United States Patent [19]

Minami et al.

[11] **3,750,382**

[45] **Aug. 7, 1973**

[54] **PROCESS AND APPARATUS FOR FEEDING FIBER IN AN OPEN END SPINNING MACHINE**

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[73] Assignee: **Toray Industries, Inc.,** Tokyo, Japan

[22] Filed: **Mar. 10, 1972**

[21] Appl. No.: **233,576**

[52] **U.S. Cl.** **57/58.91,** 57/58.95

[51] **Int. Cl.** **D01h 1/12**

[58] **Field of Search** ..... 57/58.89–58.95, 50, 90, 156; 19/105; 66/9 B

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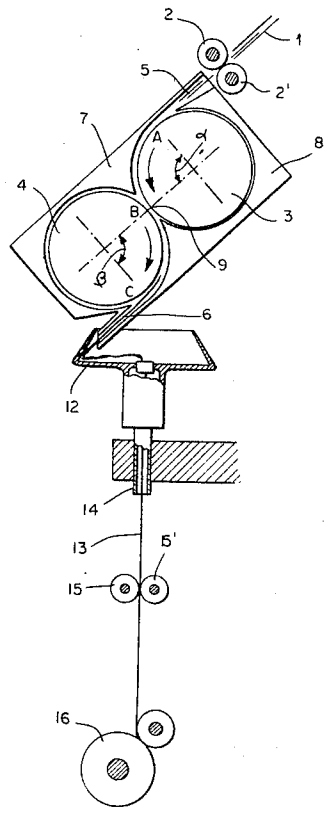
Attorney—Austin R. Miller et al.

[57] **ABSTRACT**

The present invention relates to a process and to an apparatus for feeding fibers in a process for manufacturing spun yarn using the open end system. More particularly, the invention relates to an improvement in a process for separating and feeding a fiber bundle in an open end spinning machine using combing rollers.

7 Claims, 11 Drawing Figures



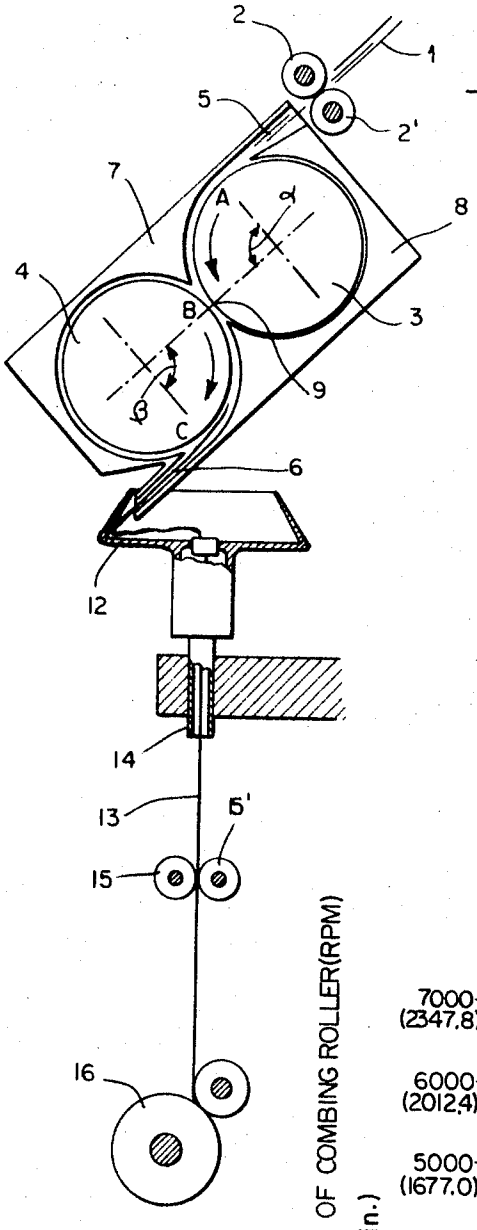


Fig. 1

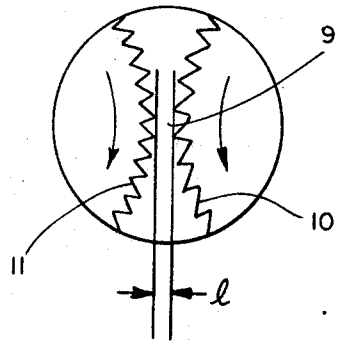
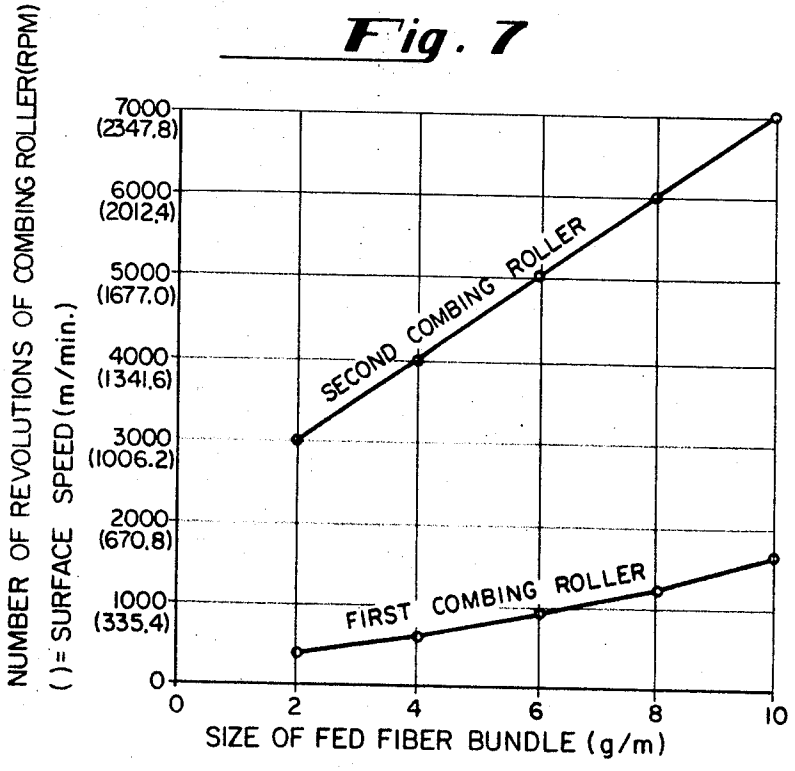


Fig. 2

Fig. 7



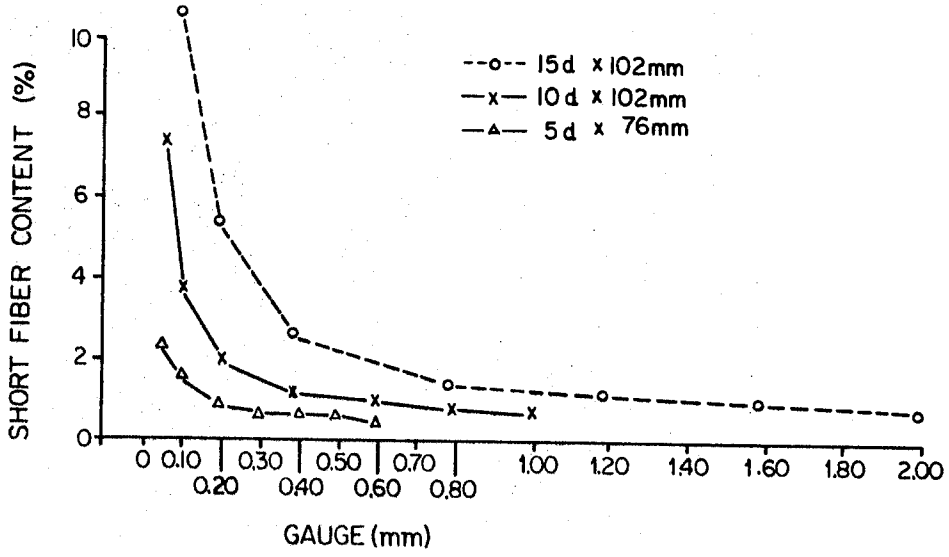

SHORT FIBER CONTENT (%)
10
8
6
4
2
0
15d x 102mm
10d x 102mm
5d x 76mm
0 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 1.00 1.20 1.40 1.60 1.80 2.00
GAUGE (mm)

Fig. 3

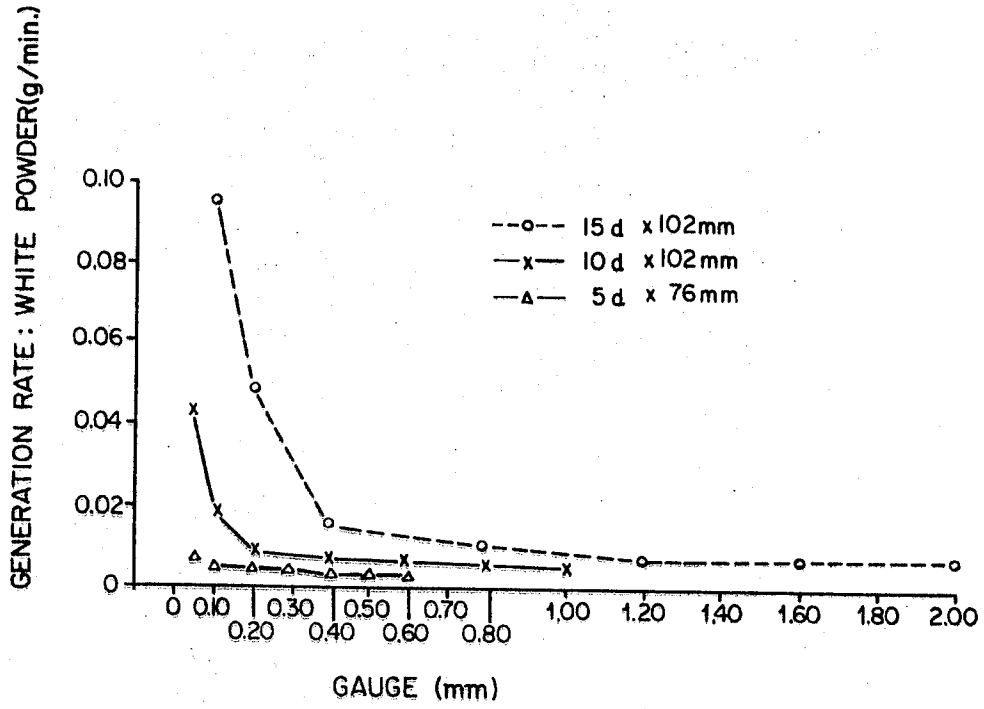

GENERATION RATE : WHITE POWDER(g/min.)
0.10
0.08
0.06
0.04
0.02
0
15d x 102mm
10d x 102mm
5d x 76mm
0 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 1.00 1.20 1.40 1.60 1.80 2.00
GAUGE (mm)

Fig. 4

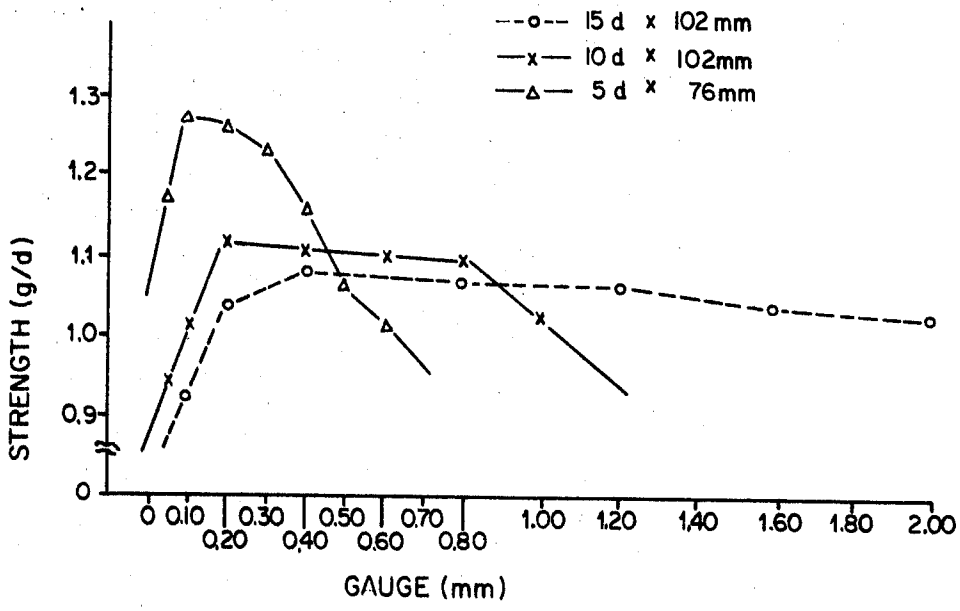

15 d x 102 mm
10 d x 102mm
5 d x 76mm
STRENGTH (g/d)
1.3
1.2
1.1
1.0
0.9
0
0 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 1.00 1.20 1.40 1.60 1.80 2.00
GAUGE (mm)

Fig. 5

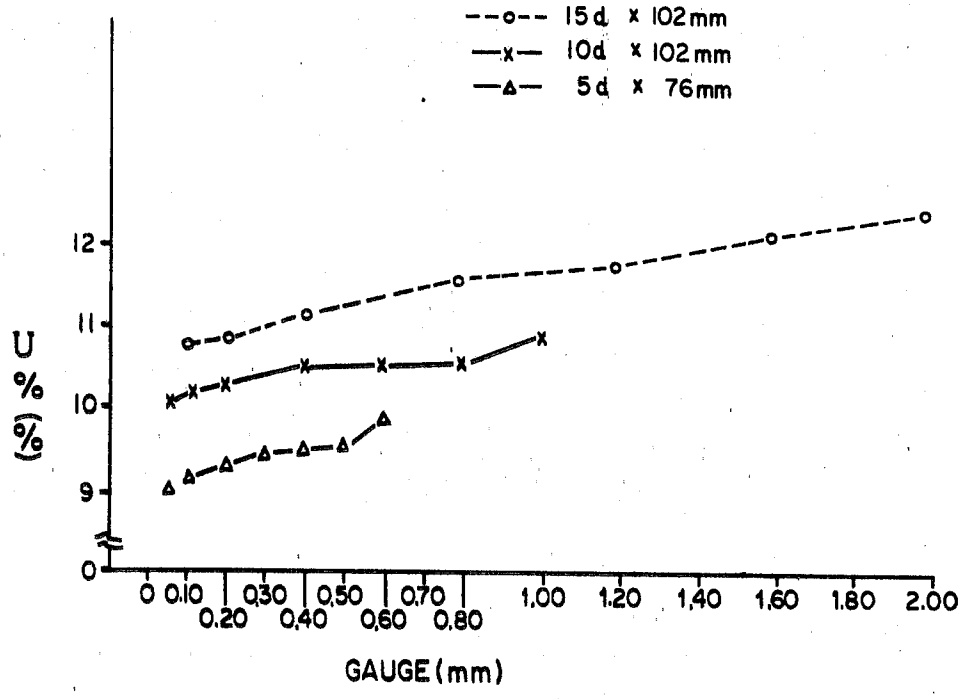

15 d x 102mm
10d x 102mm
5 d x 76mm
U %
12
11
10
9
0
0 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 1.00 1.20 1.40 1.60 1.80 2.00
GAUGE (mm)

Fig. 6

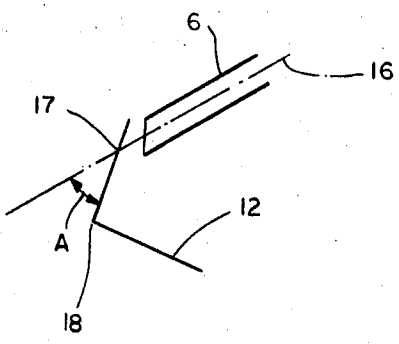


Fig. 8

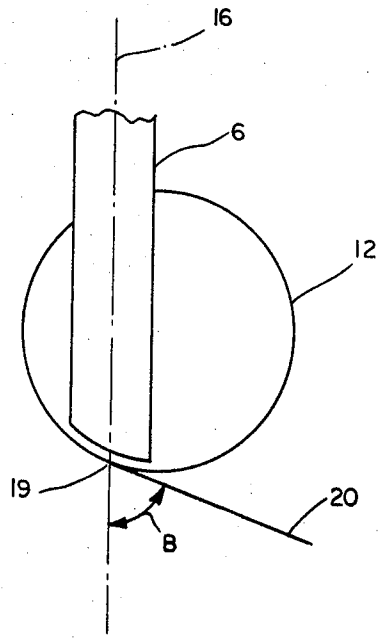


Fig. 9

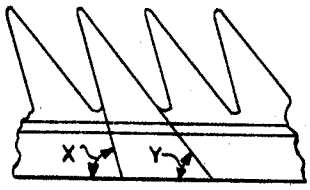
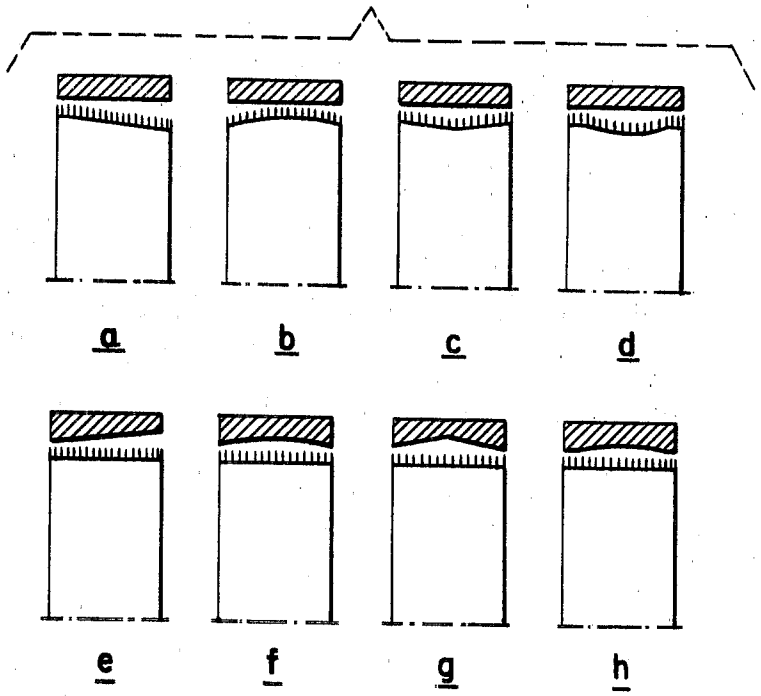


Fig. 11

Fig. 10



PROCESS AND APPARATUS FOR FEEDING FIBER IN AN OPEN END SPINNING MACHINE

FIELD OF THE INVENTION

In spinning in an open end system, a fiber bundle is separated into individual fibers by the force of air or by a mechanical combing apparatus, and separated fibers are fed into a twisting apparatus such as a twist chamber having a helical air current or rotary spinning chamber which causes the fibers to be rebundled and twisted and taken up in the form of twisted spun yarn. And in such a process, it is no exaggeration to say that the performance of the combing apparatus determines the performance of the spinning machine.

DISCUSSION OF THE PRIOR ART

In separating a fiber bundle into individual fibers with the use of air, feeding of a fiber bundle to a combing apparatus may be easily carried out by using the air current as the transporting means. The fibers are not injured by the combing operation and feeding of the separated fibers to the bundling and twisting apparatus is carried out in such a way that the separated fibers are suspended in an air current. Therefore, the process may be carried out smoothly.

In a mechanical combing process using a combing roller or combing blade, the ability of the combing device for separating the fiber bundle into individual fibers is by far superior to the air process. However, it is difficult to feed the fiber bundle smoothly into the combing apparatus and the fibers are likely to be damaged when they receive the mechanical combing operation.

When feeding of the fiber bundle is not carried out smoothly, the spun yarn becomes uneven and yarn breakage is encountered. Also, injury to the fibers and cutting or breakage of the fiber bundle bring about various problems such as reduction of the tenacity and elongation properties of the spun yarn due to reduction of the average fiber length as well as interference with the continuous operation of the machine.

In order to separate a fiber bundle consisting of long fibers such as wool into individual fibers, it is almost impossible to do so by means of air; a mechanical combing process is needed. In such mechanical combing process, it is necessary to make the feeding of the fiber bundle into the combing apparatus smooth, to decrease as much as possible the damage to the fibers in the combing apparatus and to carry out completely the separation into individual fibers. However, in the processes hitherto employed, no fiber feeding and separating apparatus satisfying such conditions has, to our knowledge, been obtained.

OBJECTS OF THE INVENTION

An object of the present invention is to overcome the aforementioned drawbacks of the prior art and to provide a process for separating and feeding a fiber bundle capable of smoothly feeding the fiber bundle to a combing apparatus and, at the same time, decreasing the chances of damage to the fiber, effectively carrying out separation of the fiber bundle and feeding the fibers in a highly oriented state, in other words, in a parallel state without interfering with the operation of the spinning chamber.

Another object of the present invention is to obtain open end spun yarn from long fibers, for example, average fiber lengths of about 50 mm – 200 mm, free from any of the aforementioned difficulties, on a commercial basis at a high speed and of very high quality.

BRIEF DESCRIPTION OF THE INVENTION

This invention relates to the concept of separating and feeding fibers in a combing apparatus in an open end spinning machine adapted for feeding a fiber bundle to a spinning chamber via a combing zone consisting of two combing rollers adjoining at a very small interval and rotating in mutually opposite directions. It has been discovered that the fiber may be, with surprising advantage, fed and discharged in tangential directions to the combing rollers, such that the angle at which the first combing roller acts on the fiber is about 90° – 135° and the angle at which the second combing roller acts on the fiber is about 45° – 135°, when the diameters of the respective combing rollers are not smaller than the average fiber length but not larger than about 1.5 times the average fiber length.

DRAWINGS

FIG. 1 is a drawing (partially schematic) showing one embodiment of a process for feeding fibers according to the present invention;

FIG. 2 is an enlarged view of portion B in FIG. 1, namely, the area where the two combing rollers approach each other most closely;

FIG. 3 is a graph showing the relationship between the gauge and the short (staple) fiber content;

FIG. 4 is a graph which shows the relationship between the gauge and the rate at which white powder is generated (spinning oil on fiber);

FIG. 5 is a graph which shows the relationship between the gauge and the tenacity or strength of the fibers;

FIG. 6 is a graph which shows the relation between the gauge and U percent;

FIG. 7 is a graph showing the relationship between the size of the fed fiber bundle and the number of revolutions of the combing rollers;

FIGS. 8 and 9 are schematic drawings showing the relationship between the fiber discharge pipe and the rotor of the apparatus for separating and feeding the fiber bundle;

FIG. 10 *a* through *h* is a series of schematic drawings serving as a specific example showing the relationships between the combing rollers and the casing; and

FIG. 11 is a schematic drawing showing in fragmentary form one example of the needles of a combing roller.

DETAILED DESCRIPTION OF THE INVENTION

We have conducted a strenuous study with reference to such drawbacks of the prior art, as mentioned above, and problems arising in the use of fibers having a fiber length of not less than 50 mm, which has not been even thought of in the conventional open end spinning process. As a result, we have succeeded in effectively making staple having long fibers into high quality open end spun yarn. This has been done by using two combing rollers rotating in mutually opposite directions and by critically relating therewith the feed direction of the fiber, the discharge direction to the rotor, the length of the combing zone and the relation between the combing rollers and the fiber length.

The present invention makes it possible to provide excellent separation and combing of the fiber bundle which is the basis of the open end spinning process, to reduce the damage to the fibers, and to feed the combed fibers to a bundling and twisting apparatus while retaining the parallelism of the combed fibers. This is attributable to the fact that the fiber bundle is fed to two combing rollers adjoining at a very small interval, and to rotating them in mutually opposite directions, to carry out precombing, and by rotating a first roller at a low speed and further combing by the first combing roller and a second combing roller rotating at a higher speed. This relaxes the impact imparted to the fibers between the fiber feed apparatus holding the fiber bundle and the first combing roller, and also between the first combing roller and the second combing roller, to minimize the damage to the fibers while providing excellent separation of the individual fibers.

The two combing rollers adjoin at a very small interval. Thus, we provide a first combing roller and a second combing roller so arranged that fibers on the surface of the first combing roller may be transferred to a second combing roller which is rotating at a speed higher than that of the first combing roller. This interval varies, depending upon the kind of fiber and the operating conditions. However, it is preferably 0.1 – 2 mm.

In this invention, two combing rollers are used, rotated in opposite directions. As compared to a case wherein the two rollers are rotated in the same direction, the fiber is transferred smoothly from the first combing roller to the second combing roller. At the same time, the combing effect is enhanced.

It is considered necessary that feeding of the fiber bundle from a positively holding fiber bundle feed apparatus to the first combing roller should be done in a substantially tangential direction to the first combing roller. By such feeding process, precombing is imparted to the fiber bundle. At the same time, fiber damage is minimized.

Further, after pre-combing, the fiber on the first combing roller is transferred to the vicinity of the second combing roller mainly by centrifugal force. Because that transfer of the fiber to the second combing roller may be carried out easily, the fiber is further combed efficiently by the second combing roller, which is rotating at a speed higher than that of the first combing roller. Utilizing centrifugal force acting on the fibers, the fibers are continuously fed to a bundling and twisting apparatus.

Furthermore, in the present invention it is considered necessary that the discharge of the fibers separated from the second combing roller should be accomplished in a substantially tangential direction to said roller. It is possible easily to feed the fibers to the bundling and twisting zone due to the centrifugal force that exists, and the action of the air current.

A specific example with reference to a fiber feeding process in an open end spinning machine of the present invention will be explained while referring to FIG. **1**.

In FIG. **1**, a fiber bundle **1** is fed continuously at a constant speed by a fiber bundle feed apparatus consisting of a pair of feed rollers **2, 2'**. The fiber bundle **1** fed from the feed rollers **2, 2'** is fed to a first combing roller **3** in a tangential direction via a fiber bundle guide hole of the combing apparatus. Because the first combing roller **3** rotates at a speed by far higher than that of the feed rollers **2, 2'** and the distance between the holding point of the feed rollers **2, 2'** and the point at which the fed fiber bundle **1** acts on the combing roller is established at a length close to the average fiber length of the fibers constituting the fiber bundle **1**; the fiber bundle **1** is pulled out from the nip by the first combing roller **3** and transferred to the adjoining portion **9** of the two combing rollers along a space between an upper casing **7** and the surface of the first combing roller **3**. Because the second combing roller **4** rotates at a higher speed than that of the first combing roller **3**, the fibers arriving at said adjoining portion **9** of the two combing rollers are stripped off by the second combing roller **4** and fed to a rotary spinning chamber **12** (which is a bundling and twisting apparatus) via a fiber feed pipe **6** located below the second combing roller **4** and in the lower casing **8**. On the surface of the first and the second combing rollers, for example, saw tooth combing members such as **10, 11** shown in FIG. **2** are mounted in order to comb the fibers.

The fibers arriving at the rotary spinning chamber **12** are re-bundled and twisted into yarn inside the rotary spinning chamber **12** which is rotating at a high speed, and the yarn is taken up by rollers **15, 15'** via a yarn discharge pipe **14** of said rotary spinning chamber **12**, and is wound up by a winder roller **16** to form a yarn package.

We have found that factors of importance include the working amount of the fibers, the arrangement of the two combing rollers, the surface speeds of the combing rollers and the relationship between the fiber length and the diameters of the combing rollers.

The diameters of the combing rollers, surface speeds of the combing rollers, namely, inertia force imparted to the fibers in order to smooth the transfer of the fibers, and the length of time through which the needles of the combing rollers act up on the fibers, are significant.

As a result of examining the combing action and transfer of the fibers in the present invention, we have found that it is preferable that the angle of rotation through which the first combing roller acts on the fibers (α in FIG. **1**) is about 90° –135° and the angle of rotation through which the second combing roller acts on the fibers (β in FIG. **1**) is about 45° – 135°.

When angles $\alpha\beta$ are defined, the fiber bundle fed in substantially the tangential direction to the first combing roller begins to receive the action of the first combing roller from the point of contact of the fiber guide pipe **5** with the first combing roller **3** to the area of closest approach **9** between the combing rollers **3, 4**, (angle α). The fibers receiving the action of the second combing roller **4** at the adjoining area **9** receive the action of the second combing roller **4** to the area adjacent the fiber feed pipe **6** (angle β). α is the angle subtended by an arc extending from the position where the fibers first contact the fitst combing roller to the area of closest approach, and β is the angle subtended by an arc extending from the area of closest approach to the position at which the fibers part from the second combing roller.

In the event that angle α is below 90°, the transfer of the fibers to the second combing roller is poor and the fibers surround the combing rollers, because the centrifugal force imparted to the fibers is small, in the area of closest approach of the two rollers. When α is above about 135°, the fibers tend to twine in the pre-combing

stage and the action of the combing rollers is excessively great and bending of and damage to the fibers results. When β is below about 45°, insufficient centrifugal force is imparted to the fibers and feeding of the fibers to the rotary spinning chamber **12** becomes difficult. When β is above about 135°, bending of and damage to the fibers increases, as will be mentioned in further detail later.

Not only are the acting angles of the combing rollers important; the inertia force imparted to the fibers matters as well.

When combing of the fiber bundle in the first combing roller is considered, the role played by the first combing roller is to introduce smoothly the fiber bundle fed at a constant speed into the combing apparatus, to comb the introduced fiber bundle without disturbing its parallelism, and to carry the fibers to the point of transfer to the second combing roller. In this case, in the first combing roller, it is necessary to so constitute the fibers that they may easily be stripped off to the second combing roller and easily carried to the adjoining point of the two combing rollers. Accordingly, it is necessary to bring the fibers into a state wherein almost all of the fibers come up from the surface to the combing member of the first combing roller. On the other hand, in the case of the second combing roller, it is necessary to impart enough centrifugal force to the fibers for throwing or forcing the fibers out of the exit portion of said fiber separating and feeding apparatus to the bundling and twisting apparatus **12**. Further, it is also necessary to carry out this feeding of the fibers always at a constant rate in a completely separated state, since yarn unevenness and yarn cutting or breakage are otherwise brought about.

From the foregoing comments, it is apparent that the inertia force to be imparted to the fiber has an important significance. From the results to be mentioned later, we have found that the surface speed of the first combing rollers V_1 (cm/sec) and the weight of one single fiber m (g) are in the relationship $50 \leqq mV_1^2 < 700$ and the surface speed of the second combing roller V_2 (cm/sec) and m are in the relationship $700 \leqq mV_2^2 \leqq 2000$.

In order to demonstrate the relationship between the acting angles α, β and the surface speeds (s) of the respective combing rollers in the present invention, runs were conducted using the apparatus of FIG. 1. The average fiber length used was 102 mm and fibers of the polyacryl series, polyester series and polyamide series were used. For the variation of "m", the denier was varied from 5 d to 20 d. The diameters of the first combing roller and the second combing roller were both 100 mm. The speed of the spinning chamber was established at 10,000 r.p.m. The results obtained appear in Tables 1 and 2.

As observed from Table 1, it is critical that the angle at which the first combing roller acts on the fiber is within the range of about 90° – 135° and in consideration of wind-up of the fibers around the combing roller, intertwining of the fibers and damage the fibers, the relationship $50 \leqq mV_1^2 < 700$ is highly preferable.

Upon transferring the fibers from the first combing roller to the second combing roller, unless the second combing roller is higher in surface speed than the first combing roller, it is not possible completely to strip off the fibers from the first combing roller, but wind-up of the fibers around the first combing roller and extreme disturbance of the parallelism of the combed and fed fibers are brought about. In the second combing roller, it is necessary tr discharge the fibers out of the separating and feeding apparatus by centrifugal force imparted to the fibers by said roller only. Accordingly, as is apparent from Table 2, in order to impart definite centrifugal force to the fiber, it is necessary that the second combing roller should have a distance for which said roller acts on the fiber at an angle of at least about 45°. However, when this distance is too long, the combed fibers intertwine again; therefore, it is preferable that the angle at which the second combing roller acts on the fiber is within the range of about 45° 14 135°. The centrifugal force which should be imparted to the single fibers by said combing roller should be within such range that the single fibers completely part from the surface of the second combing roller and damage to the fibers upon being stripped off mainly from the first combing roller is inhibited as much as possible and from Table 3, the relationship $700 \leqq mV_2^2 \leqq 2000$ is highly preferable.

TABLE 1

[Relation among the angle at which the first combing roller acts on the fiber, mV_1^2, and combed condition]

mV_1^2 (g. cm.²/sec.²)	Angle at which the first combing roller acts on the fiber		
	45–90°	90–135°	135–180°
0.1 1.0 10	Combing is poor. Winding of the fibers around the combing rollers takes place.		
50 200 400 700	Transfer to the second combing roller is not smooth.	Combing in good shape. Damage of fiber is little.	Many fibers are bent.
1,000 2,000 3,000	....do.....	The higher the speed, the more fiber damage	Do.

TABLE 2

[Relation among angle at which the second combing roller acts on fibers mV_2^2 and combed condition]

mV_2^2 (g.cm.²/sec.²)	Angle at which the second combing roller acts on the fiber		
	0–45°	45–90–135°	135–180–270°
10 50 200 400	Stripping off from first combing roller of the fibers is impossible, or winding of fibers around first and second combing rollers takes place. Fibers cannot be spun.		
700 1,000 2,000	Transfer of the fibers is difficult.	Stripping off from the first combing roller and peeling off from the second combing roller of the fibers are complete. Transfer of the fibers from the fiber feed pipe to the rotary spinning chamber is smooth.	Much bending.
3,000	....do.....	Damage to the fibers increases. Fiber powder accumulates inside the rotary spinning chamber.	Same as above. As the speed becomes high damage to fibers increases remarkably.

In the present invention, it is desirable that the diameter of the second combing roller be greater than the average fiber length of the fiber used, as in the case of the first combing roller.

The diameters of the two combing rollers may be the same or different provided that they satisfy all of the aforesaid conditions. Various forms of rollers can be used, such as metal rollers having surface unevenness, and surfaces wound with a metallic wire such as in a card, or toothed wheels, for example.

It is preferable that in the present invention, a rotary spinning chamber be used as a bundling and twisting apparatus. However, such apparatus is not limited to said chamber.

Because the fibers are fed in a tangential direction to the first combing roller in said combing apparatus, it is possible to feed the fiber bundle smoothly, and it is also possible to minimize the injury to the fibers due to the combing roller utilizing an absorbed air current created by the high speed of revolution of the first combing roller.

Again, because the separated fibers are discharged from the second combing roller in a tangential direction to said roller, it is possible easily to feed the fibers to the rotary spinning chamber by the centrifugal force of said combing roller with the significant assistance of the generated air current.

As mentioned above, by utilizing the separating and feeding apparatus of the present invention, it has become possible to realize open end spinning of long fibers whose average fiber length is even above 70 mm, the spinning of which has heretofore been considered impossible.

Even the present invention is considerably affected by denier of the fibers used; unless the size of the fibers and the combing action are in proper relation, damage to and cutting of the fibers take place often, it is not possible effectively to carry out separation and combing of the fibers. We have found that the relation of the denier of the fibers with the gauge (*l* in FIG. 2) between the two combing rollers is important. If the gauge is too broad, the degree of combing and transfer of the fibers become poor, spinnability becomes poor and the yarn characteristics suffer. On the other hand, when the gauge is too narrow, fiber damage becomes remarkable and the yarn characteristics suffer; such phenomena are affected remarkably by fiber denier.

In the case of fiber the denier of whose fibers is small, even when the gauge is small, injury of the fibers is small and the degree of combing increases. When the gauge becomes broad, the degree of combing lowers. On the other hand, in case of heavy denier fibers when the gauge is narrow, fiber damage is considerable and even when the gauge is broad, the degree of combing is not reduced.

In order to make the aforesaid relation clear, we have examined the relationship between the gauge (*l* in FIG. 2) and the denier in terms of yarn quality and spinnability of materials of 15 *d* × 102 mm, 10 *d* × 102 mm and 5 *d* × 76 mm using the apparatus of FIG. 1, obtaining the following results.

The examined results of the relations between the gauge and the denier in terms of yarn quality and spinnability of fiber of 15 *d* × 102 mm are shown in Table 3, the examined results of fiber of 10 *d* × 102 mm are shown in Table 4 and the examined results of fiber of 5 *d* × 76 mm are shown in Table 5.

TABLE 3

[15 d. x 102 mm.]

Items	Gauge (mm.)						
	0.10	0.20	0.40	0.80	1.20	1.60	2.00
Tenacity (g./d.)	0.93	1.04	1.08	1.07	1.06	1.04	1.03
Elongation (percent)	12.2	13.8	13.7	13.1	12.9	13.1	12.5
U% (percent)	10.8	10.9	11.2	11.7	11.8	12.2	12.5
Containing ratio of short fiber (percent)	10.5	5.3	2.5	1.3	1.1	1.0	0.7
Generated amount of white powder (g./min.)	0.095	0.049	0.015	0.010	0.007	0.007	0.007
Yarn breakage during operation for 10 hrs. (times/machine)	3	1	None	None	1	2	5

TABLE 4

[10 d. x 102 mm.]

Items	Gauge (mm.)						
	0.05	0.10	0.20	0.40	0.60	0.80	1.00
Tenacity (g./d.)	0.95	1.01	1.12	1.11	1.10	1.09	1.03
Elongation (percent)	13.4	13.8	14.8	14.2	14.0	14.1	13.3
U% (percent)	10.1	10.2	10.3	10.5	10.6	10.6	10.7
Containing ratio of short fiber (percent)	7.4	3.7	2.0	1.1	1.0	0.8	0.6
Generated amount of white powder (g./min.)	0.044	0.018	0.009	0.007	0.007	0.007	0.005
Yarn breakage during operation for 10 hrs. (times/machine)	3	1	None	None	None	1	2

TABLE 5

[5 d. x 76 mm.]

Items	Gauge (mm.)						
	0.05	0.10	0.20	0.30	0.40	0.50	0.60
Tenacity (g./d.)	1.17	1.27	1.26	1.22	1.16	1.06	1.05
Elongation (percent)	13.9	14.2	14.5	14.1	13.2	13.2	13.1
U% (percent)	9.0	9.2	9.3	9.5	9.5	9.6	9.8
Containing ratio of short fiber (percent)	2.3	1.5	0.8	0.6	0.5	0.6	0.4
Generated amount of white powder (g./min.)	0.007	0.005	0.004	0.004	0.003	0.003	0.003
Yarn breakage during operation for 10 hrs. (times/machine)	None	None	None	1	1	5	7

The spinning conditions in the aforesaid experiments were as follows:

	15 d.	10 d.	5 d.
Material	Acrylic fiber.	Acrylic fiber.	Acrylic fiber.
Yarn count	1/5	1/5	1/6.
Spinning speed (m./min.)	40	40	33.3.
Turns of twist per meter (T./m.)	250	250	300.

First combing roller:	
Working angle	65°
Number of needle points	544
Outer diameter	100 mm
Speed	3000 rpm
Second combing roller:	
Working angle	90°
Number of needle points	272
Outer diameter	100 mm
Speed	6000 rpm
Speed of the rotary spinning chamber	10000 rpm
Gauge	0.05 mm
	0.10 mm
	0.20 mm
	0.30 mm
	0.40 mm
	0.50 mm
	0.60 mm
	0.80 mm
	1.00 mm
	1.20 mm
	1.60 mm
	2.00 mm

The aforesaid results are shown in the drawings. The relationship between denier and gauge in terms of tenacity is shown in FIG. 5, said relationship in terms of U percent is shown in FIG. 5, said relationship in terms of the amount of white powder generated is shown in FIG. 4, and the relationship between the gauge and the containing ratio of short fibers is shown in FIG. 3. The containing ratio of short fibers as referred to herein is the ratio of single fibers whose lengths are shorter than one-half of the prescribed length of the single fibers in a constant weight of the spun yarn. The generated amount of white powder is the weight of white powder

generated in the combing apparatus and accumulated in the rotary spinning chamber, measured by a balance and shown by weight (*g*)/min.

From the foregoing examination, the optimum gauge and range of good gauge with reference to yarn quality and spinnability in the respective deniers will be shown in Table 6.

TABLE 6

Denier	Optimum gauge (mm)	Range of good gauge (mm)
5 d	0.10	0.05 – 0.50
10 d	0.20	0.10 – 1.00
15 d	0.30	0.20 – 1.50

When the relationship between the gauge and the denier is sought from Table 6, the optimum gauge becomes *d*/50 (mm) and the range without problems with reference to the yarn quality and spinnability is *d*/10 – *d*/100 (mm).

Further, in order to decrease fiber damage and to advance the separating and combing effects of the fibers, in the present invention, the working angles of the needles and number of the needle points of the two combing rollers become problems. We found that it is preferable to use a working angle of about 60° – 90° and number of needle points of about 200 – 600/in² in the first combing roller and a working angle of about 60 ° – 90° and number of needle points of about 200 – 300/in² in the second combining roller. This keeps the combing properties within a satisfactory range and inhibits damage to the fibers within an easily acceptable range. Any working angle of the first combing roller can be selected for practical use.

The working angle of saw teeth is shown by angle X in FIG. **11**. Angle Y in FIG. **11** is a back angle, and it is preferable that Y is about (X – 20°) so that the fiber combed and hooked by said teeth does not tend to come off. It is preferable that the depth of the tooth be substantial so that the combing action may be carried out sufficiently, and it is preferable that the needle point portion be flat rather than sharp, and that its area be about 0.02 – 0.04 cm².

In order to make the aforesaid relation clear, the apparatus shown in FIG. **1** was used and observed in the following manner:

The working angle of the saw tooth-like member which is a combing member of the first combing roller **3** is referred to as X_1 in FIG. **11** and the working angle of the saw tooth-like member of the second combing roller **4** is referred to as X_2. With reference to coarse denier fiber such as 10 *d* and 15 *d*, the relationship between the combination of X_1 with X_2 and the damage to the fibers is shown in Table 7. The relationship between the combination of X_1 with X_2 and the combing effectiveness is shown in Table 8. When the results are observed with reference to the damage to the fibers, at a working angle of the second combing roller of 80° – 90°, good results are shown regardless of the working angle of the first combing roller. When the results are observed with reference to the combing effectiveness within the range at which the damage to the fibers is small, the combing effectiveness is generally poor. The damage to the fibers operationally causes various problems and the poor combing properties cause poor yarn quality and increase of yarn breakage. When it is attempted to reduce the damage to the fibers, combing becomes poor and when it is tried to improve the combing effectiveness, the damage to the fibers increases remarkably. Accordingly, when continuous operations are in mind, reference being had to Tables 7 and 8, the following can be said of the working angles for coarse denier fiber:

It is preferable that the working angle of the first combing roller be within the range of about 60° – 90° and that the working angle of the second combing roller be within the range of about 80° – 90°.

TABLE 7

X_2(°) \ X_1(°)	60	70	80	90
60	XX	XX	XX	XX
70	XX	XX	XX	XX
80	X	X	X	X
85	O	O	O	O
90	O	O	OO	OO

NOTE: XX — very poor; X — poor; **0** — good; **00** — without problems at all

TABLE 8

X_2(°) \ X_1(°)	60	70	80	90
60	**00**	**00**	**00**	**00**
70	**00**	**00**	**00**	**00**
80	**0**	**0**	**0**	**0**
85	**0**	**0**	**0**	X
90	**0**	**0**	X	X

However, the denier of the fibers used for spun yarn is within the broad range of about 1.5 – 20 *d*, and it is generally true that a coarse denier fiber is used for coarse count yarn and a fine denier fiber is used for fine count yarn.

Because fine denier fiber such as 3 *d* and 5 *d* is soft and easy to bend, as compared with coarse denier fiber such as 10 *d* and 15 *d*, when the fine denier fiber receives the combing action by combing rollers, the fiber is virtually unharmed.

Fine count yarn constituted by fine denier fiber is often used for clothing and it is necessary to make yarn which has as little unevenness as possible.

Accordingly, with reference to fine denier fiber, it is preferable that the working angle of the first combing roller be about 80° – 90° and that the working angle of the second combing roller be about 60° – 90°.

Next, the relation of the number of needle points of the combing members having these working angles to the damage to the fibers and the combing qualities of the fibers, is shown in Table 9. With reference to the number of needle points also, the relationship with the damage to the fiber with its combing properties is entirely the same, and from Table 9, it is preferable that the number of needle points be within the following ranges:

Number of needle points of the first combing roller: about 150 – 600/in²

Number of needle points of the second combing roller: about 150 – 300/in²

TABLE 9

No. of needle points/in²	Damage to the fiber		Combing properties	
	First combing roller	Second combing roller	First combing roller	Second combing roller
100	X	X	**00**	**0**
150	**0**	**0**	**00**	**0**
200	**0**	**00**	**00**	**00**
300	**0**	**0**	**00**	**00**
400	**00**	X	**00**	**0**
500	**00**	X	**00**	X
600	**00**	X	**0**	XX
700	**00**	XX	X	XX

Because the first combing roller is small in working angle and rotates at less speed than the second combing roller, so that it may pre-comb the fibers fed by the feed rollers and feed the fiber smoothly to the second combing roller, the number of needle points is great. It is preferable that the second combing roller have a speed higher than that of the first combing roller and sufficient for transferring the fiber combed by the second combing roller to the bundling and twisting apparatus by centrifugal force.

The particulars of the spun yarn used in the aforesaid runs are as follows:

Material:	Acrylic fiber 10 d × 102 mm
Yarn count:	1/5 (meter system)
Number of twists	200 T/m

rollers and the mass of the single fiber is made clear, however, it is known that the size of the fed fiber bundle as a whole greatly affects the combing properties. It is found that by keeping the size of the fiber bundle and peripheral speeds of the two combing rollers under the optimum conditions, a fiber bundle of any size is combed adequately. Using the apparatus shown in FIG. 1, runs were conducted with reference to fiber bundles of acrylic fiber of 10 d × 102 mm having various sizes and the results were examined. In Table 10, the relationship between the weight of the fiber bundle and the r.p.m. of the combing rollers is shown in terms of whether the combing properties are good and whether the fibers wind around the rollers.

TABLE 10

	Size of fiber bundle				
	2 g./m.	4 g./m.	6 g./m.	8 g./m.	10 g./m.
R.p.m. of the first combing roller; peripheral speed (m./min.) is indicated within the parentheses:					
200 (67.0)	X	X	X	X	X
400 (134.1)	O	X	X	X	X
600 (201.2)	O	O	X	X	X
800 (268.3)	O	O	O	X	X
1,200 (402.4)	O	O	O	O	X
1,600 (536.6)	O	O	O	O	O
2,000 (670.8)	O	O	O	O	O
3,000 (1,006.2)	O	O	O	O	O
4,000 (1,341.6)	O	O	O	O	O
5,000 (1,677.0)	O	O	O	O	O
R.p.m. of the second combing roller	5,000	5,000	5,000	5,000	5,000
Peripheral speed (m./min.) is indicated within the parentheses	(1,677.0)	(1,677.0)	(1,677.0)	(1,677.0)	(1,677.0)

NOTE.—X indicates that the fibers wind around the rollers; O indicates that the fibers do not wind around the rollers.

In the present invention, as mentioned earlier, the relation between the peripheral speeds of the combing

The following findings were made as to whether the combing property was good (O) or bad (X):

	Size of the fiber bundle				
	2 g./m.	4 g./m.	6 g./m.	8 g./m.	10 g./m.
R.p.m. of the second combing roller; peripheral speed (m./min.) is indicated in parentheses:					
400 (134.1)	X	X	X	X	X
800 (268.3)	X	X	X	X	X
1,600 (536.6)	X	X	X	X	X
2,000 (670.8)	X	X	X	X	X
3,000 (1,006.2)	O	X	X	X	X
4,000 (1,341.6)	O	O	X	X	X
5,000 (1,677.0)	O	O	O	X	X
6,000 (2,014.2)	O	O	O	O	X
7,000 (2,347.8)	O	O	O	O	O
8,000 (2,683.2)	O	O	O	O	O
R.p.m. of the first combing roller	400	600	800	1,200	1,600
Peripheral speed (m./min.) is indicated in parentheses	(134.1)	(201.2)	(268.2)	(402.4)	(536.4)

Other spinning conditions are as follows:

Material:	Acrylic fiber 10 d × 102 mm
Yarn count:	1/5
First combing roller:	
Working angle of combing member	65°
Number of needle points in combing member	408/in²
Outer diameter:	
Working width of combing roller	20 mm
Second combing roller:	
Working angle of combing roller	80°
Number of needle points	272/in²
Outer diameter:	110 mm
Working width of combing roller:	20 mm
Gauge between first combing roller and second combing roller:	0.2 mm

Size of fiber bundle (g/m)	Peripheral speed of feed roller (m/min)	Speed of rotary spinning chamber (rpm)	Spinning Speed (m/min)
2	7	15,000	70
4	3.5	15,000	70
6	2.4	15,000	70
8	1.8	15,000	70
10	1.4	15,000	70

The aforesaid results are shown in FIG. 7 of the drawings. The peripheral speeds of the combing rollers capable of continuous spinning without winding around said rollers V_1, V_2 (m/min) are functions of the size of the fiber bundle fed M (g/m), which can be shown as follows:

$$V_1 = 33.5\ M + 67.0$$

$$V_2 = 167.7\ M + 670.8$$

Next, in the present invention, upon carrying out open end spinning using a combing apparatus having the aforesaid structure, it is preferable to consider the amount of draft between the second combing roller and the rotary spinning chamber. It has been determined that it is proper that the draft of this portion is 10 – 50 times.

Again, in the present invention, in order to transfer the separated fibers from the combing apparatus to the rotary spinning chamber effectively without disturbing the arrangement of the fibers, it is necessary that the combing apparatus and the rotary spinning be arranged in a certain relation. The factors governing said mutual relation are, as shown in FIGS. **8** and **9**, an angle A at which the central axis **16** of the fiber feed pipe **6** crosses the fiber blowing plane of the rotary spinning chamber and an angle B at which the central axis **16** of said fiber feed pipe crosses the tangent **20** in the circumferential direction of the rotary spinning chamber at an intersecting point of the central axis of said fiber feed pipe and the fiber blowing plane of the rotary spinning chamber.

The angle A at which the central axis **16** of the fiber feed pipe **6** crosses the fiber blowing plane **17** of the rotary spinning chamber, and its relationship with spinnability is shown in Table **11**. Next, the angle B at which the central axis **16** of the fiber feed pipe **6** crosses the tangent **20** in the circumferential direction of the rotary spinning chamber **12** at the intersecting point **19** of the central axis **16** of the fiber feed pipe and the fiber blowing plane **17** of the rotary spinning chamber **12** is shown in Table 12.

TABLE 11

Item	A (°) 20	30	40	50	60	70
Yarn properties:						
Yarn count	1/10.1	1/10.1	1/10.1	1/10.1	Connection of the combing apparatus to the rotary spinning chamber is difficult. (The bottom of the combing apparatus contacts or tends to contact the rotary spinning chamber.)	
Twist (T/m)	295	295	295	295		
Strength (kg.)	1.08	1.16	1.21	1.20		
Elongation (percent)	16.3	17.2	17.3	17.2		
Yarn unevenness U% (percent).	13.4	12.0	11.2	11.3		
Spinning situation (fly generating situation).	Because fiber is fed at acute angle to the rotary spinning chamber, the fiber on entering said chamber flies out again.	Number of flies generated is small. The larger becomes, the less the number of flies.				
Slub generating situation	The combed fiber directly contacts yarn under twisting, intermingling therewith. Many slubs.	Number of fibers directly contacting and intermingling with yarn is small and almost no slubs generated.				
No. of yarn breakages/1,000 sp. hr.	110	68	45	50		

Spinning conditions:

Acrylic fiber "Toraylon"	5 d × 76 mm
First combing roller	
Diameter:	100 mm
Speed:	2000 rpm
Second combing roller	
Diameter:	100 mm
Speed:	5000 rpm
Rotary spinning chamber	
Largest inner diameter:	100 mm
Speed:	15000 rpm
Spinning speed:	45 m/min

TABLE 12

Item	B (°) 30	40	50	60	70	80	90
Yarn properties:							
Yarn count	Connection of the combing apparatus to the rotary spinning chamber is difficult.		1/10.1	1/10.1	1/10.1	1/10.1	1/10.1
Twists (T/m.)			295	295	295	295	295
Strength (kg.)			1.18	1.22	1.22	1.16	1.17
Elongation (percent)			17.2	17.4	17.4	17.3	17.3
Yarn unevenness U% (percent)			11.5	11.2	11.2	11.3	12.2
Spinning situation (fly generating situation)			Almost no fibers fly out of the rotary spinning chamber.				
Slub generating situation			Almost no slub is generated				
No. of yarn breakages/1,000 sp. hr			55	40	45	51	67

[1] A few fibers fly out of the rotary spinning chamber.

The spinning conditions of Table 12 are the same as those of Table 11. However, the angle A at which the fiber feed pipe of the combing apparatus crosses the fiber blowing plane of the rotary spinning chamber was fixed at 40°.

As will be apparent from Table 11, when A is small, viz. when the angle at which the fibers are fed to the rotary spinning chamber is acute, obstruction takes place such that the fibers are blown directly to the yarn being twisted or the fibers once hitting the bottom surface of the rotary spinning chamber flies out of the rotary spinning chamber again. And when A becomes large, the inclined angle of the fiber feed pipe becomes close to the horizontal, touching the rotary spinning chamber, which is dangerous.

Accordingly, in order to provide optimum industrially stable spinning conditions, it is necessary that A should be within the range of about 30°– 50°.

Next, from Table 12 also, it is preferable that B should be within the range of about 50° – 80°.

As mentioned above, when A is within the range of about 30° – 50° and B is within the range of about 50° – 80°, for the first time the fiber does not scatter in the environs of the machine frame, the amount of slub generated is small and it is possible to obtain spinning conditions satisfactory from the aspects of operability and safety.

When mention is made about the combing rollers used in the present invention, the provision of a gap between the combing rollers and the casing 7 is an important matter, and in the many combing rollers hitherto employed, the gap between said rollers and the casing 7 has been constant. However, when they are in such relationship, it becomes necessary to make this gap extremely narrow, and excessive combing action is brought about which tends to damage the fibers. Because of this, in order to improve such drawbacks, we vary the gap between the casing 7 and the combing rollers. Various methods of carrying this into effect are operable, such as those from *a* to *h* of FIG. **10**, and in each case good results are obtained.

The yarn obtained by open end spinning using the aforesaid separting and feeding process is a coarse denier spun yarn containing many bent fibers, excellent in raising property and suitable for obtaining raised products having long fur.

There are various ways of analyzing spun yarn obtained by the present invention. If it is cut into a length which is one-half the average fiber length L of the individual fibers constituting the spun yarn, the cut spun yarn is separated and a length shrunken by twisting and a length shrunken by crimping are taken into account, and the weight W of fiber having fiber lengths longer than the sum of these lengths and $L/2$ is measured, then the ratio thereof to the entire weight W_0 of the cut spun yarn W/W_0 is within the range of 0.2 – 0.4. In other words, it is spun yarn containing a plurality of fibers bent to the axial direction of the spun yarn.

Because the yarn according to the process of the present invention is obtained, as mentioned above, by twisting single fibers constituting the spun yarn in a bent state, the spun yarn yarn has many voids, the yarn structure is coarse and raising of the yarn after it is made into knitted or woven fabric is easy.

It is preferable to raise the spun yarn obtained in accordance with the process of the present invention after it is knitted or woven into fabric or after it is used for all raised products such as pile fabric, carpet and blanket. Very useful products are obtained from said spun yarn.

The following is claimed:

1. A process for separating and feeding a bundle of fibers by a combing apparatus of an open end spinning machine which process comprises feeding the bundle of fibers to a spinning chamber via a combing zone consisting of two combing rollers spaced apart from one another at a very small interval and rotating in mutually opposite directions, characterized in that feeding and discharging of the fibers are carried out in tangential directions to the combing rollers, the angle of rotation through which a first combing roller acts on the fibers being about 90° – 135°, the angle of rotation through which a second combing roller acts on the fibers is about 45° – 135° and diameters of the respective combing rollers are substantially within the range from the average fiber length L to 3/2 L.

2. The process according to claim **1** wherein V_1 represents the surface speed (cm/sec) of the first combing roller and V_2 the surface speed (cm/sec) of the second combing roller, and the weight of one single fiber is represented by m (grams), and wherein $50 \leqq mV_1^2 < 700$ and $700 \leqq mV_2^2 \leqq 2000$.

3. The process according to claim **1** wherein the denier of the single fibers constituting the fiber bundle is d, and wherein the gauge between the two combing rollers is in the range of about $d/10 - d/100$ (mm).

4. The process according to claim **1** wherein the amount of draft of said combing apparatus is about 10 – 50 times.

5. A combing apparatus in an open end spinning machine which comprises two combing rollers adjoining at a very small interval and rotating in mutually opposite directions in a casing, providing an exit of a fiber bundle feed pipe on a first combing roller, wherein the angle made by the line from said exit to the center of the first combing roller and the line from the closest point of the two rollers to the center of said first combing roller is about 90° – 135°, and an entrance of a fiber discharge pipe on a second combing roller wherein the angle made by the line from said entrance to the center of the second combing roller and the line from the closest point of the two rollers to the center of said second combing roller is about 45° –135° and said fiber bundle feed pipe and said fiber discharge pipe are disposed in tangential directions to the respective combing rollers.

6. The combing apparatus according to claim **5** wherein the working angle of the combing member of the first combing roller is about 60° – 90° and the number of needle points of said combing roller is about 400 – 600/in², the working angle of the combing member of the second combing roller is about 60° – 90° and the number of needle points of said combing member is about 200 – 300/in².

7. The combing apparatus according to claim **5** wherein said fiber discharge pipe and a rotary spinning chamber are so disposed that an angle A at which said fiber discharge pipe crosses the rotary spinning chamber is about 30° – 50° and an angle B at which said fiber discharge pipe crosses the tangent of the rotary spinning chamber is about 50° – 80°.

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