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

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Abstract
This paper proposes a new covered yarn system in which the tension of spandex elastic yarn drawing is controlled. By analysing the relationship between the draw ratio and yarn tension, it was verified that the new tension controlled drawing system is feasible and results in yarns of superior quality and process stability.

Key words: *tension controlled, elastic fibre, draw ratio, spandex covered yarns.*

Introduction

Spandex covered yarns consist of bare spandex as the core material wrapped in various yarns and fibres. 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 covering yarn selection [3]. The critical factors responsible for the various properties of spandex covered yarns are the pre-draft of spandex and the core spun yarn twist multiplier, which should be used in a reasonable way to match the purpose of the fabrics [4].

The drawing roller is the most critical part of the drawing system, controlling the equipment performance and product quality in the textile machinery. The drawing system also has a great influence on the quality of semi-finished products, the evenness of yarn, and on the appearance of finished products. The development of drawing devices of modern textile machinery has reached a considerable degree of maturity. Standardisation 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 optimisation of critical drawing equipment [8].

Usually, for the drawing of general and elastic yarns, a roller drawing based drawing system is used, whereas the drawing system of a traditional covered yarn machine uses the speed ratio of two rollers for the drawing of elastic yarn [9-13]. The spandex unwinds actively by being led out of the feeder roller, then it enters the pre-drawing roller, and finally goes into the hollow spindle. The smooth unwinding of spandex is controlled by the speed ratio of the feeding roller to the pre-drawing roller. The spandex is drawn due to the speed ratio of the pre-drawing roller and the doffing roller. The spandex is covered by the hollow spindle driven outer wrapping fibre, 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.

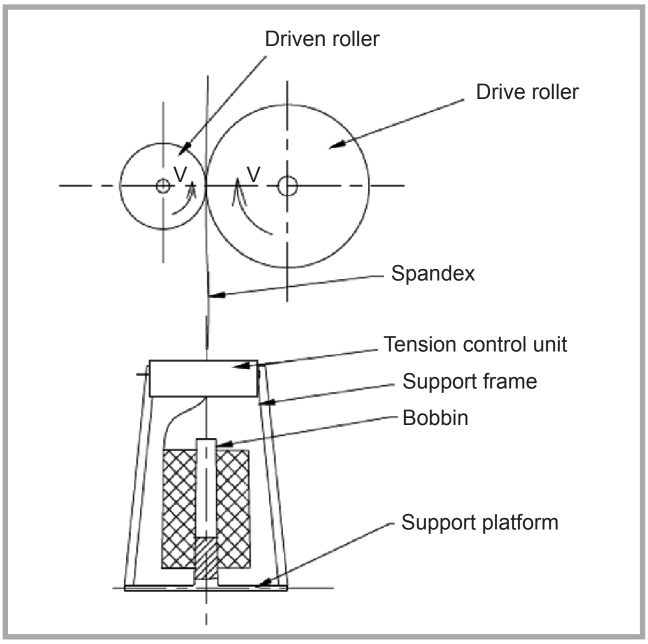

Figure 1. Schematic of the new elastic yarn drawing process.

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Methods

Experimental setup

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

- Unwinding of spandex is passive;
- Tension control device manages its tension;
- Drawing roller provides the covering power to drive the spandex moving forward;
- After passing the tension control device, the turning covering yarn (polyamide) covers the 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 a better product. In comparison to traditional drawing technology, this method has the following advantages: decrease of power dissipation, reduction of the space of the roller, and elimination of the roller's noise. Nevertheless, the product quality must be maintained.

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

Factors affecting spandex drawing tension

It has been found that the drawing tension is driven largely by the 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 were 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]. Thus, 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 so well, and hence the effect of tension will be poor. Therefore, 4 levels of drawing linear velocity were employed: 19 m/min, 21 m/min, 23 m/min and 25 m/min.

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

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 (***Ta-***

Table 1. *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

Table 2. *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

Table 3. *Average value of the evaluation index and range based on tension.*

Average value of evaluation index 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

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	—

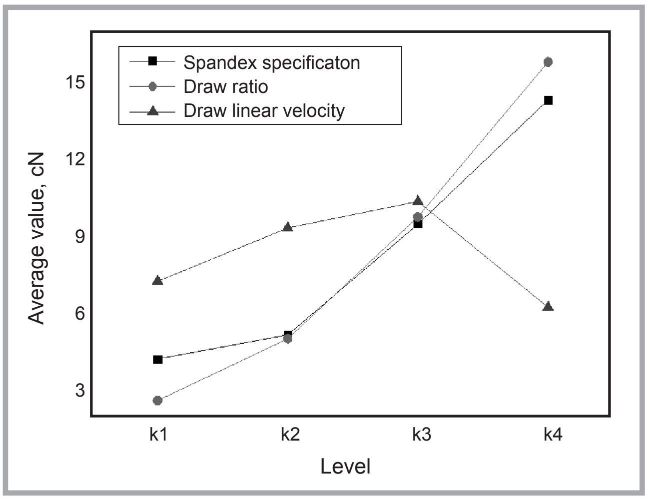

Figure 2. Relation between the factors and tension.

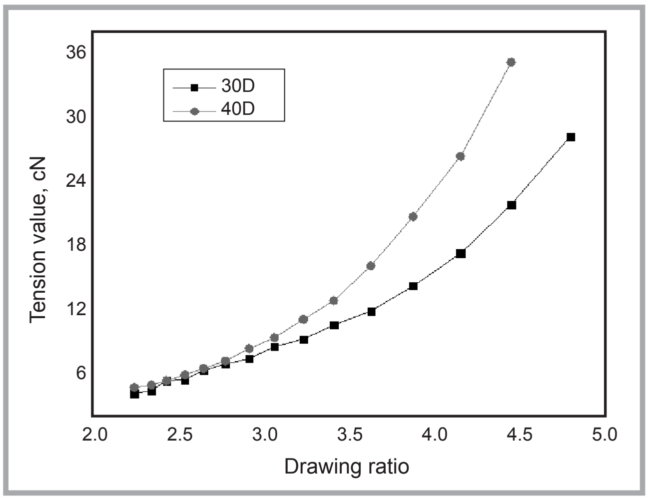

Figure 3. Tension value of spandex with various draw ratios.

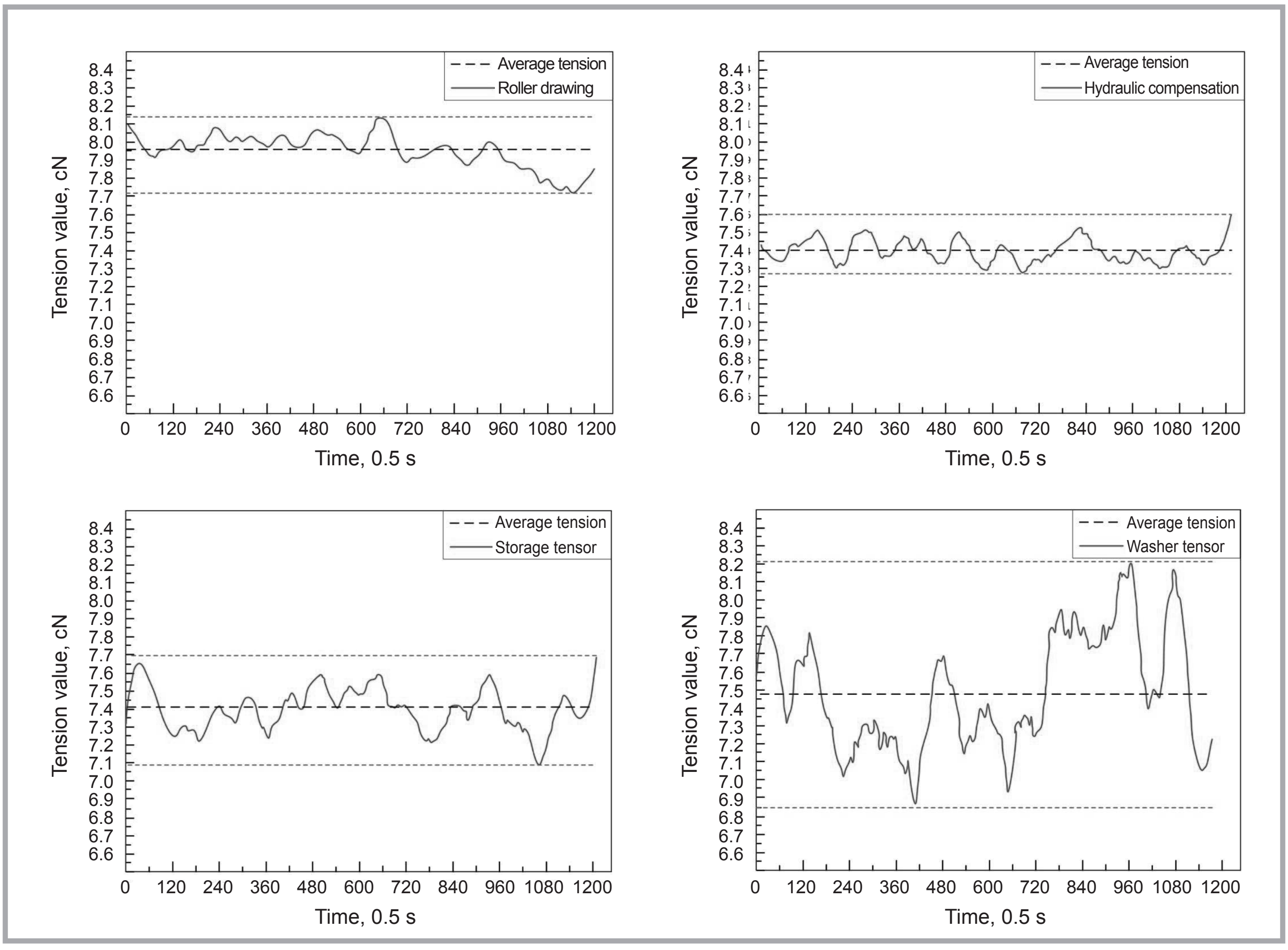

Figure 4. Stability of four kinds of tension control devices.

ble 3), with k1, k2, k3 and k4 being the average values of corresponding levels. Ranges are the differences between the maximum and minimum of each level; the values denote the extent of the variation in the factors' evaluation indexes. The larger the range, the stronger the effect of the evaluation index will be. Also, this factor is more important [20].

In addition, ***Figure 2*** shows the relationship between the factors and tension effects. The draw ratio is found to be the most important factor for tension, the spandex's specification second, followed by the drawing linear velocity. Thus, from ***Figure 2*** it can be inferred that the draw ratio should be considered as a priority for covered yarn production.

Results and discussions

Change in spandex tension with draw ratio

The relationship between the draw ratio and tension is presented in ***Table 4***. Tension values of spandex of 30 dtex and 40 dtex were measured and recorded by a dynamic monitoring densi-

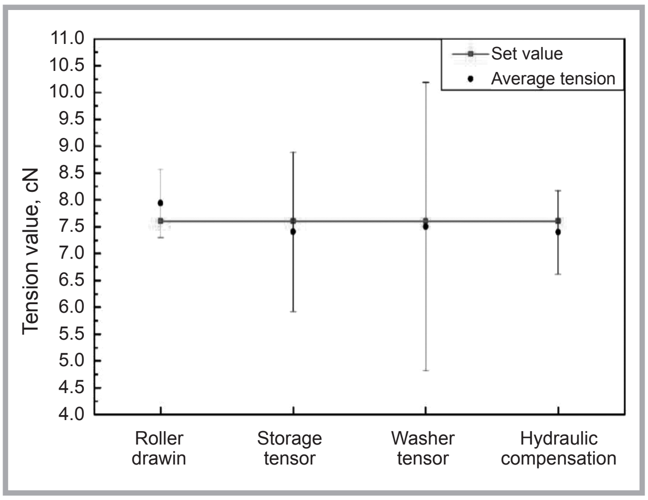

Figure 5. Control accuracy of the four kinds of tension control devices.

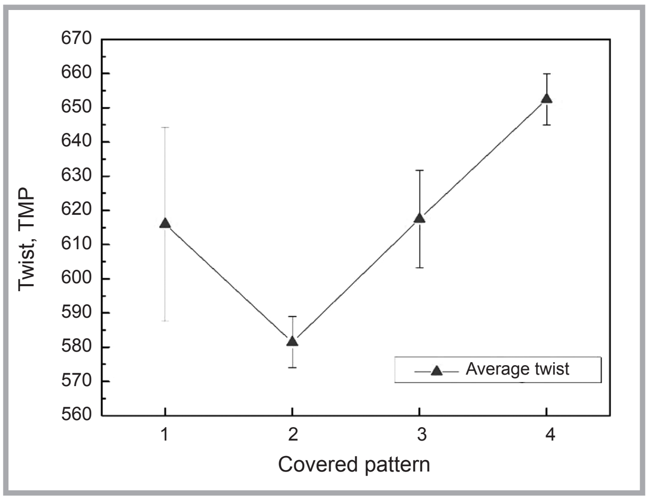

Figure 6. Average twist of the four kinds of covered yarn.

tometer at a drawing linear velocity of 22 m/min.

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

Stability of different tension control devices

For this drawing technology, based on tension control for elastic yarn, the major task is to choose an appropriate tension control device as the control of tension must be accurate and robust. Hence, 3 different kinds of tension control device 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 a drawing ratio of 3.05. The drawing linear velocity was 22 m/min, and the tension values of the control devices were set to 7.6 cN.

According to *Figures 4* and *5*, the range of fluctuations in tension by the roller drawing device was about 0.45 cN, with the average being 7.95 cN. The roller drawing device controls the drafting ratio by adjusting the feeding speed of spandex and the winding velocity of the covered yarn. Thus, it does not necessarily 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. However, it cannot 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 is not suitable for the new elastic yarn drafting technology. For the hydraulic tension-controlled device, the range of the tension value was 0.30 cN, with the mean value being 7.40 cN. The tension value has the smallest variation, and accordingly the stability is the highest.

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

Test data	Different kinds of covered / Different yarn sections	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 covered yarn produced by the traditional spandex drawing system.
2[b] is covered yarn produced by drawing technology based on tension control with 4.5 cN tension.
3[c] is covered yarn produced by drawing technology based on tension control with 5 cN tension.
4[d] is covered yarn produced by drawing technology based on tension control with 5.5 cN tension.

Feasibility validation of elastic yarn drawing technology based on tension control

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

In traditional spandex drawing technology, the draw ratio is directly controlled by varying the speed ratio of the feeding roller and drawing roller, whereas in tension controlled spandex drawing technology, the draw ratio is indirectly controlled by controlling the tension between the spandex. In order to verify the feasibility of spandex drawing technology based on tension control, both 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 are both found to have the same or very similar twist with same drawing ratio of spandex in the two drawing technologies, then the tension controlled spandex drawing system is feasible. The experiment conditions were set as below:

- Spindle speed – 12000 rpm;
- Drawing speed – 20 m/min;
- Outer wrapping fibre – nylon 50 dtex;
- Core fibre – spandex 30 dtex;
- Speed ratio of two rollers – 2.8 in the traditional spandex drawing system.

Using the relationship between the 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 to measure the twist. The results are shown in ***Table 5***.

As shown in ***Figure 6***, the average twist of the covered yarn produced by the traditional spandex drawing system is close to that of the drawing technology based on tension control with 5 cN tension. The twist range of the 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 the traditional one.

Conclusions

In this article, a new kind of elastic yarn drawing technology based on tension control is introduced. A one-to-one correlation was established between spandex's drawing ratio and tension through experiments. It was found that the tension increases in the drawing ratio range of 1.5~5.0. Besides this, for the same drawing ratio, greater tension will be generated for thicker spandex. What is more, the spandex drawing technology with a 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 one 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 drawing. The tension-control based technology can be used for improvement of existing machines and product quality, and even for other textile machines.

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