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High Efficiency Covering Technology for Covered Yarns Production: Equipment and Experiment

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Abstract

A new covering technology for producing covered yarns is proposed in this article. On a traditional yarn covering machine, a hollow spindle rotates with a bobbin of the outer wrapping yarn. In the new equipment, the turntable rotates with only one single outer wrapping yarn. With a magnetic device, the bobbin of core yarns is suspended in a balloon formed by outer wrapping yarns. The rotation speed of the turntable can reach 40000 rpm. A series of experiments on the new equipment were conducted and some covered yarn samples were obtained. The performance of these samples were tested and compared with that produced by traditional machines.

Key words: *high efficiency, covering technology, covered yarn, rotation speed, low cost.*

Introduction

Increasing demands for energy-saving and highly efficient, high speed and low cost devices have stimulated the development of textile-structured [1]. Covered yarn is a yarn with a kind of filament or short fiber as the core and another kind of filament as the wrapping, also known as wrapped yarn [2-4]. It is a perfect yarn of upscale wool fabric, and hence it is often used for high-elastic knitwear as well as for woven fabric [5-9]. Covered yarn can be divided into air jet covered yarn and mechanical covered yarn. For the latter, the uniform drafted core yarn is wound with outer wrapping fiber in a spiral way, and then the core yarn will be spun with some twist. The fabric should be flat and tidy.

Mechanical covered yarn can be produced by a hollow spindle spinning machine and modified ring spinning machine [10-13]. Hollow spindle wrapped yarn has many advantages. Compared with ring spinning, it has higher speed, a shorter process and better economic benefits. For open-end spinning, its twist is easier to control. For such reasons, mechanical covered technology has been developed rapidly. Currently the yarn covering machines used are mainly from Switzerland – SSM, Germany – Suessen, and Italy – Menegatto [14-17].

The rotation speed of the hollow spindle in production is usually 18000 rpm. According to the relationship between the twist, draw linear velocity and the rotation speed of the hollow spindle, in order to produce covered yarns which have the same twist, production efficiency increases with a higher speed of the spindle [18-21].

Wrapped spinning (also called covering spinning) was initiated by Phil Rolla of the DuPont Company in the 1950s. In the 1970s, a Bulgarian produced wrapped yarn by means of a hollow spindle for the first time, which has been widely used in spinning cotton, wool and flax in Russia. Then the Elisha company of the US developed a wrapped spinning machine that can produce short and long fibers. A more advanced machine was developed in the 1980s. Suessen developed the Parafil-1000 type and Parafil-2000 Parallel spinning machines. There was also the wrapped spinning machine produced by the Whitin Roberts Company of the United States and the ON-1000 wrapping spinning machine produced by the Ozeki company of Japan [22-24]. Researchers have made many important achievements in the study of hollow spindle wrap spinning [25-26].

A schematic diagram of a traditional mechanical yarn covering machine [27] is shown in ***Figure 1*** and its processing technology is shown in ***Figure 2***. Core yarn through the hollow spindle is achieved by drawing between the feed roller and draw roller. The whole outer wrapping yarn and bobbin are rotation driven by a hollow spindle, which can reach the free end of the outer wrapping yarn to cover the core yarn.

With the rapid development of the textile industry, the demand for covered yarn has increased. The bobbin of outer wrapping yarn needs to rotate with a high speed driven by the hollow spindle to cover the core yarn. Greater quality from the outer wrapping yarn bobbin is achieved when there is more energy consumption of the high rotation speed. Thus

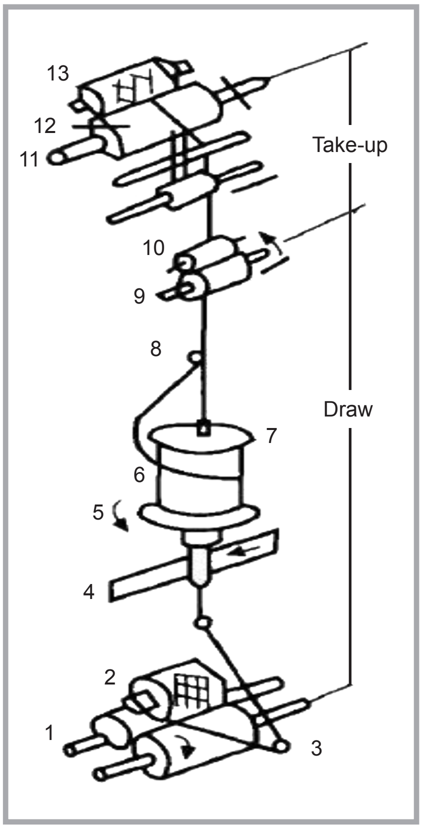

***Figure 1.** Schematic diagram of traditional mechanical yarn covering machine: 1) feed roller, 2) core yarn, 3) pre-draw roller, 4) tangential belt, 5) hollow spindle, 6) outer wrapping yarn, 7) bobbin of outer wrapping yarn, 8) thread eye, 9) drawing roll, 10) press roller, 11) guiding roller, 12) winding roller, 13) covered yarn.*

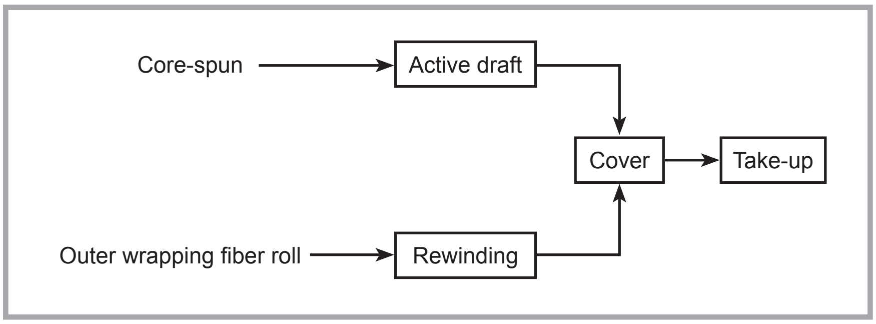

Figure 2. Production process of traditional covered yarn.

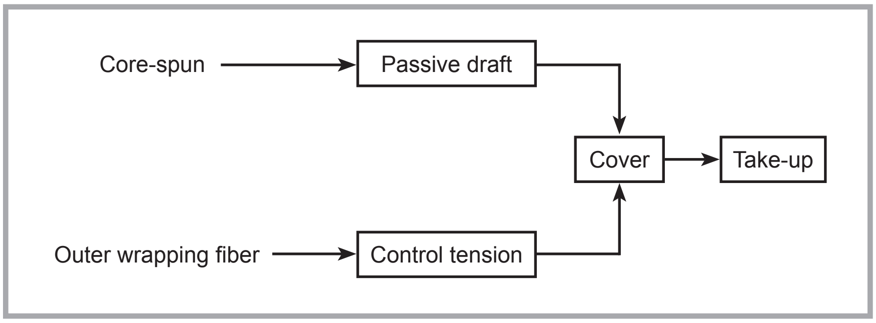

Figure 3. Production process of high-efficiency covered yarn.

the weight of the outer wrapping gets less and hence the unbalanced mass and its position constantly change. This will cause bigger unbalanced torque and dramatically increased power consumption. The imbalance will cause vibration and noise, accelerate the wearing of bearings and other parts, and, which is worse, the components could fracture. Thus the rotation speed of the hollow spindle is usually less than 25000 rpm. In this article, a more efficient production technology is presented and the design of a device based on the traditional hollow spindle is introduced.

Methods and experiments

A. Analysis of the technology

This article presents a new covering technology. The outer wrapping yarn rotates with high speed by means of a turntable. A balloon is formed by adjusting applicable tension which can contain the core yarn bobbin. The core yarn draw ratio is adjusted by changing the tension. The technology overcomes the deficiencies of a traditional mechanical yarn covering machine and is beneficial in increasing the spindle speed. However, it will create a problem where the core yarn cannot have reasonable settlement nor uniform transfer as in the traditional way. The problem can be solved by putting the core yarn in the balloon formed by the outer wrapping yarn. The production process is shown in ***Figure 3***.

B. Device design

A new covering device was designed and modified based on the traditional mechanical yarn covering machine.

1. A disk-shaped rotary part was used instead of the traditional elongated hollow spindle.
2. Considering the core yarn needs suspended support, the whole structure was changed from the vertical to horizontal type to increase the support space of the core yarn.

The whole device is shown in ***Figure 4***. A single motor is used to directly drive the turntable. A single yarn is driven by the turntable to form a balloon at high speed. The tension in the outer wrapping yarn can be controlled to adjust the balloon shape. And the core yarn is drawn by controlling the speed difference between the drawing linear velocity and conveying linear velocity. The core yarn bobbin is suspended in the balloon by a support frame through the principle of magnetic suspension in the vertical direction. The support limits the movement of the core yarn support frame in the horizontal direction. The largest balloon room for the core yarn can be obtained by studying factors that affect the balloon shape. In the equipment, the drawing of core yarn is controlled by a passive approach. Constant tension drawing of the core yarn is completed by a tension controller instead of controlling the core yarn draw ratio with different speeds of the drawing rollers.

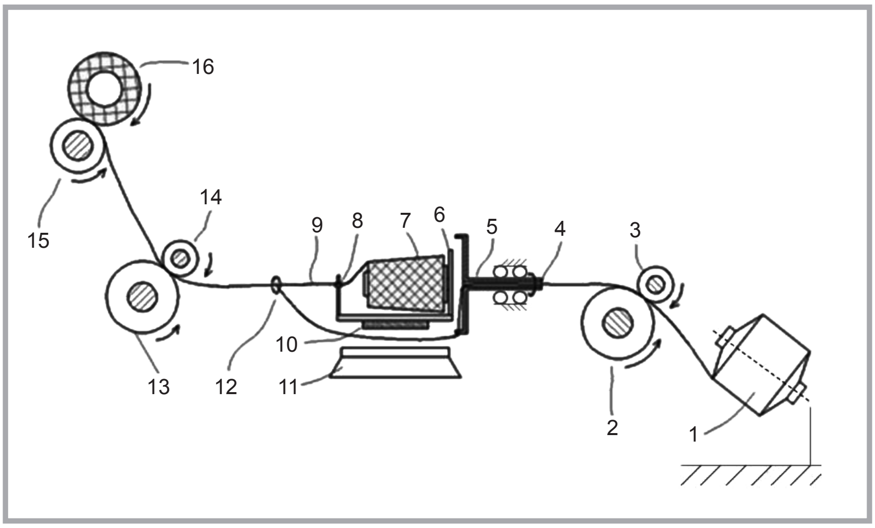

Figure 4. Schematic of new covering device: 1) outer wrapping yarn bobbin, 2) feed roller, 3) press roll, 4) outer wrapping yarn, 5) turntable, 6) core yarn support frame, 7) core yarn bobbin, 8) core yarn tension, 9) core yarn, 10) permanent magnet, 11) electromagnet, 12) thread eye, 13) drawing roller, 14) press roll, 15) winding roller, 16) covered yarn bobbin.

The working principle of the covering device is as follows: the outer wrapping yarn reaches the covering point from the bobbin to the inner hole of the turntable and then through a hole in the turntable edge. The bobbin of core yarn is suspended in the place between the turntable and covering point, and the core yarn reaches the coating point after tension.

A single outer wrapping yarn is driven by the turntable to form a balloon at high speed, and covers the core yarn. Finally the covered yarn is wound onto a bobbin after the drawing roller. The significantly different features of the scheme compared to traditional covering technology are as follows: the balloon of outer wrapping is large enough to get round the core yarn bobbin to covering. The shape formed when covering is similar to the balloon shape formed by the spindle of traditional covering.

C. Experiments

Control of outer wrapping yarn

Different specifications of polyamide fibers were used for covering the core yarn at different speeds. When the polyamide's balloon shape became stable, its tension was measured using a dynamic tensile tester.

According to ***Table 1***, when the covering rotation speed was higher, the tension to form a stable balloon shape of polyamide was bigger. With a large specification of polyamide, the tension is easier to reach the breaking strength when the rotation speed increases. The tension of yarn can be decreased by studying the yarn balloon and balloon controller [28, 29]. A test of tension control was completed with a balloon control ring. An attempt was made to decrease the tension of outer wrapping in the situation where the balloon shape formed by outer wrapping yarn was big enough. The experimental details were as below.

When the covering rotation speed was 30000 rpm, the diameter of the turntable was 7 mm, the balloon height 290 mm, and when the polyamide yarn was 5 dtex without a balloon control ring, the average tension value of outer wrapping yarn was 5 cN.

A two balloon control ring was added with a line diameter of 3 mm, the inner diameter of one ring 80 mm, and the other was 90 mm. The installation locations were 170 mm and 125 mm from the hole of the turntable edge. Then the tension of outer wrapping yarn was measured, and the average value was reduced to 60 cN.

During the test, the average tension value of the outer wrapping polyamide was decreased to 20 cN, demonstrating with the experiments that the yarn tension can be reduced by controlling the balloon.

Table 1. *Tension to form a stable balloon from polyamides of different specifications at various rotation speeds.*

Rotation Speed, rpm	Tension of 20 dtex, cN	Tension of 30 dtex, cN	Tension of 50 dtex, cN
15000	–	15-20	16-23
20000	–	23-33	32-35
25000	24-25	41-50	49-55
30000	30-33	60-70	81-95
35000	35-36	–	–

Table 2. *Covering rotation speeds of different specifications of polyamides.*

Rotation speed, rpm	25000 and under	25000~30000	30000~35000	35000~40000
Polyamide specifications	All	≤50 dtex	≤30 dtex	≤15 dtex

Table 3. *Energy consumption of single motor.*

Rotation speed of turntable, rpm	16000	19000	22000	25000	28000	31000
Energy consumption of motor idling, W	65	75	90	105	115	120
Energy consumption of 60 mm turntable, W	75	85	95	110	120	130
Growth rate of energy consumption, %	15.4%	13.3	5.6	4.8	4.3	8.3

Covering experiments at different rotation speeds

Due to the limit of outer wrapping yarn tension, the covering rotation speeds were different for the various specifications of polyamides. When the diameter of the turntable was 70 mm and the stable balloon height 290 mm, the rotation speeds reached by the turntable with polyamides of different specifications are shown in ***Table 2***.

The experiment verified the stable covering rotation speed of the new covering technology can reach 40000 rpm.

Joint of covered yarn

In the process of traditional covering, a full package of spandex directly used in covering is about 2 kg. Polyamide used as covering after the rewinding process is about 300 g. For example, they are 20 dtex spandex and 50 dtex polyamide, respectively, the spandex drawing ratio 3, the rotation speed of the spindle 15000 rpm, and the winding speed is 25 m/m in. Producing 340 g of covered yarn needs 300 g of polyamide. However, a full package of covered yarn is about 2 kg, which needs to be replaced after the polyamide bobbin is exhausted. A joint will be formed. 300 g polyamide can constantly produce covered yarn for about 30 hours.

In the new covering process, a full package of polyamide is used directly in covering of about 5 kg, and spandex which the polyamide covers after the rewinding process is about 200 g. With the same specification of covered yarn, the rotation speed of the turntable is 30000 rpm, and the winding speed is 50m/min. For example, 200 g spandex can produce covered yarn of about 1.7 kg. When the spandex bobbin is exhausted, a full covering yarn package without a joint is formed. 200 g of spandex can constantly produce covered yarn for about 90 hours. Its efficiency is two times higher than for a conventional machine, and the frequency of changing bobbins is one-third of the traditional process.

Energy consumption at different rotation speeds

In the new covering process, the single-motor only takes single yarn for covering. The load is determined by the weight of the turntable, and the amount of dynamic unbalance depends on the balancing precision of the turntable.

The energy consumption of the motor idling increases with the rotation speed. In this paper, the power consumption is evaluated by a power meter. The power meter measures the voltage and current of the motor and calculates the power by:

$$P = \vec{U} \times \vec{I} \times \sqrt{3}$$

The power consumption increases 10-15w with a rise in the rotation speed of 3000 rpm. The energy consumption has a smaller increase when the 60 mm diameter turntable is driven by the motor at

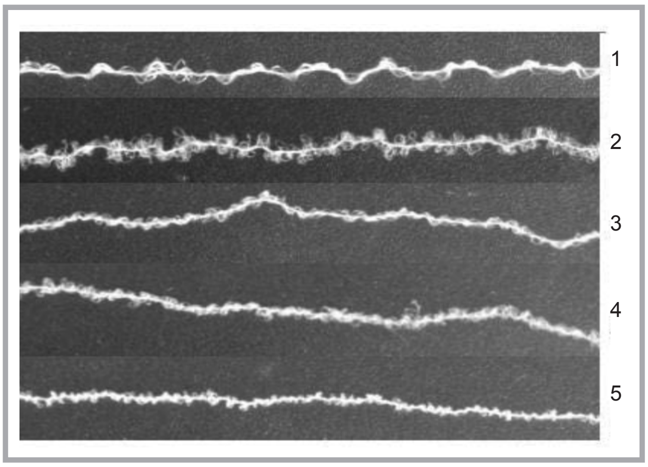

Figure 5. Different shapes of the same specification 20/30 covered yarn.

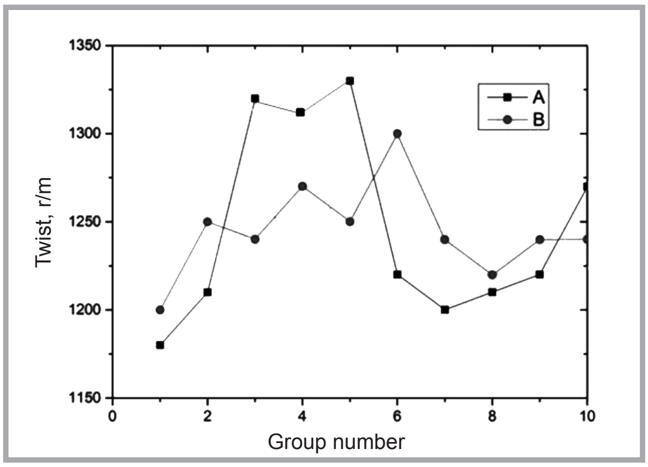

Figure 6. Twist change curves of two covering types.

a high rotation speed as compared to the motor idling. The average growth rate is about 10% if the rotation speed is greater than 16000 rpm. The results are shown in ***Table 3***.

Result and discussion

A. Shape of new covered yarn

The shapes of same specification 20/30 covered yarn at different speeds are shown in ***Figure 5***. The different covering speeds are shown in ***Table 4***.

The covering parameters will affect the quality of the covered yarn [30-32]. It can be obtained from ***Figure 5*** that the styles of covered yarn are different under different rotational speeds, due to the fact that the tension of the outer wrapping yarn will vary with different rotation speeds. In this case, the outer wrapping yarn wraps in a different state.

B. Comparison of new covered yarns and traditional ones

A covering test comparison between the traditional covering process and the new process is described herein. The outer wrapping yarn was 215 g polyamide of the 70 dtex type. The tester was the same type of 20/70 covered yarn. The specific process parameters are shown in ***Table 5***.

We measured the twist of two kinds of covered yarn. Ten segments were selected randomly from each kind. The tension of covered yarn was set at 1.5 cN during measurement. The results are shown in ***Table 6***. A represents covered yarn produced by traditional covering technology and B that obtained by the new one.

As shown in ***Figure 6***, the average twist of the two kinds of covered yarn is about 1250 rpm. In terms of the fluctuation of twist, B is smaller than A, illustrating that the twist of the new covering technology is more uniform than conventional ones.

In order to obtain details of the two kinds of covered yarn, we used a microscope to observe them. The results are shown in ***Figure 7***, in which the traditional covered yarn looks fluffy, whereas the new covered yarn has good evenness and large bending deformation. The reason may be that the tension of outer wrapping yarn on the new device is greater than that on a traditional machine.

Through comparison between the two kinds of covered yarn, we can know that the twist uniformity of the new covered yarn is better, because the new covering device uses synchronous belt drive so that the rotation speed fluctuation is smaller.

Conclusions

This paper presents an innovation for covering technology and novel mechanical yarn covering machine. A single outer wrapping yarn is driven by covering the turntable with a single motor. With this new technology, the problem of excessive load of the traditional hollow spindle in the covering process is solved. As a result, the device can work stably at 35000 rpm, even reaching 40000 rpm. The rotation speed is nearly twice that of a traditional machine and improves the production efficiency of a yarn covering machine. The performance of the finished product was examined through experiments, showing that the uniformity of yarn twist was greatly improved, which indicates the feasibility of the production process.

Table 4. *Different covering speeds.*

Number	1	2	3	4	5
Rotation speed, rpm	12000	20000	27000	32000	35000

Table 5. *Technical parameters of two covering types.*

Type	Covering speed, rpm	Outer wrapping yarn	Core yarn	Drawing speed, m/min	Drawing ratio
Traditional covering technology	15000	70 dtex Polyamide	20 dtex Spandex	27.5	3.08
New covering technology	15000	70 dtex Polyamide	20 dtex Spandex	27.5	3.08

Table 6. *Twist of two kinds of covered yarn.*

Group number	1	2	3	4	5	6	7	8	9	10
A	1180	1210	1320	1160	1330	1220	1200	1210	1220	1270
B	1200	1250	1240	1270	1250	1300	1240	1220	1240	1240

Outlook

The development of the process has brought about the renewing of outer wrapping yarn in the traditional production process of covered yarn, and laid the foundation for the development of a single false-twist texturing covering machine.

Because the outer wrapping yarn bobbin does not need to be rotated in the new process and combined with outer wrapping yarn processing technology, we can also propose the concept of an all-in-one false-twist texturing and covering machine, as shown in ***Figure 8***. The all-in-one false-twist texturing and covering machine will be a new device combining a false-twist texturing machine and yarn covering machine. Both of the processes will be developed to have higher efficiency and fewer steps in the process.

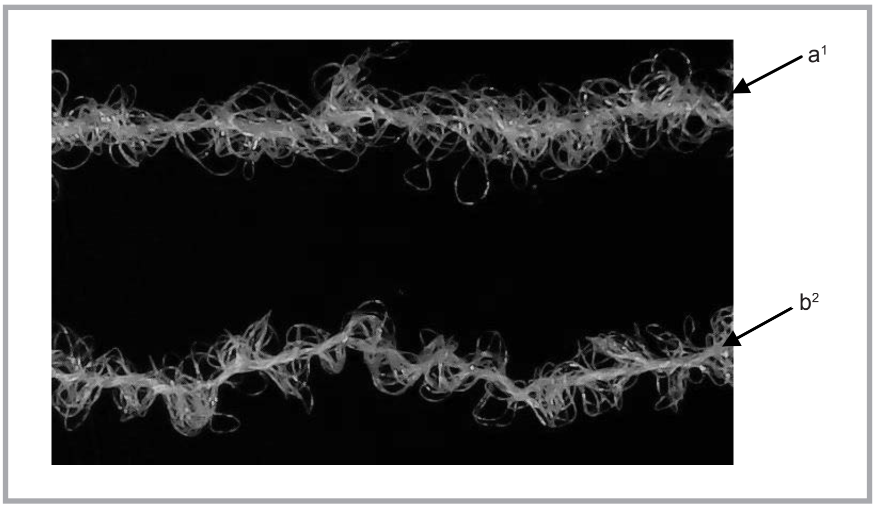

Figure 7. *Comparison of two kinds of covered yarn: a[1] represents 2070 (spandex/polyamide) covered yarn produced by a traditional mechanical yarn covering machine, b[2] represents 2070 (spandex/polyamide) covered yarn produced by the new covering device.*

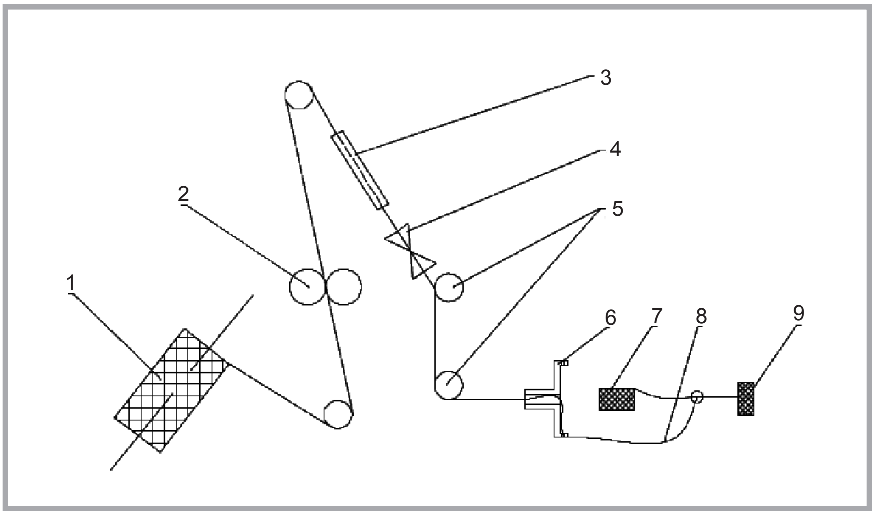

Figure 8. *False-twist texturing and covering all-in-one machine: 1) raw filament, 2) rollers, 3) heating box, 4) false twister, 5) drawing rollers, 6) turntable, 7) core yarn, 8) outer wrapping yarn, 9) covered yarn.*

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