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Hino et al.

[11] **3,772,873**
[45] **Nov. 20, 1973**

[54] **PROCESS FOR FALSE-TWISTING A YARN**

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Dec. 25, 1970 Japan....................45/117,552

[52] **U.S. Cl.** .... **57/157 TS,** 57/34 HS
[51] **Int. Cl.**.............................. **D02g 1/02**
[58] **Field of Search** .... 57/34 HS, 157 TS, 57/77.4, 77.42

[56] **References Cited**

UNITED STATES PATENTS

3,156,084	11/1964	Van Dijk et al.	57/77.4
3,488,941	1/1970	Asaka	57/157 TS
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Primary Examiner—John Petrakes
Attorney—Leonard W. Sherman et al.

[57] **ABSTRACT**

A process for false-twisting a yarn, which comprises passing a continuous filament yarn through the frictional engaging surface of two frictional rotors of the same diameter which face each other with the rotary shafts not being on the same axis and rotate in opposite directions to each other, wherein the yarn is fed to the frictional engaging surfaces at a speed of at least 500 meters per minute and imparted a tension defined by the following formula

$$0.85 > F_1 > 6.35 \times 10^{-4} V - 0.100$$

wherein F_1 is the tension of the yarn in grams per denier, and V is the speed of feeding the yarn in meters per minute,

in a twisting zone, and then the yarn is withdrawn from the frictional engaging surfaces.

8 Claims, 8 Drawing Figures

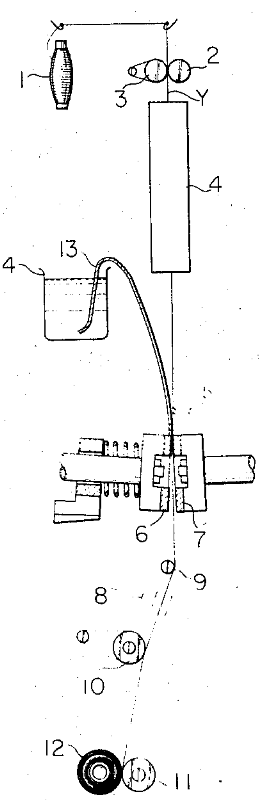

Fig. 1

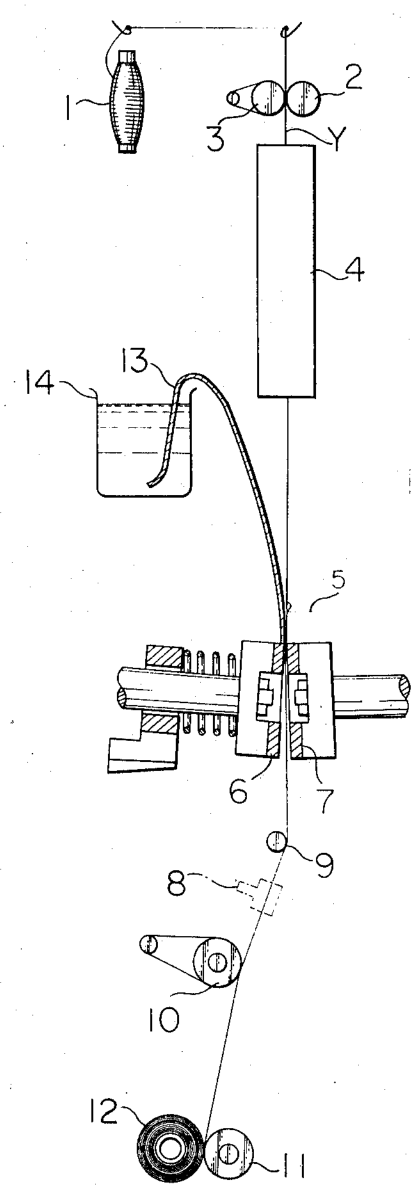

Fig. 2

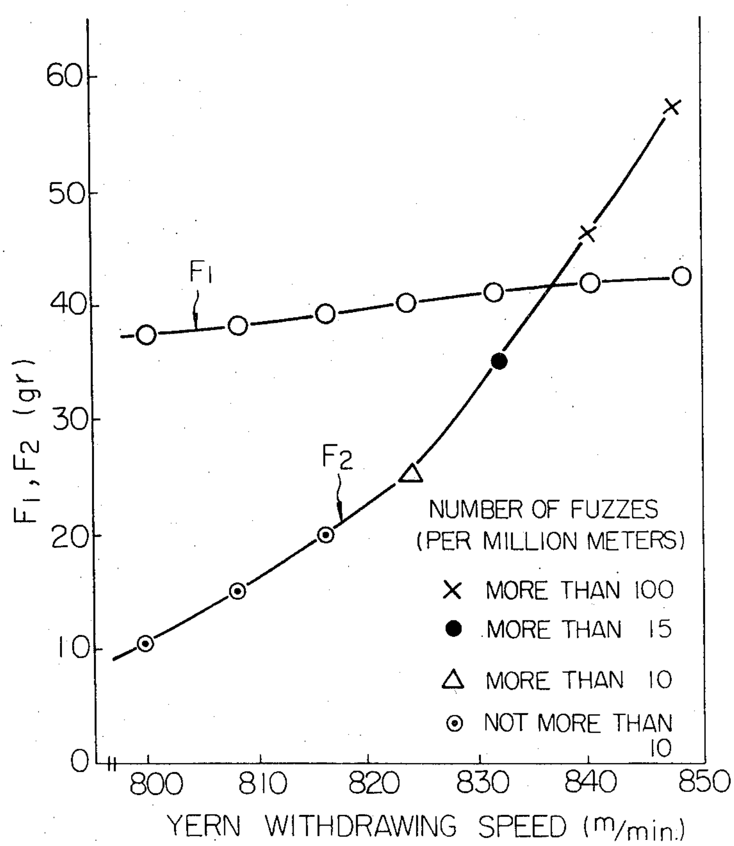
60
50
40
30
20
10
0
F_1, F_2 (gr)
F_1
F_2
NUMBER OF FUZZES
(PER MILLION METERS)
MORE THAN 100
MORE THAN 15
MORE THAN 10
NOT MORE THAN 10
800
810
820
830
840
850
YERN WITHDRAWING SPEED (m/min.)

Fig. 3

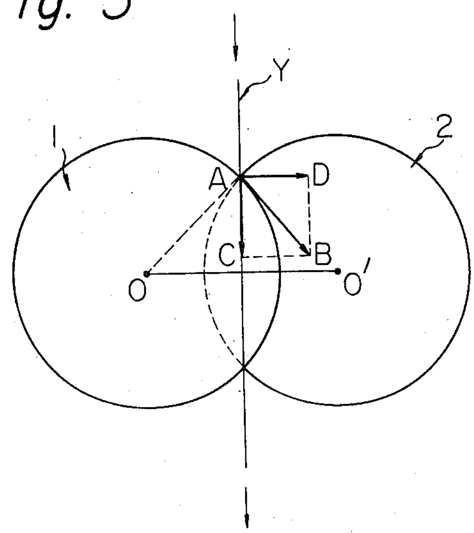

Fig. 4

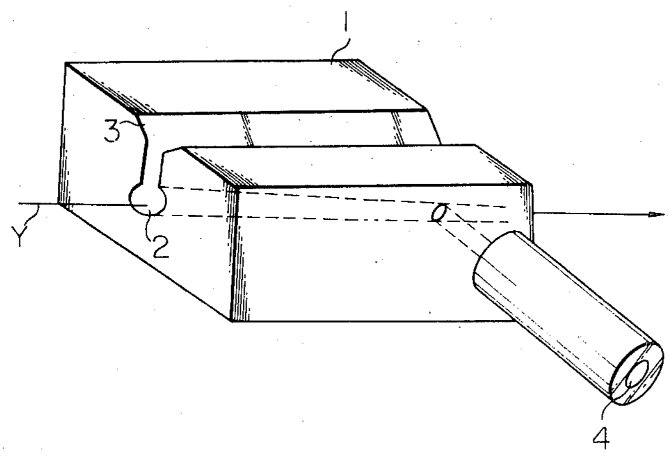

Fig. 5

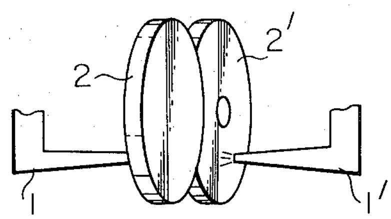

Fig. 6

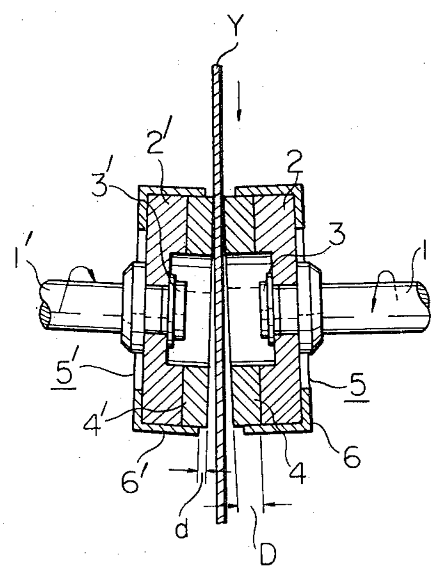

Fig. 7

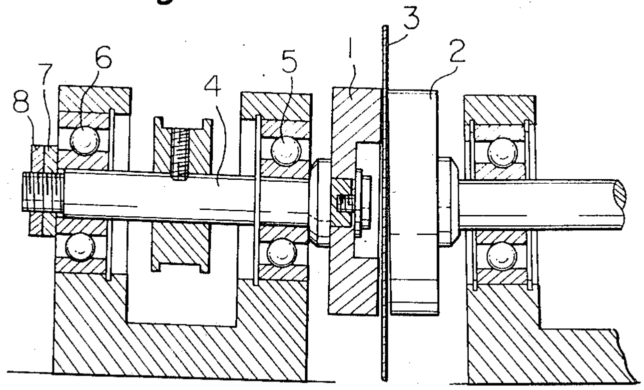
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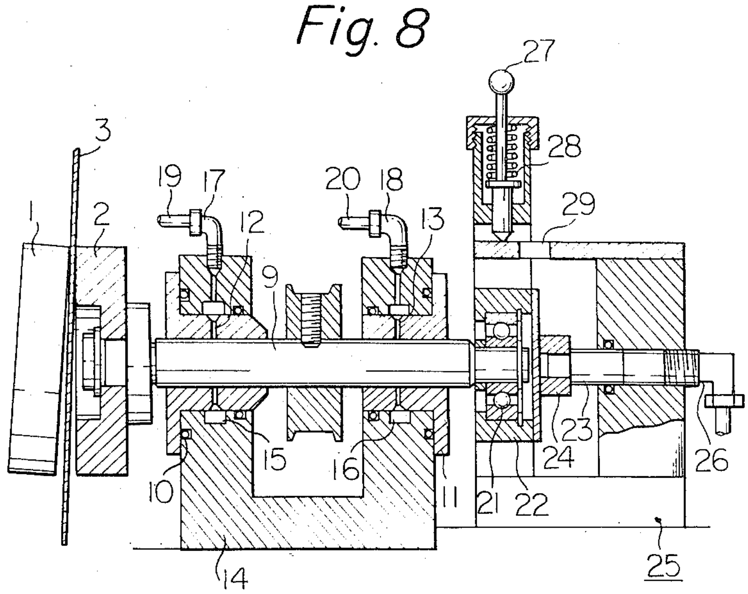
Fig. 8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PROCESS FOR FALSE-TWISTING A YARN

This invention relates to a process for false-twisting a yarn stably at high speed by passing a continous yarn such as multifilaments (to be referred to simply as yarn) between the frictional engaging surfaces of two frictional rotors of the same diameter opposing each other and rotating in opposite directions to each other.

A method has previously been known in which a yarn is introduced between contact surfaces (this will often be referred to as engaging surface hereinafter) of two frictional rotors of the same diameter rotating in opposite directions to each other (U.S. Pat. No. 3,156,084 and Japanese Patent Publication No. 1467/65).

It is generally thought that these frictional falsetwisting methods can be operated at very high speed. But investigations have shown that the operational stability of the method is poorer than has been previously imagined (this tendency is especially pronounced in the high speed processing, and false-twisting itself becomes impossible), and uniform crimped yarns cannot be obtained. These false-twisting methods are different from the frictional false-twisting method (for example, Japanese Patent Publication No. 2348/58) which has generally been used in that a yarn is held between the frictional engaging surfaces of two frictional rotors to thereby deliver and false-twist the yarn at the same time. Therefore, in a high speed operation in which the processing speed is at least 500 meters/min., it is extremely difficult to twist a yarn to a degree desired for crimped yarns and at the same time deliver the yarn in a stable condition. These frictional methods, however, have the characteristic that as compared with the above-mentioned frictional false-twisting method, a yarn is not bent at the twisting portion. This characteristic has an effect of reducing the formation of fuzzes in a high speed operation.

It is an object of this invention to provide a process for false-twisting a yarn at a speed of more than 500 meters per minute with reduced yarn breakage by passing a yarn between the frictional engaging surfaces of two frictional rotors opposing each other and rotating in opposite directions to each other.

The above object of the invention can be achieved by a process for false-twisting a yarn which comprises passing a yarn between the frictional engaging surfaces of two frictional rotors of the same diameter, the rotors opposing each other and rotating in opposite directions to each other, and the rotating axes of the two rotors being not on the same axis, wherein the yarn is fed to the frictional engaging surfaces at a rate of at least 500 meters per minute, exerting a tension defined by the following expression

$$0.85 > F_1 > 6.35 \times 10^{-4}V - 0.100$$

wherein

F_1 is the tension of the yarn. (gr/de), and

V is the rate of feeding the yarn,

on the yarn in a false-twising zone, and withdrawing the yarn from the frictional engaging surfaces.

The rate of feeding the yarn as mentioned herein is the speed of a yarn to be fed to frictional rotors which advances in a helical fashion. In the case of a non-stretchable yarn, this yarn speed is almost the same as the speed of the yarn at feed rollers located upstream of the frictional rotors. When the yarn is stretchable, the rate of feeding the yarn (or yarn speed) can be measured at withdraw rollers where the yarn is withdrawn under a tension (usually, about 0.1 g/d) required to remove the crimping of the yarn upon withdrawing from the frictional rotors.

In the conventional false-twisting processing at a relatively low speed, the number of rotations of the yarn per minute is at most 1,200,000 to 1,500,000 r.p.m. (300 to 400 meters per minute) in the direct twisting method (for instance, Japanese Patent Publication No. 21494/65) utilizing frictional rotors or a method (for instance, U.S. Pat. No. 3,156,084) in which a yarn is false-twisted by holding the yarn between two frictional rotors rotating in opposing directions to each other, and 600,000 rpm (150 meters per minute) in the spindle method.

Furthermore, in the conventional false-twisting methods, it has been considered best to process a yarn at the lowest possible tension (for example, 0.1 gr/de to 0.15 gr/de) for the purpose of reducing yarn breakage.

Investigations have been conducted the determine the factors which render the processing unstable, and led to the discovery that the greatest factor is the generation of an extraordinary tension on the yarn at the twisting point of a false-twister due to balooning of the yarn, which tension renders the twisting action nonuniform, and causes a stress concentrating point in the twisted yarn to an extent of yarn breakage.

It has been found that contrary to the previous concept of processing tension, the yarn can be false-twisted stably with reduced yarn breakage by removing the balooning of the yarn utilizing a high stretching zone of the yarn. Thus, it has been found that in order to remove such balooning, the yarn is processed at a yarn speed of at least 500 meters per minute while maintaining a tension F_1 in the twisting zone at a value defined by the following empirical formula

$$0.85 > F_1 > 6.35 \times 10^{-4}V - 0.100$$

wherein

F_1 is the tension of the yarn (gr/de), and

V is the speed of the yarn (meters/min).

If the tension F_1 in the twisting zone is higher than 0.85 gr/de, breakage of the yarn due to the twisted structure of the yarn tends to occur, although the balooning of the yarn does not take place. Also, fuzzes tend to occur, and there are extremely frequent yarn breakages. On the other hand, if F_1 is below $6.35 \times 10^{-4}V - 0.167$, the balooning of the yarn occurs occasionally at random, and when balooning occurs, the yarn rarely returns to the original state, which in turn may result in yarn breakage.

Very superior false-twists can be imparted to the yarn when the twisting tension F_1 is defined as follows:

$$0.70 > F_1 > 6.35 \times 10^{-4}V - 0.100$$

The yarn breakage can be reduced as compared with the ordinary false-twisting operations.

The invention will be further illustrated by reference to the accompanying drawings in which:

FIG. 1 is a schematic view showing one example of the false-twisting step according to the invention;

FIG. 2 is a graphic representation showing the relationship among the twisting tension, withdrawing tension, and the number of fuzzes formed;

FIG. 3 is a view illustrating the components of the peripheral speed of frictional rotors used in the invention;

FIG. 4 is a perspective view showing one example of a liquid removing nozzle used in the invention;

FIG. 5 is a view showing the cooling method for frictional rotors in the present invention;

FIG. 6 is a sectional view of the twisting portion of a false-twisting device used in the invention;

FIG. 7 is a sectional view of the false-twisting device used in the invention, in particular a fixed disc using radial ball bearings; and

FIG. 8 is a sectional view of the false-twisting device used in the invention, in particular a freely-movable disc using a pneumatic bearing.

Referring to FIG. 1, yarn Y leaves a bobbin 1, and fed by a feed roller 3 pressed by a press roller 2. It is heat-treated by a heater 4, and after passing guide 5, is false-twisted by frictional rotors 6 and 7 whose surfaces are covered with rubber. The yarn is then withdrawn by a withdraw roller 10 via a guide 9, and wound up on a package 12 by means of a winder 11. The reference numeral 13 represents a wool-like cord, one end of which is connected to a tank 14 containing liquid inert to the yarn, and from the other end of which the liquid is fed to the surfaces of the frictional rotors 6 and 7.

A nozzle for removal of the liquid is designated at 8, and is adapted to blow off the liquid contained in the yarn by air. The yarn is false-twisted while being held by the engaging surfaces of two opposing frictional rotors of the same diameter rotating in opposite directions to each other.

The twisting of the yarn is imparted between the frictional rotors 6 and 7 and the feed roller 3 (to be termed a twisting zone). The tension of the yarn in the twisting zone is controlled mainly according to the speed of the frictional rotors, and the interaxial distance between the rotors. Delicate control can also be made by varying the contact pressure between the yarn and the heater 4, or the withdrawing speed of the withdraw roller 10.

The lower limit of the tension of the yarn in the twisting zone at which tension the balooning of the yarn is removed, and the false-twisting operation becomes stable was examined for various speeds using an apparatus of the type shown in FIG. 1 under the conditions shown in Table 1. In this experiment, the lower limit of tension at which false-twisting could be performed for 30 hours without yarn breakage was defined as the lower limit of tension for stable processing. The results obtained are shown in Table 2. It is seen from the results that at a processing speed of at least 500 meters per minute, a tension of at least $6.35 \times 10^{-4}V - 0.100$ is required.

TABLE 1

Yarn: Polyethylene terephthalate, 75 denier/24 filaments
Diameter of the rotors: 90 mm
Material of the frictional rotors: Polyurethane rubber with a hardness of 55°
Interaxial distance of the rotors: 48 mm
Contact pressure of the rotors: 25 Kg
Inclined angle of the rotors: 1°
Inert liquid: water, 300 cc/min.
Length of the heater: 2m
Temperature of the heater:

300 meters/min. or less	220° C.
400 meters/min.	223° C.
500 meters/min.	226° C.
600 meters/min.	230° C.
700 meters/min.	235° C.
800 meters/min.	240° C.
900 meters/min.	245° C.
1000 meters/min.	250° C.

TABLE 2

Speed of yarn (meters/min.)	Lower limit of tension for stable processing (grams)
50	6–10
100	6–10
150	6–10
200	6–10
250	6–10
300	10–12 (15–20)
400	10–12 (15–20)
500	16 (16)
600	21 (21–22)
700	25 (25)
800	30 (30–31)
900	35 (35–36)
1,000	40 (40)

The tension was measured between the heater 4 and the guide 5 of FIG. 1 by means of an electron tension meter (product of Roschild Company, Switzerland). The figures in the parentheses show the detwisting tension of the yarn.

It is seen form the results that the lower limit of tension required for false-twisting a yarn stably at a speed of 500 meters per minute or more is far higher than that required for false-twisting the yarn at lower speeds.

Furthermore, under the conditions shown in Table 1, the yarn tension for stable processing is between 35 and 64 g at a yarn speed of 1,000 meters per minute. In this case, the number of rotations of the yarn reaches as much as 3,200,000 rpm. As one example, when a two-spindle machine was operated for a total of 2,520 hours at a processing speed of 1,000 meters per minute using a tension of 45 + 2 g, six yarns were broken during this time, and this means that per yarn breakage, the processing was continued for 420 hours. This is comparable to the conventional false-twisting operation in which an average time needed for one yarn breakage is 400 hours. In the conventional wooly processing, the tension at the twisting zone is 7 ± 1 g, and at such a tension, the processing speed is at most 400 meters per minute. According to the process of the invention, a processing speed unexpected from the conventional methods can be attained. Thus, the processing can be made at extremely high speeds.

In order to demonstrate further that according to the process of the invention, stable twisting can be performed at a yarn speed of at least 500 meters per minute, processability was examined using an apparatus of the type shown in FIG. 1 at varying tensions of the yarn in the twisting zone and at varying yarn speeds between 500 and 1,000 meters per minute. The conditions and the results obtained are shown in Table 3.

TABLE 3

Speed of yarn (meter/min.)	Twisting tension (grams)	Processability
500	16 (16)	O
	12 (12–14)	Δ
	10 (10–12)	X
	less than 8 (8)	X
600	21 (21–22)	O
	16 (16–18)	Δ
	14 (14–15)	X
	less than 12 (12)	X
700	25 (25)	O
	21 (21–23)	Δ
	19 (19–21)	X

	less than 17 (19)	X
800	30 (30–31)	O
	26 (26–28)	Δ
	24 (24–25)	X
	less than 22 (22)	X
900	35 (35–36)	O
	31 (31–33)	Δ
	29 (29)	X
	less than 27 (27)	X
1000	40 (40)	O
	36 (36)	Δ
	34 (34)	X
	less than 32 (32)	X

The processability was evaluated on a scale of three stages in which:

O shows there was no yarn breakage for more than 30 hours;

Δ shows yarn breakage occurred in 10 minutes to 30 hours; and

X shows yarn breakage occurred in less than 10 minutes or processing totally failed.

It has been found that by employing the abovementioned tension, the balooning the yarn can be eliminated, and a stable twisting can be performed, but that the resulting crimped yarn has considerable fuzzes.

If the occurrence of fuzzes can be prevented, this high speed processing method is most desirable from the viewpoint of the quality of the product also. Therefore, this point was furthered in our research and development work. As a result, it was found that the twisting tension should be within the range of from 0.85 to $(6.35 \times 10^{-4}V - 0.100)$, and by rendering the withdraw tension lower than the tension within this range , a stable false-twisting operation and the prevention of fuzzes become possible.

The relation among the tension F_1 of yarn in the twisting zone, the tension F_2 of yarn being withdrawn from the frictional rotors, and the number of fuzzes formed is shown in Table 4. The yarn used was a polyethylene terephthalate yarn (75 denier/24 filaments), and processed under the conditions shown in Table 5. The apparatus used was a 12-spindle machine, and the evaluation of the results was made with respect to 300 kg of the yarn for each set of the conditions employed.

TABLE 4

F_1(gr)	F_2(gr)	Speed of withdraw rollers (meters/min)	Number of fuzzes (per million meters)
46	50	1040	837
46	44	1030	28
45	36	1020	15
45	30	1015	5
45	25	1010	4
45	20	1008	4
45	10	1000	3

TABLE 5

Frictional rotors: 90 mm in diameter, made of polyurethane rubber having a hardness of 55°; interaxial distance 52 mm; contact pressure, 3.0 kg; counter angle of inclination 1°

Inert liquid: 300 cc/min. of water

Yarn feed rate: 1000 meters/min.

Length of the heater: 2 mm

Temperature of the heater: 250° C.

The tension in the twisting zone was measured at a place between the heater and the frictional rotors, and the withdraw tension, between the guide **9** and the withdraw roller **10**. The measurement of the tensions was performed using an electronic tension meter (product of Roschild Company, Switzerland). The measurement of the number of fuzzes was made using a fuzz detector (product of Kasuga Electric Co., Ltd.), and the number of fuzzes per million meter of the yarn was counted while maximizing its sensitivity. It is seen from Table 4 that when the withdraw tension F_2 is larger than the tension F_1 in the twisting zone, the occurrence of fuzzes becomes remarkable abruptly, and a crimped yarn of good quality cannot be obtained. On the other hand, if the tension F_2 is smaller than the tension F_1, the occurrence of fuzzes is reduced, and a very good crimped yarn is obtained.

Table 6 shows the tension F_1 of yarn in the twisting zone, the withdraw tension F_2 of yarn, and the number of fuzzes formed in the processing of a nylon 6 yarn (70 denier/34 filaments) under the conditions shown in Table 7. It is seen from the table that for good results, the tension F_1 of yarn in the twisting zone should be smaller than the withdraw tension F_2.

TABLE 6

Yarn feed speed (meters/min.)	Yarn withdraw speed (meters/min.)	F_1 (gr)	F_2 (gr)	Temperature of the heater (°C)	Number fuzzes per million meters of the yarn
480	522	26	28	190	168
	517	25	17	190	13
	512	25	10	190	8
	504	24	7	190	4
720	773	32	34	200	314
	767	31	28	200	32
	760	31	17	200	11
	748	30	10	200	8

TABLE 7

Frictional rotors
- diameter: 82 mm
- material: nitrile rubber with a hardness of 52°
- interaxial direction: 33 mm
- contact pressure: 0.7 kg
- counter angle of inclination: 1°

Inert liquid
- water 160 cc/min.

Length of the heater
- 1.5 m

The relation among the withdraw speed, the tension F_1 in the twisting zone, the tension F_2 in the withdrawing zone, and the extent of occurrence of fuzzes is shown in FIG. 2 with respect to a polyethylene terephthalate yarn (75 denier/24 filaments) processed at a yarn feed speed of 800 meters per minute under the conditions shown in Table 8. It is seen from FIG. 8 that the number of fuzzes changes greatly beyond the intersectiong point of the curves representing F_1 and F_2, and that in the false-twisting process of the present invention, tension F_1 should be larger than the tension F_2. Furthermore, in order to reduce the number of fuzzes remarkably it is preferred that the withdraw tension F_2 should be not more than 80 percent of the twisting tension F_1.

TABLE 8

Frictional rotors diameter: 90 mm
- material: polyurethane with a hardness of 55°
- interaxial distance: 48 mm
- contact pressure: 2.5 kg

counter angle of inclination: 1°
Inert liquid: water 300 cc/min.
Yarn feed rate: 800 meters/min.
Length of the heater: 2m
Temperature of the heater: 240°C.

As shown above, in the false-twisting method using frictional rotors, different from the conventional spindle false-twisting method, the occurrence of fuzzes can be reduced only when the withdraw tension F_2 is lower than the tension F_1 of the twisting zone.

If the withdraw tension F_2 is reduced to below 0.05 g/d, complicated interlacings are formed in the individual filaments which constitute the crimped yarn, and when such yarn is woven into a fabric, the feel of the fabric is rough. Therefore, it is possible to obtain a woven fabric which has a different feel from that of a woven fabric made of ordinary crimped yarns.

According to the present invention, therefore, the processing can be performed at high speed of more than 500 meters per minute and in a stable condition, and it is possible to obtain a crimped yarn of reduced fuzzes by such a high speed processing.

As previously mentioned, the tension of the twisting zone can be maintained within the range required of the present invention by mainly controlling the rotation speed of the frictional rotors and the interaxial distance between the two frictional rotors. It has been further discovered that when the rotation speed of the frictional rotors and the interaxial distance between the two frictional rotors satisfy the following relation with respect to the yarn, greater improvements can be achieved in the stability of twisting operation and the occurrence of fuzzes.

$$V/\text{Yarn twisting speed } (\overline{AD}) = V/(\sqrt{D^2-e^2}\cdot\pi\cdot r) = 0.7\text{–}0.9 \qquad (1)$$

$$V/\text{Yarn feeding speed } (\overline{AC}) = V/(e\pi r) = 1.05\text{–}1.40 \qquad (2)$$

wherein

D is the diameter of the frictional rotors,
e is the interaxial distance between the frictional rotors (0,0′),
r is the speed of rotation of the frictional rotors, and
V is the speed of the yarn.

In other words, in order to perform the false-twisting process of the invention effectively using frictional rotors made of rubber with a hardness of 40°–70°, the ratio of the yarn speed to the yarn twisting speed should be 0.7–0.9, and the ratio of the yarn speed to the yarn feeding speed should be 1.05–1.40. These requirements should be met simultaneously.

If the ratio of the yarn speed to the yarn twisting speed is less than 0.7, the twisted yarn assumes a state near the so-called double twist (also called kink twist) because of excessive twists. In particular, when the yarn speed is above 500 meters per minute, there is a tendency toward yarn breakage in the twisting part, and stable processing cannot be performed. If the ratio of the yarn speed to the yarn feeding speed exceeds 0.9, the usually desired number of twists are not imparted, and the resulting yarn has a reduced value as crimped yarn.

On the other hand, if the ratio of the yarn twisting speed to the yarn feeding speed is in the range of 0.7 to 0.9, but if the ratio of the yarn speed to the yarn feeding speed (AC) is smaller than 1.05, the tension F_1 of the yarn in the false-twisting zone becomes higher beyond 0.85 gr/de, and there is a frequent breakage of yarn. If the ratio is larger than 1.40, the yarn tension F_1 in the false-twisting zone becomes smaller than $(6.35 \times 10^{-4}V - 0.100)$. Thus, similarly to the case of excessive twist, yarn breakage at the twisting portion becomes frequent, and stable processing cannot be performed.

Japanese Patent Publication No. 16748 discloses that the ratio of the yarn speed to the surface speed of a twisting tube is optimum at 0.5 to 0.9. Tracing experiments show however that this relation holds true with yarn of less than 75 denier at a speed of up to 300 meters per minute. At a higher speed above 300 meters per minute, especially more than 500 meters per minute, the number of twists becomes a maximum at the above ratio in the vicinity of 0.7. This number is less than 85 percent of that actually required, and it has also been confirmed that fuzzes occur frequently, and good processing cannot be expected. Furthermore, with a yarn of 150 denier, the speed ratio of 0.54 is an optimum value as shown in the above-mentioned Japanese patent. On the other hand, in the present invention, the optimum value is obtained at a yarn speed/yarn twisting speed of around 0.80. This demonstrates that the false-twisting method shown in the above Japanese patent differs in twisting action from the frictional false-twisting method of the present invention.

In the practice of the process of the invention, the frictional surfaces of the frictional rotors **6** and **7** are preferably wetted with a liquid inert to the yarn which is fed from the tank **14** through the wool-like cord **13.** This prevents the frictional rotors from stick slipping or burning during high speed processing operations, and stable high-speed twisting can be performed. At this time, the yarn undergoes a considerable twisting moment on the engaging surfaces, and its physical structure tends to be changed greatly. Therefore, the liquid used for the above-mentioned purpose should be inert to the yarn so that is does not extremely deteriorate the physical and chemical properties of the yarn during processing. Typical examples of the liquid include water, aqueous solutions containing textile finishing oils (for example, antistatic agents, or lubricants), or liquid textile finishing agents.

Such a liquid is applied to the engaging surfaces of the two frictional rotors so that at least that part where the yarn comes into contact with the rotors becomes wet. The application can be effected by a method shown in FIG. **1.** Also, it can be effected by a method wherein the liquid surface of a liquid reservoir tank is pressed by pressurized air, and the liquid or air containing the liquid is jetted out from a nozzle, or a method wherein a liquid level in a tank is utilized, or a method in which the liquid is sprayed by a sprayer.

The crimped yarn obtained from a false-twisting apparatus in such a state contains excessive amounts of the above liquid. When an excessive amount of liquid is contained in the crimped yarn, the moisture plasticizes the yarn wound up on a bobbin, and with the passage of time, the amount of crimps is reduced. Furthermore, the liquid contained in the yarn wound up on a bobbin evaporates gradually or diffuses into other substances, and therefore, the liquid content of the yarn decreases. When the selling and buying of yarns are conducted on the basis of weight, the liquid content fluctuates. In order to maintain the liquid content of the yarn at a constant or reduce it to nearly zero, an additional moisture-controlling step or drying step becomes necessary, and the significance of reducing the cost by processing at high speed will be lost.

Where a heater is provided at the rear of the false twisting apparatus to re-set the yarn (in the case of producing a heat-stabilized yarn), the efficiency is poor if a liquid is adhered to the yarn, and also unevenness tends to occur. Furthermore, if the bobbin is a paper tube, it becomes wet and broken. Furthermore, molds are formed to deteriorate the quality of the yarn to a marked extent. Therefore, it is necessary to remove the excessive liquid contained in the crimped yarn.

The crimped yarn tends to contain liquid more than ordinary filament yarns, and the rate of yarn travel is high. It is therefore difficult to remove the liquid within a very short time, that is, over a short distance in the machine. The liquid could not be removed sufficiently by a method in which a rotary body having a diameter of not more than 20 mm is rotated at a speed of more than 5,000 rpm, and the liquid is thrown off by a centrifugal force by winding the yarn around the rotary body several tens of times, a method wherein the yarn is passed through two squeeze rolls to throw off the liquid, a method wherein the yarn is heat-treated on a heating roller, or a method wherein the liquid is removed by passing the yarn through a heater.

It has now been found that by impinging a high speed air flow against the yarn between the false-twisting device and the take-up device, the detrimental liquid adhered to the yarn can be removed in a very small space. Specifically, by passing the yarn through a nozzle **8** for compressed air as shown in FIG. **1**, a tubulent or swirling flow of high speed air flow having a sonic speed or a speed near semisonic speed acts on the yarn at right angles thereto or in parallel therewith, and the liquid adhering to the individual fibers is thrown away, thus wiping away all liquid drops.

FIG. 4 shows one example of the pressurized air jetting nozzle used-in the present invention. The reference numeral **1** represents a main body **1**; **2** and **3**, yarn-passing slits; and **4**, a pressurized air pipe. By the pressurized air fed from the pipe **4**, the liquid adhering to the yarn Y is thrown away.

By using the above-described nozzle, compressed air is jetted out from a jet pipe in the nozzle, and collides directly with the yarn travelling along the yarn path. If the pressure of the compressed air is low, the effect of blowing away the liquid is poor, and if the pressure is too high, the liquid is violently blown off, but the efficiency becomes low. Furthermore, the liquid removing action differs somewhat according to the diameter of the jet pipe or the angle of the jet pipe to the axis of yarn.

As the pressure of compressed air suitable for the object of the present invention, pressures of at least 0.5 Kg/cm^2 gauge can be used. If the pressure is below 0.5 Kg/cm^2 gauge, the liquid contained in the interior of the yarn cannot be removed. Most desirably, a compressed air jet pipe with a diameter of at least 1.0 mm (area of at least 0.8 mm^2) is used for compressed air of at least 2 Kg/cm^2 gauge.

In the nozzle used in the present invention, the diameter of the yarn path **2** is effectively at least five times and up to 100 times the diameter of the yarn. If the diameter of the yarn path exceeds 100 times the diameter of the yarn, irregularities occur in the action of blowing off the liquid. For practical purposes, the yarn path has a diameter of 0.5 to 10 mm. It is desirable that the sectional area of the air jet pipe is not more than two times the area (generally the sectional area of the yarn path) of the nozzle to discharge air. If the area of the jet pipe becomes large, the effect of blowing off the liquid is low as compared with an increased rate of flow of air.

The angle between the jet pipe and the yarn axis (yarn path) is between 20° to 160° C. As the air stream to be jetted out against the direction of yarn travel becomes stronger, the effect of removing the liquid becomes higher. The jet nozzle for air may be merely an opening (circular or non-circular shapes) provided in the yarn path, or provided annularly along the circumference of the yarn path.

Compressed air may be heated. When compressed air is heated, the effect of drying by heat adds to the air jetting effect, but an additional step of heating is required.

The position of fitting the nozzle may be at any place between the frictional rotor and the wind-up device. The position between the rotor and the delivery device is convenient for a machine having the delivery device since the delivery device is not contaminated. For ease of passing the yarn, slit-like notches may be provided in the yarn path. It is possible to swirl the air flow by providing the jet nozzle eccentrically to the axis of the yarn path, but in this case, care should be taken not to provide the slit-like notches in a position to make the yarn deviate from the yarn path.

The stick slipping and burning of the contact surfaces of the frictional rotors can also be prevented by positively cooling the engaging surfaces. The resulting yarn has some crimp irregularities (fully allowable for limited applications), but the level of crimps and the high speed of processing are comparable to the above-mentioned wet method. In addition, the scattering of the liquid can be avoided, and the liquid does not adhere to the yarn. This method is a very good false-twisting method in operability and handling from the industrial standpoint.

The positive cooling of the yarn holding surfaces of the frictional rotors is conveniently performed by the method shown in FIG. **5** in which compressed gases **1** and **1'** are jetted out at high speed. As the gas, the use of air is generally economical. Air is first compressed by a compressor, and if possible, cooled to the greatest possible extent, and then jetted out from a nozzle at a place as close as possible to the surfaces **2** and **2'** of the frictional rotors. If the nozzle is of a small opening, more than one nozzle can be provided at intervals within an allowable range on the circumferential surface of the frictional rotor, which surface does not overlap the opposing frictional rotor. Furthermore, the shapes of the jet openings of the nozzle may be made slit-like on the circumference which does not overlap the opposing frictional rotor. The pressure and the amount to be jetted out of air are selected according to the material of the surfaces of the rotors, the pressure of contact between the frictional rotors (to be referred to as contact pressure), the speed of rotation, and the shape and number of the nozzles. Usually, the pressure of the air is at least 0.5 Kg/cm^2 gauge, and the amount of air is at least 10 Nl/min. Compressed air may be used after having been cooled.

In the process of the present invention, the yarn is rotated while being held between the engaging surfaces of two frictional rotors. In order to rotate the rotors while firmly securing the yarn, the yarn holding surfaces of the rotors are desirably made of rubber having a hardness of 40° to 70°. The hardness of rubber is measurrd with a spring-type hardness tester, in accordance with the specifications of JIS-K-6301-1962 (Physical testing method of vulcanized rubber).

The surface, shape and thickness of the frictional rotors that hold the yarn affect the quality of the yarn and operability especially during high speed rotation. Where the frictional rotors are rotated at high speed, the material of the frictional rotors at the outermost periphery is extremely deformed by a centrifugal force, and the condition of holding the yarn changes from that at the time of holding it in a stationary condition, resulting in reduced yarn holding power and yarn twisting power and accordingly an unstable operation.

In order to obtain stable holding power and twisting power at the time of high-speed operation, it is preferred that the thickness of the rubber with a hardness of 40° to 70° should be 0.5 mm to 5 mm. Furthermore, the rubber should be bonded firmly to a substrate second to the rotary shaft. It is also possible to increase the thickness of rubber beyond 5 mm and provide a reinforcing outer wheel on the periphery of the substrate and the rubber. In the case of providing the reinforcing outer wheel, rubber is made to extend beyond the end of the outer wheel by 0.5 to 5 mm. FIG. 6 shows a frictional rotor in which an outer wheel is provided on the periphery of the substrate and rubber. In FIG. 6, annular substrate **2**, and **2'** are fixed to the ends of rotary shafts **1** and **1'** by nuts **3** and **3'**. To the surfaces of the annular substrates **2** and **2'**, rubbery elastomers **4** and **4'** are attached, to thereby form frictional rotors **5** and **5'**. In order to prevent the deformation of the rubbery elastomers **4** and **4'** at the time of rotation in contacting relation, outer wheels **6** and **6'** are secured. Preferably, the rubbery elastomers have a hardness of 40° to 70°.

Yarn Y travels in the direction of the arrow, and is twisted and detwisted. Letter D indicates the thickness of the rubbery elastomer from the adhering surface of the frictional rotor or from the mold surface, and *d* designates the projecting thickness from the outer wheel 4 to the surface of the frictional rotor material.

It has been well known that the thickness of a frictional sustance of a frictional rotor from the adhering surface differs at its outermost circumference according to the hardness of the frictional substance. It has been found that the upper limit of thickness D is determined by a space above the apparatus, and with regard to the twisting, it appears to be about 50 mm; but that the lower limit of thickness D greatly affects the twisting and yarn stringing. If the thickness of the frictional substance is less than 0.5 mm, the adhering surface of the metal exerts a great influence, and the moldulus of elasticity of the frictional substance apparently decreases, which in turn results in a reduced holding power of the yarn.

As to the projecting thickness *d*, it has generally been thought that larger thicknesses *d* are preferred by reason of increased number of uses. However, it has been found that when the thickness *d* is increased, the projection of the outermost periphery becomes greater with high speed rotation, and yarn breakage occurs in several hours. The limit of thickness is therefore 5 mm.

The requirement that this thickness should be 0.5 to 5 mm will be specifically explained with reference to an example. In this example, a 200-denier polyethylene terephthalate yarn is processed at a yarn speed of 450 meters per minute using frictional rotors whose diameters are 90 mm, and whose interaxial distance is 50 mm. The hardness of rubber on the rotors is 60°.

A. When processing was performed using the apparatus shown in the drawings in which the thickness *d* from the outer wheel was 6 mm and the thickness of the rubbery substance D was 10 mm, yarn breakage occurred in 10 hours. Thereafter, the outermost circumference was deformed in the outside direction, and it was no longer possible to string the yarn.

B. When in the processing shown in (A), the thickness *d* was changed to 0.3 mm, fuzzes were formed frequently and yarn breakage occurred to make it impossible to continue the processing. This is because the two rotors were pushed with some force in the thrust direction, and the yarn held between them was rubbed with the outer wheel.

C. When in the processing shown in (A), the distance d was changed to 1 mm, the yarn stringing became easy, and the time required for yarn breakage was extremely prolonged, which made it possible to produce bulky crimped yarns of high quality.

D. When the processing was performed without the outer wheel while adjusting the thickness D from the adhering surface to 0.3 mm, sufficient elastic force for holding the yarn could not be obtained, and it was impossible to string the yarn. Even if the hardness of the rubbery substance is reduced, the deformation was great because of high speed rotation, and the yarn stringing was impossible.

E. When the process was performed while adjusting the thickness D from the adhering surface to 10 mm and the projecting thickness *d* from the outer wheel to 3 mm, the twisting operation could be performed stably and uniformly, and bulky yarns of high quality could be obtained.

The results obtained are shown in Table 9.

TABLE 9

Thickness D (mm)	Thickness *d* (mm)	State	Time that elapsed until breakage of yarn (hours)
20	10	Large bulging of the outermost circumference, and yarn stringing impossible	—
20	8	Yarn breakage occurred in several hours, and thereafter, yarn stringing was impossible	5
10	6	Yarn stringing possible, but stability of tension poor	100
10	5	Processing possible, twisting stable, high quality yarn obtained	500
10	4	Processing possible, twisting stable, high quality yarn obtained	500
10	3	Processing possible, twisting stable, high quality yarn obtained	500
10	2	Processing possible, twisting stable, high quality yarn obtained	500
10	1	Processing possible, twisting stable, high quality yarn obtained	500
10	0.5	Processing possible, twist-	500

		ing stable, high quality yarn obtained	
10	0.3	Yarn stringing possible, yarn contacted the outer wheel, considerable fuzzes	100
10	0.1	Yarn stringing impossible	
8.0		Large bulging of the outermost circumference, and yarn stringing impossible	—
6.0	without outer wheels	Yarn stringing possible, but stability of tension poor	100
5.0		Processing possible twisting stable, high quality yarn obtained	500
1.0		Processing possible twisting stable, high quality yarn obtained	500
0.5		Processing possible twisting stable, high quality yarn obtained	500
0.3		Yarn stringing possible, but stability of tension poor	200
0.1		Yarn stringing impossible	—

It is seen from Table 9 that stable processing becomes possible when the thickness from the mold face is at least 0.5 mm, and the projecting thickness from the outer wheel is from 0.5 to 5 mm; and the time that has elapsed until the breakage of yarn was greatly increased.

In the present invention, one of the two frictional rotors may be a fixed disc capable of being rotated in the circumferential direction but completely free of gap in the axial direction by such means as double nuts; the other rotor is rendered rotatable both in the circumferential and bearing directions. At this time, the movement of one disc in the bearing direction can be performed by the following mechanisms.

A. Using a radial ball bearing, the disc is made to slide between the disc shaft and the inner lace.

B. Using a radial ball bearing, the disc is made to silde between the outer lace and the bearing housing

C. The disc shaft is supported by an air bearing, and made to float completely.

With regard to (A), the following were confirmed as a result of a 6-month operation.

If the clearance between the inner lace and the disc shaft, the shaft rotates between them. If a proper clearance is provided between them, no trouble occurs for practical purposes. It is however necessary to apply a suitable lubricant such as grease always between the inner lace and the shaft.

With regard to (B), troubles do not occur for practical purposes. But depending upon the clearance between the outer lace and the bearing housing, the shaft does not fit straight into the bearing, and the bearing becomes heavy.

The method shown in (C) does not require lubrication, and there is substantially no resistance with regard to the movement in the axial direction. Thus, this is the most ideal supporting method, and there is little deviation among the spindles.

When an air bearing is not used, solid or liquid friction occurs between the shaft and the bearing, and it is necessary to increase the urging pressure accordingly. In the case of using a multiple of spindles, there is a difference in the variation of frictional resistance, and the resulting products differ in quality although not to an extent such as experienced in the case of fixing both shafts. Furthermore, in order to render the friction uniform, some lubricating means is always required in order to avoid solid friction.

On the other hand, the use of an air bearing render the shaft afloat by a film of air, and therefore the frictional resitance becomes a gas friction. The resistance is very low, and there is substantially no difference among the spindles. Furthermore, the life of the shaft is prolonged.

If only one of the disc shafts is rendered freely movable, the following advantages can be obtained.

That is, if one of the shafts is fixed, and the other is allowed to move freely, and if the disc on the fixed shaft is swayed, the other disc shaft moves and matches the swaying of the swaying disc. Therefore, the yarn can be maintained always at an equal contact pressure, and the deviation in the quality of yarn is reduced.

But when both of the shafts are fixed, the above-mentioned advantages cannot be obtained, and the swaying of the discs on both shafts are more emphasized. Consequently, the contact pressure varies, and deviation in the quality of yarn is caused.

The above will be explained with reference to the drawings. In FIG. 7, the reference numerals **1** and **2** represent discs which consist of discs of the same diameter rotating in mutually opposing directions. They contact each other and deliver the yarn **3** while nipping it therebetween, and imparting twists to the yarn at the same time.

The disc **1** is secured to the disc shaft **4** and supported by radial ball bearings **5** and **6**, and clamped to the disc shaft in the axial direction by double nuts **7** and **3** and thus fixed without a clearance therebetween. In FIG. **8**, the reference numeral **9** is a disc shaft on the free-moving side, and supported by bearings **10** and **11**. The bearings are made of an alloy such as phosphor-bronze, and **10** to **20** small holes **12** and **13** are provided in a radial fashion at a place in contact with the disc shaft **9**. A bearing housing **14** includes channels **15** and **16** at places corresponding to the small holes **12** and **13** provided in the bearings **10** and **11**. Compressed air openings **17** and **18** are connected to these channels through the outer circumference. Compressed air provided by pipes **19** and **20** is supplied to these holes from outside.

A radial ball bearing **21** is secured to the end of the disc shaft **9**, and supported by a bearing housing **22**. A piston **23** is in contact with the bearing housing **22** through a rubber cushion at the foreward end. A cylinder **25** receives compressed air from the pipe **26**, and urges the piston **23** against the bearing housing **22**. A lever **27** is integral with the bearing housing **22**, and comes in contact with the cylinder **25** through a spring **28**. A hole **29** is provided in the cylinder housing, and when the lever **27** reaches this position, the spring acts to separate the discs from each other and fix them.

When it is desired to twist the yarn, compressed air is first supplied from pipes **19** and **20** to make the disc shaft float. The lever **27** is pushed down, and air is sucked from the hole **29**. In this condition, compressed air is fed from the pipe **26**, whereupon the piston **23** pushes the disc shaft **9** on the left via the ahaft housing **22**, and ruges the disc **2** against the disc **1**. Since the disc shaft is completely afloat by the compressed air, there is substantially no resistance in the axial direction, and compressed air acting in the compressed air pipe **26** directly acts on the disc **2** through the disc shaft **9**.

As one example of such an apparatus, the outer diameter of the disc was adjusted to 100 mm, the diameter of the disc shaft, 20 mm, the number of holes provided in the bearings, **10**, and the air pressure on the bearing, 5 Kg/cm². The false-twisting condition of a yarn was examined with the pushing pressure of the disc maintained at 3 Kg, the yarn speed at 600 meters/-min., and the speed of rotation of the disc shaft at 2,400 rpm. The contact pressure was hardly changed, and it was possible to conduct the twisting operation stably.

The invention will now be described by the following Examples.

EXAMPLES 1 to 11

Polyethylene terephthalate yarn(PET for short) and nylon 6 yarn (N for short) were false-twisted by the false-twisting apparatus shown in FIG. **1**. The frictional rotors used were made of nitrile rubber with a hardness of 52° (Examples-1 and 2), polyurethane rubber with a hardness of 55° (Examples 3, 4, 5 and 6). The thickness of the rubber was 6 mm. A reinforcing outer wheel was provided around the substrate and the rubber, and the projecting thickness of the rubber from the foreward end of the outer wheel was adjusted to 3 mm.

The contact pressure between the two frictional rotors was 3 kg, and the engaging surfaces between the frictional rotors were wetted with water. The length of the heater was 2 m.

The results are shown in Table 10.

TABLE 10

Example No.	Yarn speed (m./min.)	Yarn denier/filament	Twisting speed ratio	Yarn feed speed ratio	Frictional rotor Diameter (mm.)	Frictional rotor Speed (r.p.m.)	Inter-axial distance (mm.)	False twisting tension (gr.) F_1	With-draw tension (gr.) F_2	Number of twists (gr.) F_2	Process-ability	Temperature of heater (° C.)
1	500	N 70/24	0.71	1.40	82	3,070	37	27	20	3,100	Good.	190
2	500	N 100/48	.73	1.37	82	3,020	35	38	15	2,200	Good.	200
3	800	PET 75/24	.78	1.24	90	4,250	48	40	20	3,200	Good.	220
4	800	PET 75/24	.81	1.23	150	2,500	83	41	23	3,200	Good.	240
5	1,000	PET 75/24	.86	1.16	150	3,050	87	46	22	3,150	Good.	250
6	800	PET 150/30	.78	1.24	90	4,250	48	60	25	2,600	Good.	265
Comp. Ex.												
7	500	N 70/24	.65	1.40	82	3,300	34.6	12	12	3,350	Poor.	190
8	500	N 70/24	.95	1.30	82	2,540	48.5	66	30	2,300	Poor.	190
9	800	PET 75/24	.78	1.00	90	4,620	55	70	15	2,800	Poor.	240
10	800	PET 75/24	.78	1.50	90	4,100	41.5	24	22	3,200	Poor.	240
11	800	PET 75/24	.60	1.45	90	4,750	36.9				Poor.	240

EXAMPLE 12

A 75 denier/24 filament polyethylene terephthalate yarn was processed by the apparatus shown in FIG. **1** under the conditions shown in Table 11.

TABLE 11

Material of rubber	nitrile rubber
Outer diameter of the frictional rotor	90 mm
Inner diameter of the frictional rotor 30 mm	
Interaxial distance	48 mm
Hardness of rubber (JIS)	52°
Contact pressure	0.65 kg
Length of heater	1.5 m
Temperature of the heater	240° C.
Number of twists	3150 T/M
Yarn feed speed	800 meters/min.
Yarn withdraw speed	824 meters/min.
Speed of the rotation of the frictional rotor	4350 rpm
The amount of liquid used	0.1 liters/min.
Liquid	water
Air jet opening diameter of the liquid removing nozzle	1.5 mm

The liquid content of the yarn with the pressure of the compressed air varied between 1 to 4 kg/cm² is shown in Table 12. It is seen from the table that by using compressed air having a pressure of at least 0.5 kg/cm², the liquid content could be reduced to less than 4 percent, and at 2 kg/cm², the liquid content could be reduced to 0.5 percent, and that good crimped yarns same as commercially available crimped yarns could be produced.

TABLE 12

Sample No.	Pressure of air (kg/cm² gauge)	Liquid content (%)	Deformation of paper tube
I	—	15	deformed
II	0.5	4	slightly wet
III	1	2	slightly wet
IV	2	0.5	none
V	4	0	none

EXAMPLE 13

A 70 denier/24 filament nylon 6 yarn was processed under the conditions shown in Table 13 using frictional rotors of nitrile rubber having a hardness of 52°, and was made into stockings. The products were of almost the same quality as that of the commercial grade article.

On the other hand, when cooling was stopped in the same procedures violent generation of heat between the rotors took place at a processing speed of 50 meters per minute, and the surface of the rubber was fused.

TABLE 13

Outer diameter of the frictional rotors		82 mm
Interaxial distance		30 mm
Contact pressure		0.7 kg/cm²
Length of the heater		1.5 m
Temperature		190° C.
Yarn speed		400 meters/min.
Ratio of the feed speed and withdraw speed of yarn		0.94
Speed of rotation of the frictional rotors		6.65 × yarn speed (m/min.) rpm
Cooling method		gas jet method shown in FIG. 5
	gas:	air
	pressure:	3 kg/cm² gauge
	flow rate:	200 N liter/min.

What is claimed is:

1. A process for false-twisting a yarn, which comprises passing a continuous filament yarn through the frictional engaging surfaces of two frictional rotors of the same diameter, said rotors facing each other with the rotary shafts not being on the same axis, said rotors rotating in opposite directions to each other and at least the engaging surfaces of said frictional rotors are wetted with a liquid inert to the yarn, wherein said yarn is fed to said frictional engaging surfaces at a speed of at least 500 meters per minute and imparted a tension defined by the following formula

$$0.85 > F_1 > 6.35 \times 10^{-4}V - 0.100$$

wherein

F_1 is the tension of the yarn in grams per denier, and

V is the speed of feeding the yarn in meters per minute,

in a false-twisting zone, the yarn being fed to the engaging surfaces of the frictional rotors at a feed speed which simultaneously satisfies the following two conditions:

1. the ratio of the yarn feed speed to the speed component (AD) of the peripheral speed of the frictional rotors in the yarn twisting direction is from 0.7 to 0.9, and
2. the ratio of the yarn feed speed to the speed component (AC) of the peripheral speed of the frictional rotors in the yarn delivering direction is from 1.05 to 1.40;

and withdrawing the yarn from the frictional engaging surfaces.

2. The process of claim **1**, wherein the yarn is withdrawn from the frictional engaging surfaces at a withdraw tension lower than the tension of the yarn in the falsetwising zone.

3. The process of claim **2**, wherein the yarn is withdrawn from the frictional engaging surfaces at a withdraw tension of not more than 80 percent of the tension of the yarn in the false-twisting zone.

4. The process of claim **1**, wherein the yarn which has passed through the engaging surfaces wetted with an inert liquid and has been withdrawn in the wet state from said engaging surfaces is subjected to the blowing of an air stream to thereby remove the inert liquid from said yarn.

5. The process of claim **1**, wherein each of said frictional rotors is constructed of a substrate fixed to a rotary shaft, with a rubbery elastomer secured to said substrates, said rubbery elastomer having a hardness of 40° to 70° and a thickness of 0.5 mm to 5 mm.

6. The process of claim **5**, wherein each of said frictional rotors is constructed of a substrate fixed to a rotary shaft, a rubbery elastomer secured to said substrate and having a hardness of 40° to 70°, and a reinforcing outer wheel provided around the substrate and the rubbery elastomer, said rubbery elastomer projecting from the forward end of said outer wheel by 0.5 to 5 mm.

7. The process of claim **5**, wherein one of the frictional rotors has its rotary shaft secured to a bearing so that the bearing surface can be slided in the axial direction, and the other is supported by a bearing so that its rotary shaft does not substantially slide in the axial direction.

8. The process of claim **1**, wherein the tension imparted to the yarn is defined by the following formula

$$0.70 > F_1 > 6.35 \times 10^{-4}V - 0.100$$

wherein F_1 and V are as defined above.

* * * * *