to verify the feasibility of the spandex drawing technology based on the tension control, both the drawing technologies can be used to produce covered yarn of the same specifications under identical conditions. By measuring the twist of these two covered yarns, if they both are found to have the same or very similar twist with same drawing ratio of spandex in the two drawing technologies, then tension controlled spandex drawing system is feasible. The experiment conditions were set below:

i) The spindle speed was 12000 rpm;
ii) The drawing speed was 20 m/min;
iii) The outer wrapping fiber is nylon, whose size was 50 dtex;
iv) The core fiber was spandex with size of 30 dtex.
v) The speed ratio of two rollers was set to 2.8 in the traditional spandex drawing system.

By the relationship between spandex draw ratio and its tension mentioned above, the spandex's tension was set to 5.0 cN in the spandex drawing technology based on tension control. Two standard packages of covered yarns were produced. Then 10 sections from each package were chosen for measuring the twist. The results are shown in Table.5.

Table.5 Twist measurement of covered yarn produced by two kinds of spandex drawing technology

Test Data	Different Kinds of Covered Yarn / Different Section	1[a]	2[b]	3[c]	4[d]
Twist(TMP)	1	590	590	600	655
	2	605	570	620	645
	3	660	575	610	650
	4	580	575	625	650
	5	665	590	650	660
	6	610	575	605	665
	7	600	585	625	660
	8	605	590	610	650
	9	610	585	610	640
	10	635	580	620	650
	Average	616	581.5	617.5	652.5

1 [a] is the covered yarn produced by traditional spandex drawing system.

2 [b] is the covered yarn produced by the drawing technology based on tension control with 4.5 cN tension.

3[c] is the covered yarn produced by the drawing technology based on tension control with 5 cN tension.

4[d] is the covered yarn produced by the drawing technology based on tension control with 5.5 cN tension.

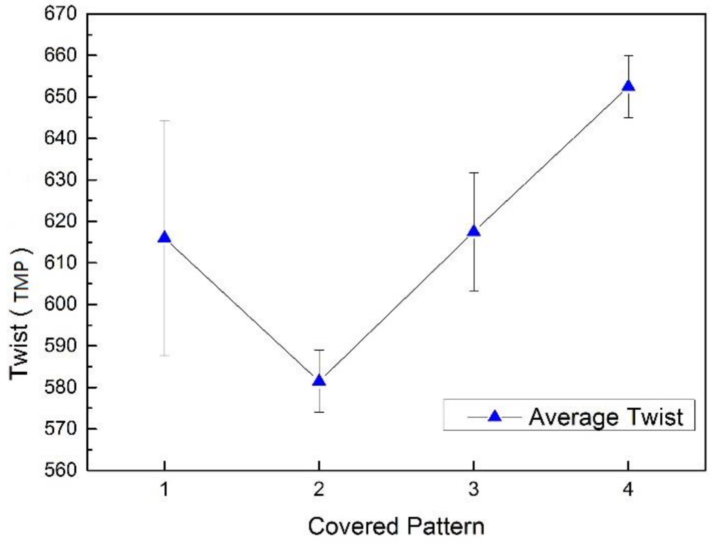

Figure 6. The average twist of four kinds of covered yarn

As shown in Figure 6, the average twist of the covered yarn produced by traditional spandex drawing system are close to that of the drawing technology based on tension control with tension 5 cN. The twist range of fluctuation of covered yarn produced by traditional spandex drawing technology is the biggest, which proves that this new drawing technology is more stable compared to traditional drawing technology.

Conclusion

In this article, a new kind of elastic yarn drawing technology based on tension control is introduced. One-to-one correlation has been established between spandex's drawing ratio and tension by experiments. It has been found that the tension is increasing in the drawing ratio range of 1.5~5.0. Besides, for the same drawing ratio, greater tension will be generated for thicker spandex. What's more, the spandex drawing technology with hydraulic tension control device shows higher stability compared to the traditional drawing system. The covered yarn produced by the new drawing technology has similar twist to that of the traditional drawing technology when the tension is 3 cN. In the end, the uniformity of the same cone yarn twist is better.

This new yarn drawing technology enriches the ways of elastic yarn's drawing. The tension-control based technology can be used for improvement in existing machines, product quality and even for other textile machines.

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