Fig. 1

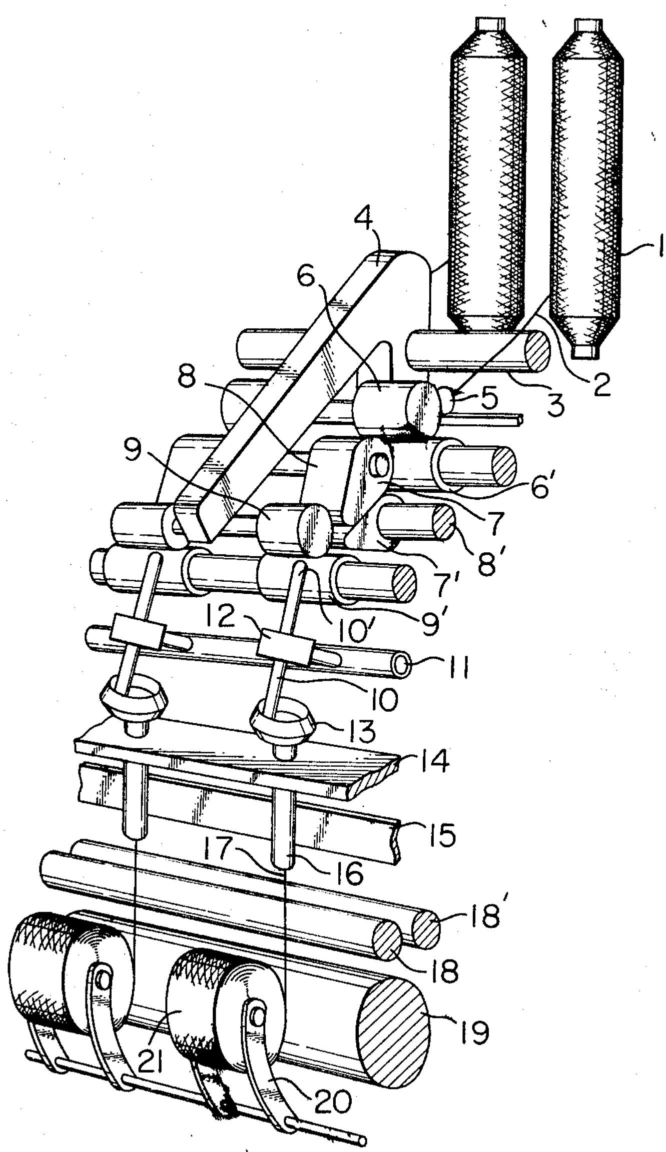


Fig. 2

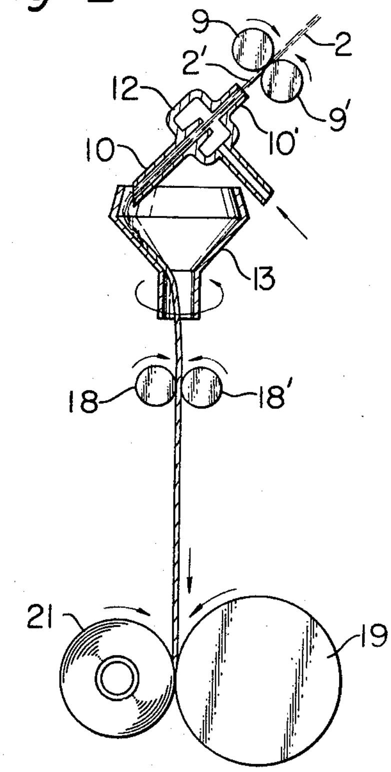


Fig. 3

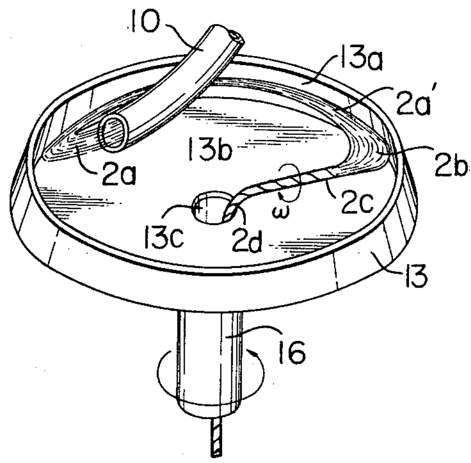


Fig. 4

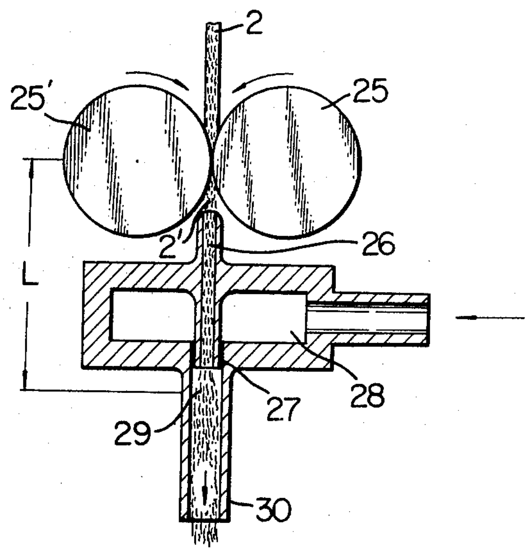
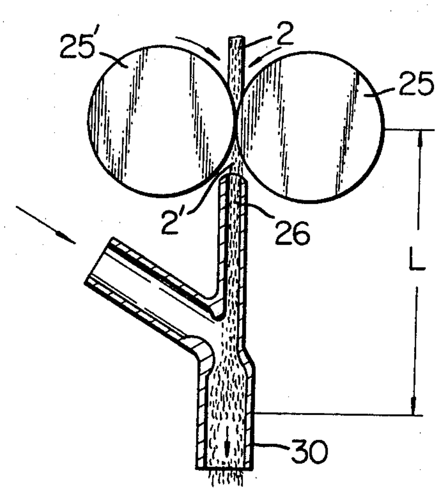


Fig. 5



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SPINNING METHOD AND APPARATUS FOR MANUFACTURING
YARN FROM TEXTILE FIBERS
Filed Aug. 16, 1967 19 Sheets-Sheet 4

Fig. 6A

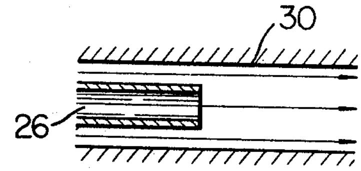


Fig. 6B

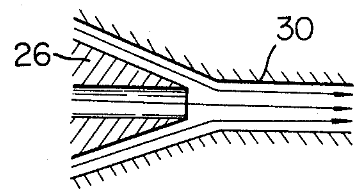


Fig. 6C

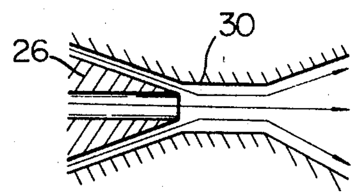
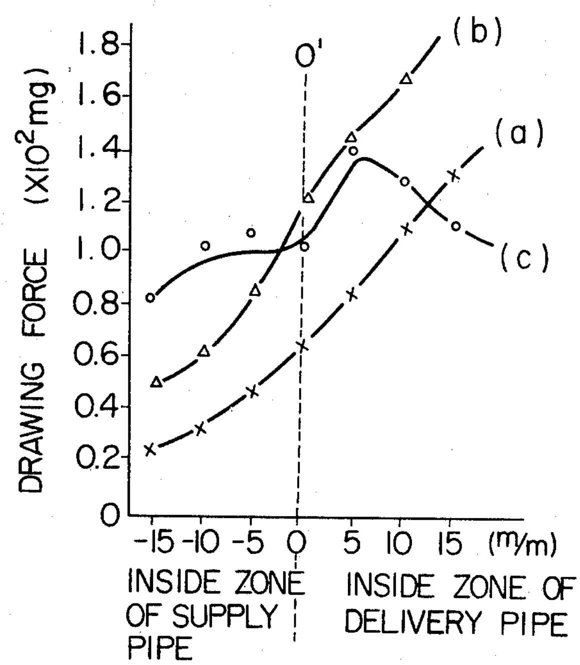


Fig. 7



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SPINNING METHOD AND APPARATUS FOR MANUFACTURING YARN FROM TEXTILE FIBERS

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Fig. 8

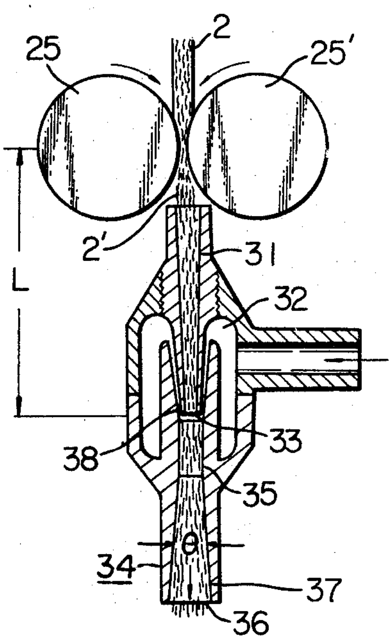
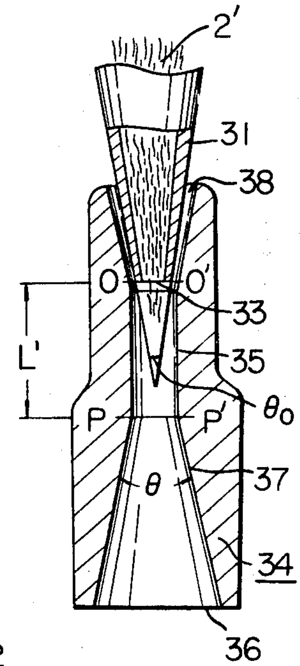


Fig. 9



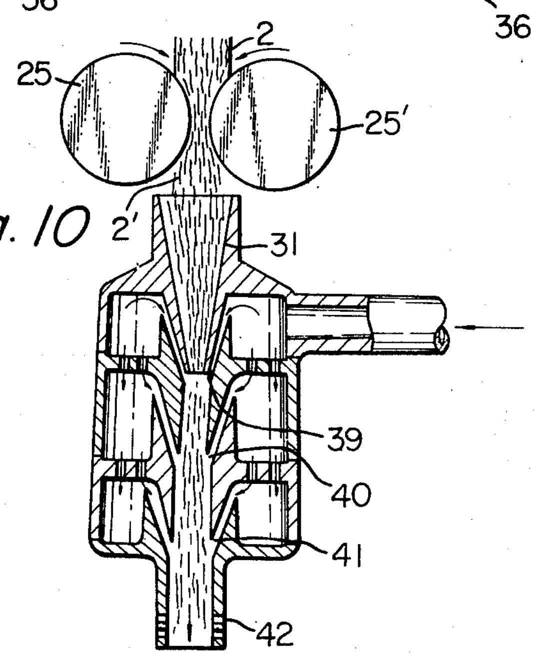


Fig. 10

Fig. 11A

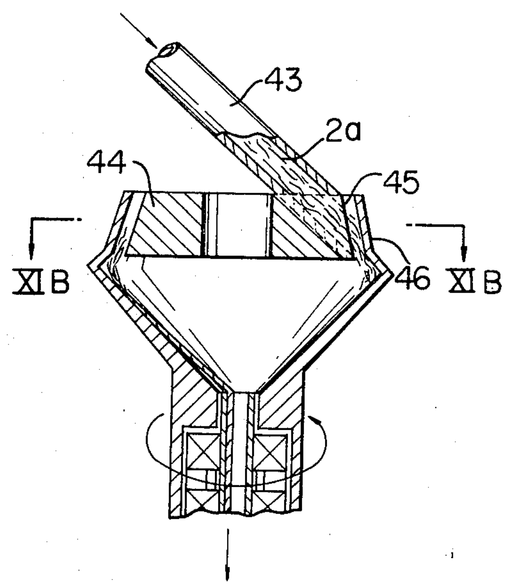


Fig. 11B

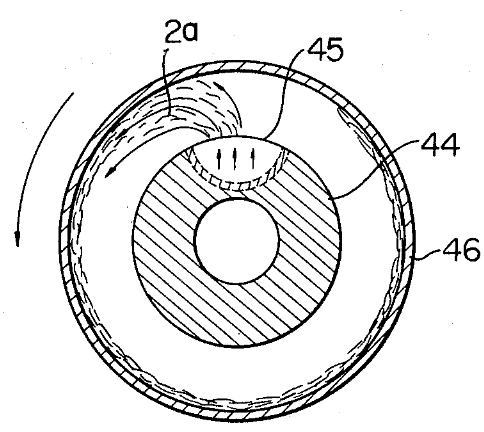


Fig. 12

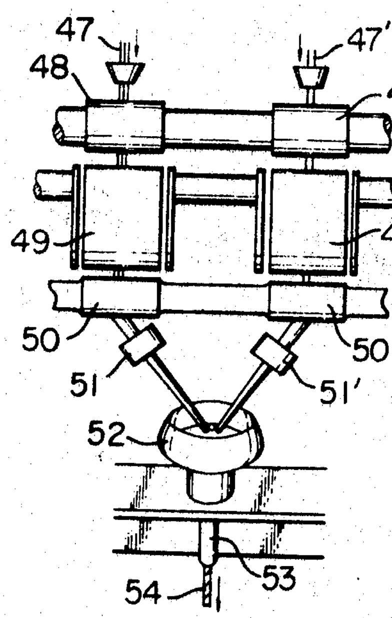


Fig. 13

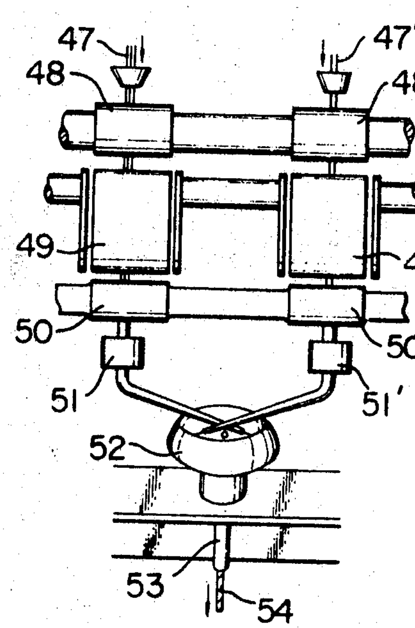


Fig. 14

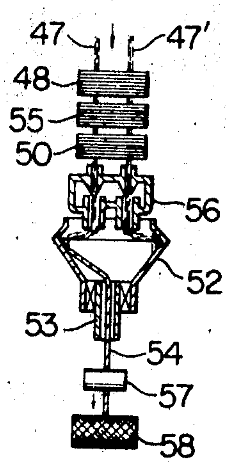


Fig. 15

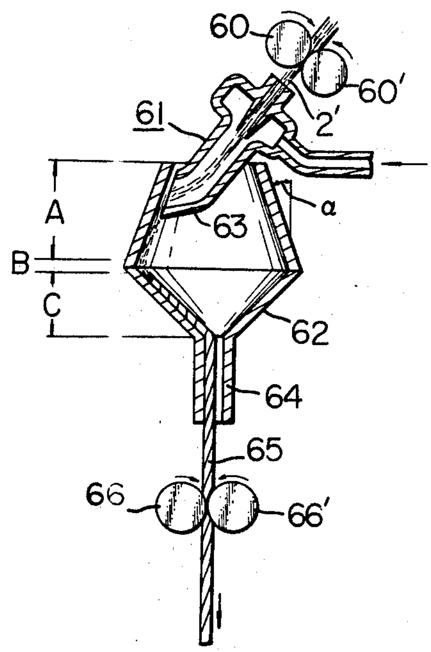


Fig. 16A

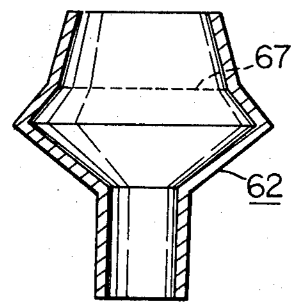


Fig. 16B

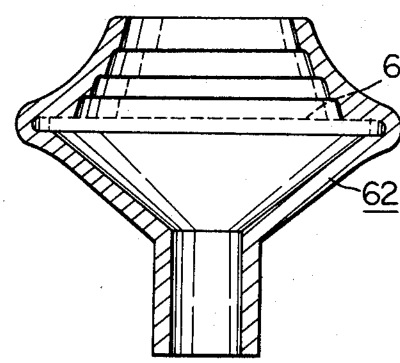


Fig. 16D

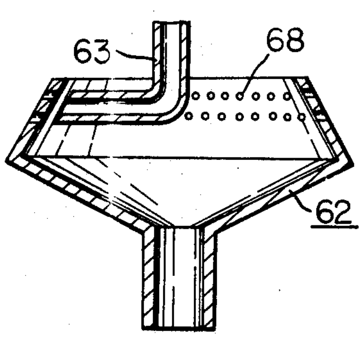


Fig. 16C

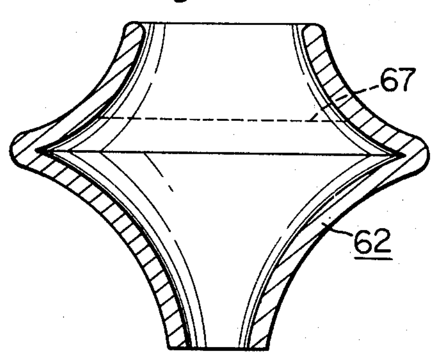


Fig. 17A Fig. 17B Fig. 17C

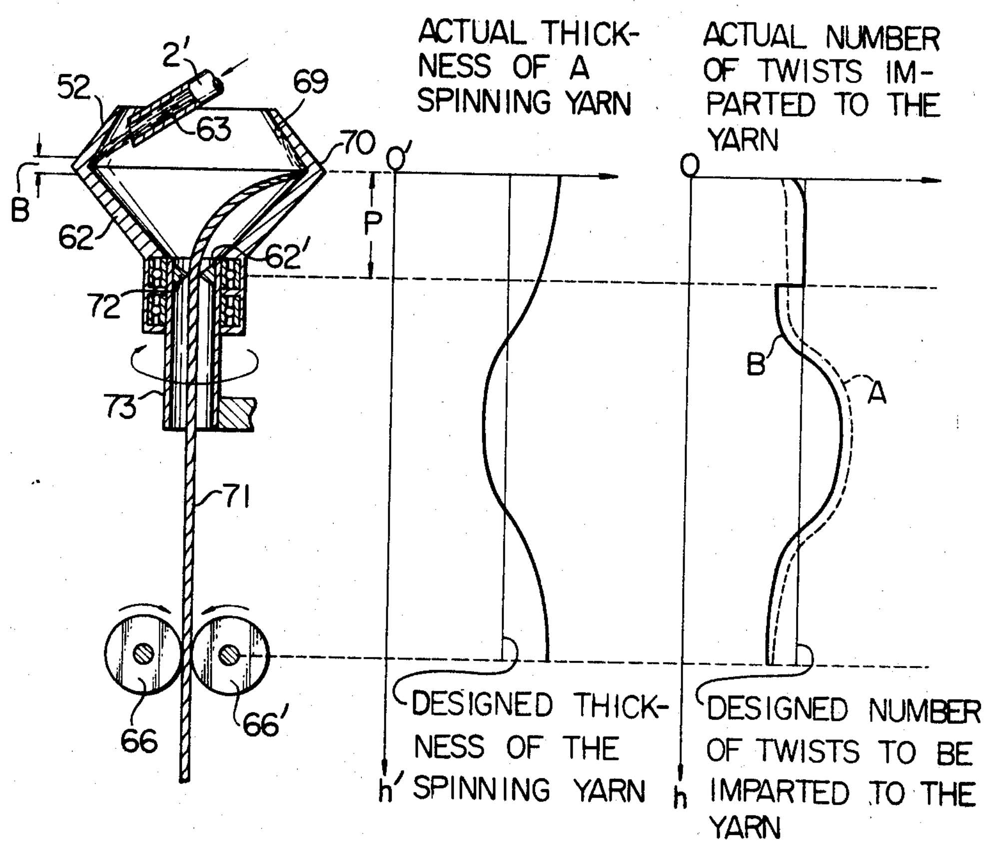


Fig. 18

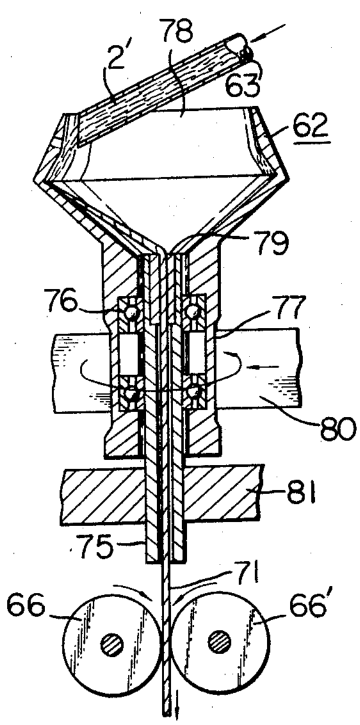


Fig. 19A Fig. 19B Fig. 19C

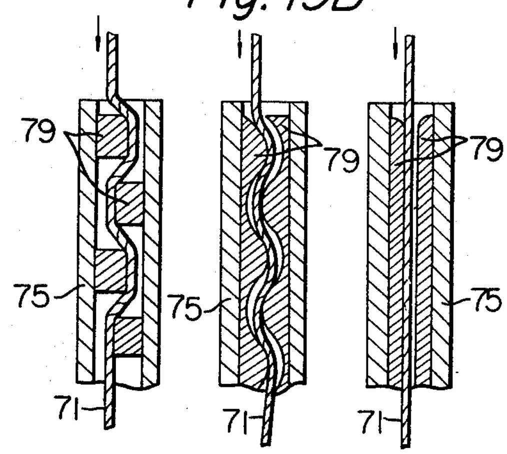


Fig. 20A

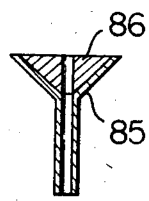


Fig. 20B

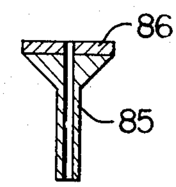


Fig. 24A

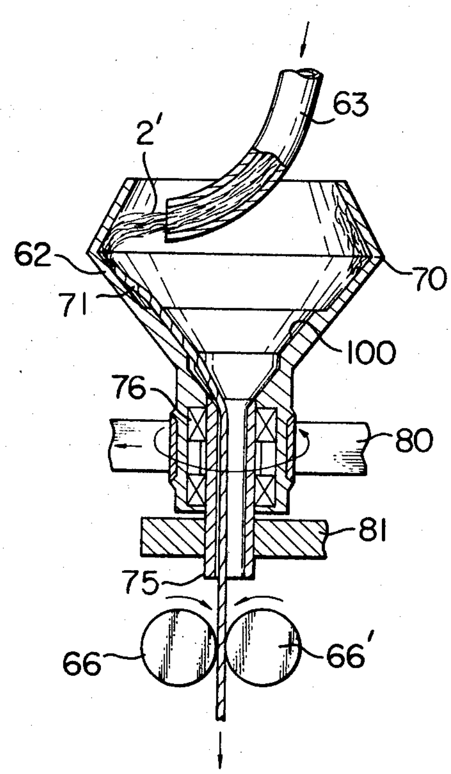


Fig. 21A

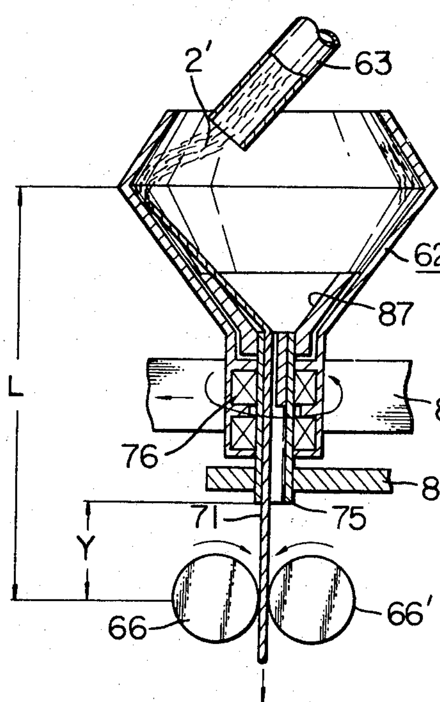


Fig. 21B

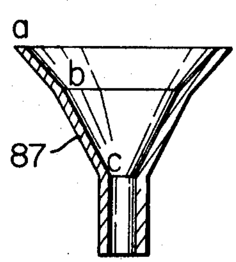


Fig. 21D

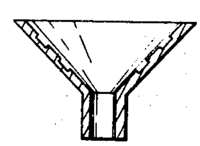


Fig. 21C

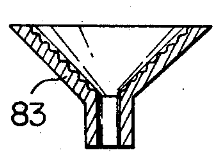


Fig. 21E

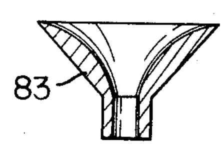


Fig. 22

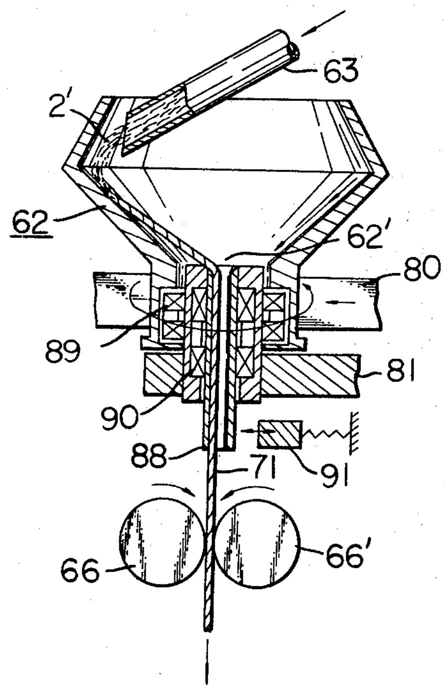


Fig. 23

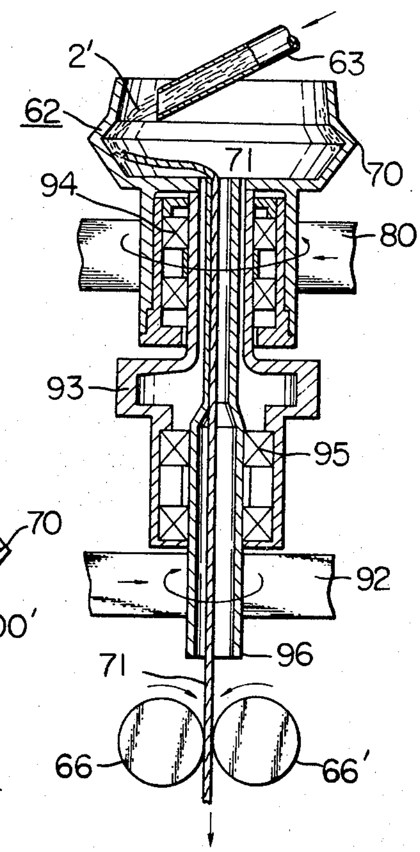


Fig. 24B

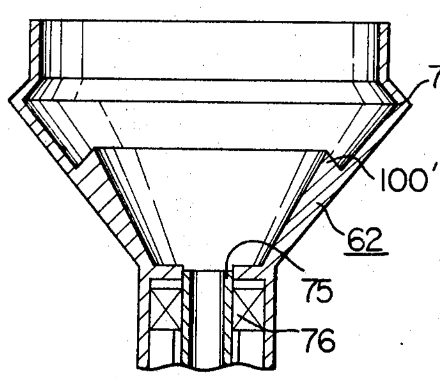


Fig. 25

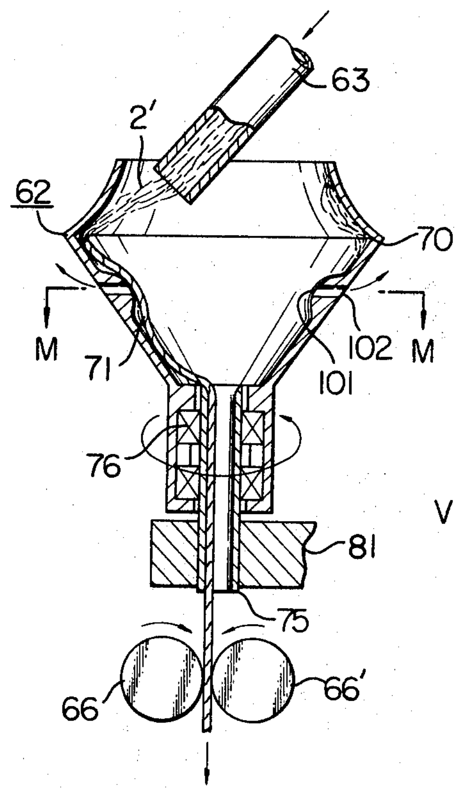


Fig. 28

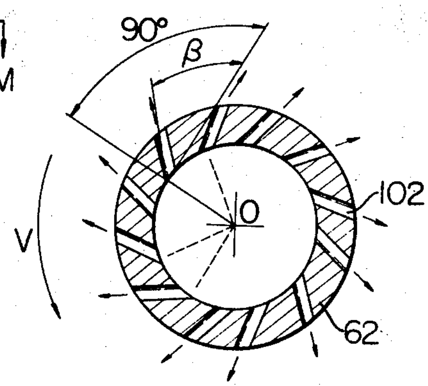


Fig. 26A

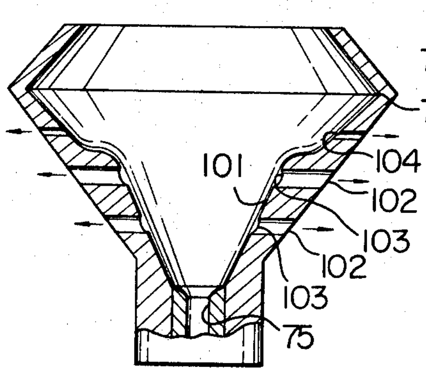


Fig. 26B

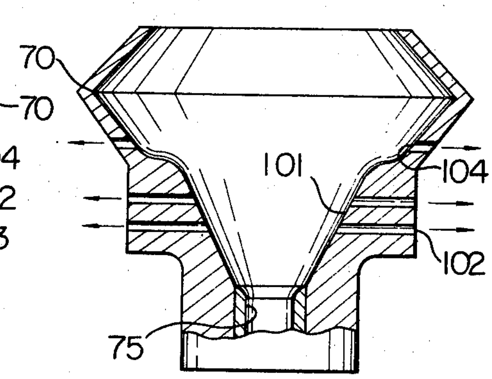


Fig. 27A

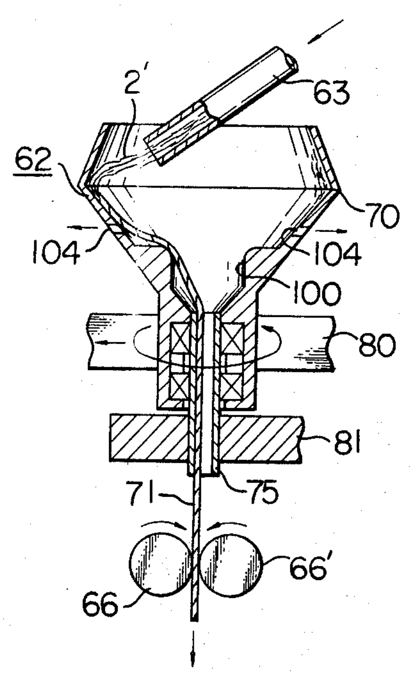


Fig. 27B

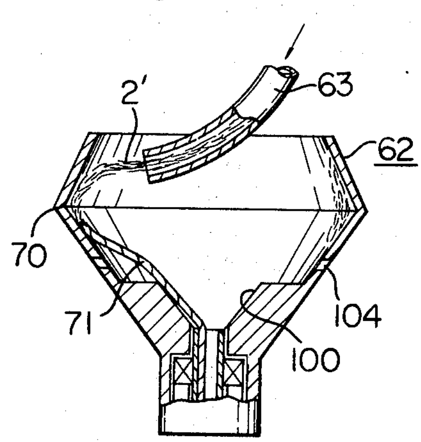


Fig. 29A

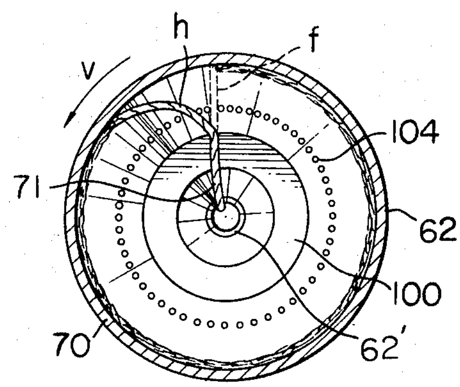


Fig. 29B

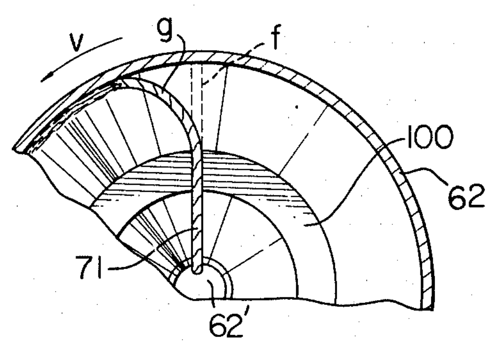


Fig. 29C

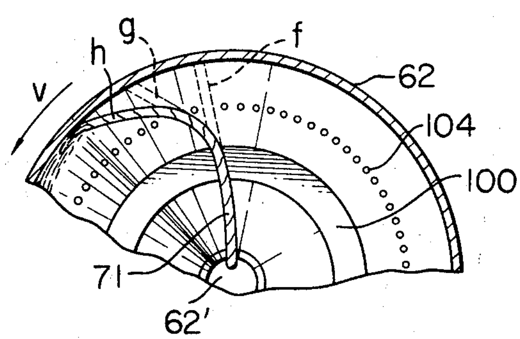


Fig. 30A

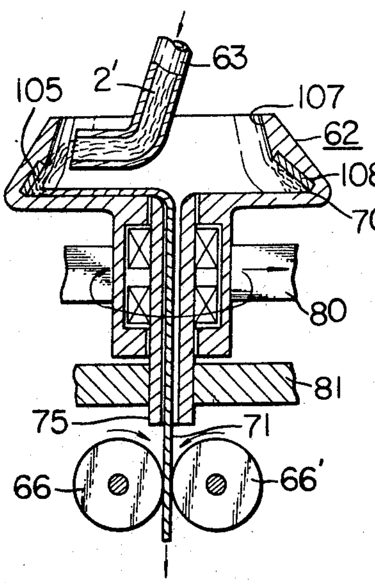


Fig. 30C

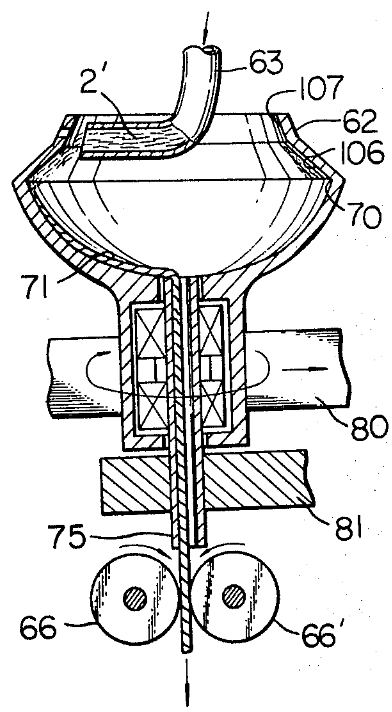


Fig. 30B

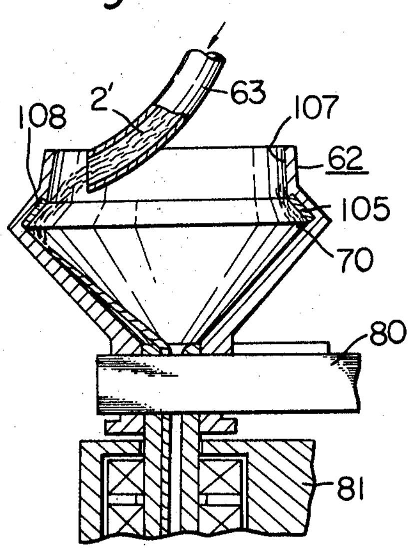


Fig. 30D

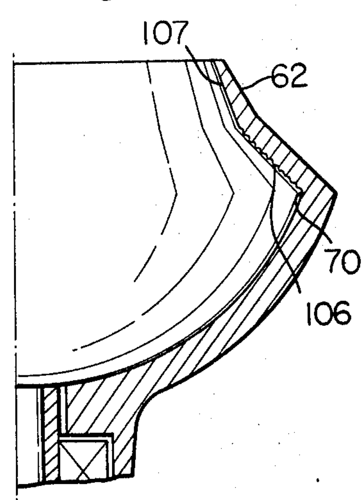


Fig. 31

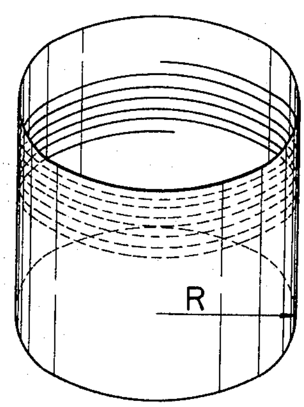


Fig. 32

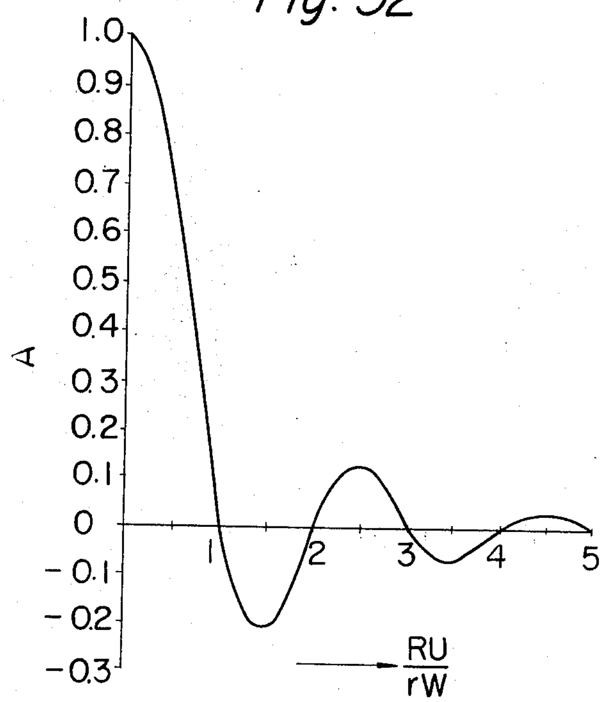
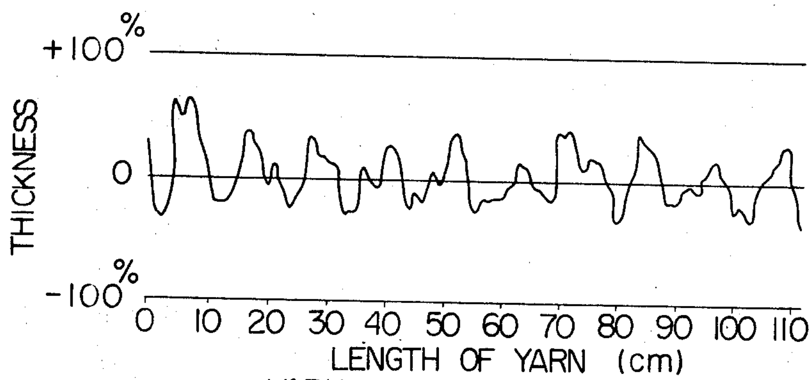
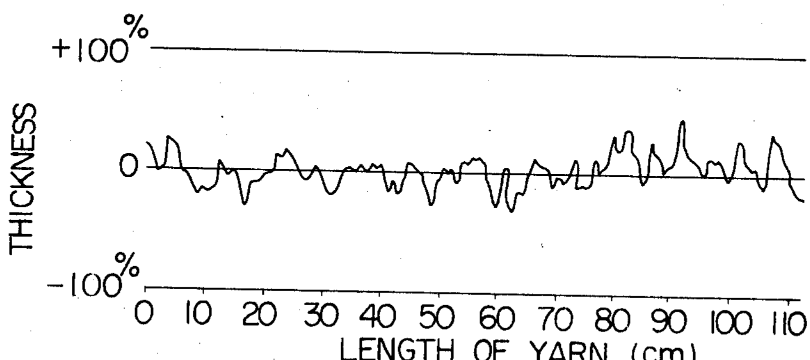


Fig. 33



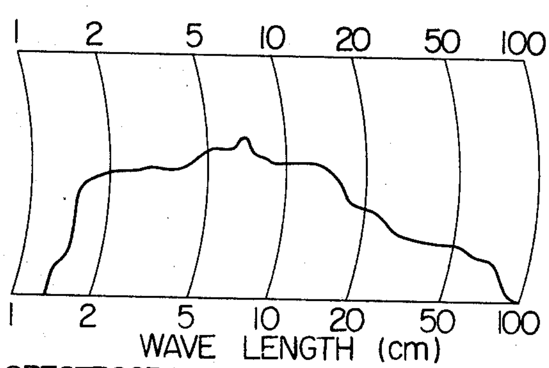
VARIATION OF THICKNESS OF YARN (CONVENTIONAL)

Fig. 34



VARIATION OF THICKNESS OF YARN (PRESENT INVENTION)

Fig. 35



SPECTROGRAM OF VARIATION OF THICKNESS OF YARN (PRESENT INVENTION)

Fig. 36

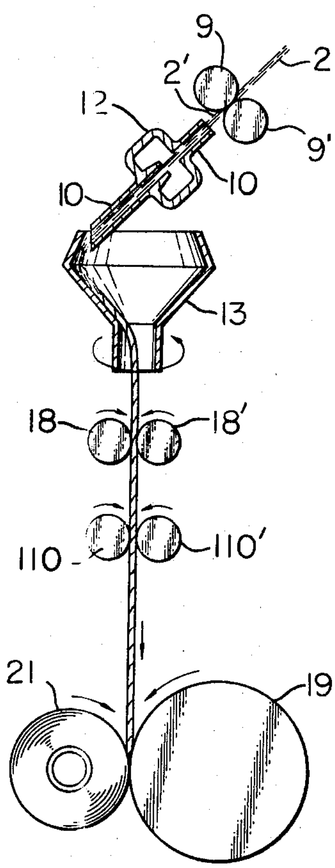
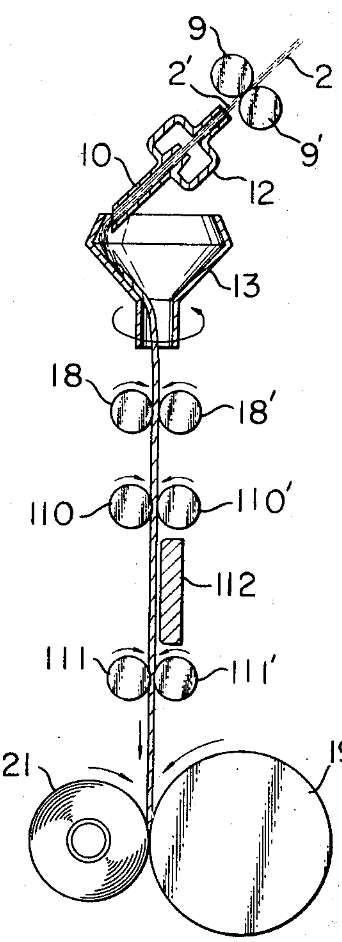

9
2'
2
12
9'
10
10
13
18
18'
110
110'
21
19

Fig. 37


9
2'
2
10
9'
12
13
18
18'
110
110'
112
111
111'
21
19

United States Patent Office

3,523,300
Patented Aug. 4, 1970

3,523,300

SPINNING METHOD AND APPARATUS FOR MANUFACTURING YARN FROM TEXTILE FIBERS

Masaaki Tabata, Kozo Susuami, and Hiroshi Edagawa, Otsu-shi, and Kunio Shinkai, Handa-shi, Japan, assignors to Toray Industries, Inc., Tokyo, Japan, a company of Japan, and Howa Machinery, Ltd., Nagoya-shi, Aichi-ken, Japan, a company of Japan

Filed Aug. 16, 1967, Ser. No. 660,990
Claims priority, application Japan, Aug. 18, 1966, 41/53,905; Mar. 22, 1967, 42/17,418; Apr. 19, 1967, 42/24,976; May 22, 1967 (utility model), 42/42,452; June 5, 1967, 42/35,472; July 4, 1967, 42/42,559; July 12, 1967, 42/44,378, 42/44,380, 42/44,381, 42/44,382, 42/44,383 (utility model), 42/59,706
Int. Cl. D01h *7/00, 1/24*
U.S. Cl. 57—58.91 **29 Claims**

ABSTRACT OF THE DISCLOSURE

An improved spinning method and its apparatus utilizing pneumatics and centrifugal force. The bundle of fibers delivered from a supply source is shredded in a supply conduit of the feeding means by a fluid stream caused by compressed air, and the shredded fibers are deposited continuously on a rotating receiving surface of a rotor and cohered on the receiving surface, then the cohered fibers in a circular bundle form are displaced to a collecting surface having larger radius than the receiving surface by the centrifugal force caused by the high speed rotation of the rotor and a continuous bundle of fibers is taken off from the collecting surface and drawn out from the outlet of the rotor while turning the bundle of fibers by the twisting action of the rotor, and thereafter the twisted bundle of fibers, that is the produced yarn, is packaged by a suitable winding mechanism. To control the above-mentioned twisting, certain twist control means attached to the rotor are provided.

The present invention relates to an improved spinning method and apparatus for manufacturing yarn from textile fibers, more particularly relates to a practical spinning method and apparatus utilizing pneumatics and centrifugal force suitable for mass-production.

Many proposals have been made on the open-end type spinning system. As it has been clearly shown by the process of open-end spinning system as disclosed in Czechoslovakian Pat. No. 91,208 issued in 1958, that generally the system is characterized by separating the twisting and the taking-up operations. After shredding the continuous structure composed of numerous fibrous materials, they are bundled again to form a new continuous structure by means of a rotating member for accumulating the individual fibers and twisting this structure.

Among these prior open-end spinning systems, a spinning method, wherein the shredded individual fibers of the bundle of fibers are conveyed onto the inside wall of the spinning rotor by utilizing suction air, and taken out through an aperture disposed to the central bottom portion of the spinning rotor, while providing twisting operation, is well known. But this method has many drawbacks such as large power consumption, inferior quality of the yarn produced, limitation in spinning speed caused by the mechanical features of this spinning system, high degree of twisting required for preventing yarn breakage and the difficulty in manual operation required at the time of starting the machine. Consequently, it is still difficult to utilize the prior type of open-end spinning method in a practical production process.

The principal object of the present invention is to provide an improved spinning method and apparatus utiliz-

ing pneumatics and centrifugal force which are accompanied by high production speed and stable spinning condition for eliminating the above-mentioned drawbacks of the prior open-end spinning methods.

Another object of the present invention is to provide an improved spinning method and apparatus which can produce improved quality of yarns at high production speed and stable spinning condition by controlling the tension and the twist of the spinning yarns.

Still another object of the present invention is to provide a spinning rotor which can produce yarns having superior properties, beautiful appearance and high bundling property in the spinning method and apparatus wherein pneumatics and centrifugal force are utilized.

A further object of the present invention is to provide a method of yarns which can produce yarns of superior qualities under a wide range of spinning conditions with simple mechanisms and small power consumption in the spinning method and apparatus wherein pneumatics and centrifugal force are utilized.

Further features and advantages of the present invention will be apparent from the ensuing description with reference to the accompanying drawings to which however the scope of the invention is no way limited.

FIG. 1 is a perspective view of an embodiment of the spinning apparatus of the present invention,

FIG. 2 is an explanatory skeleton sketch of the spinning apparatus shown in FIG. 1,

FIG. 3 is an explanatory perspective view showing the twisting mechanism of the spinning apparatus of the present invention,

FIGS. 4 and 5 are sectional side views of the main portions of the feeding device for feeding fibers used for the spinning apparatus of the present invention,

FIGS. 6A, 6B, and 6C are explanatory sectional views of several embodiments of the conduit of the feeding device according to the invention,

FIG. 7 is an explanatory diagram for showing the relation between the conduit of the feeding device of the apparatus of the invention and the drawing-out force of the fibers from the conduit.

FIGS. 8, 9 and 10 are sectional side views of the main part of another embodiment of the feeding device of the present invention,

FIG. 11A is an explanatory sectional side view of the rotor of the present invention,

FIG. 11B is a sectional plan, taking along line XIB—XIB, of the rotor shown in FIG. 11A,

FIGS. 12, 13 and 14 are sectional front and side views, respectively, of still other embodiments of the feeding device of the present invention,

FIG. 15 is an explanatory side sectional view of an embodiment of the rotor of the invention, for showing structure,

FIGS. 16A, 16B, 16C and 16D are side sectional views of another embodiment of the rotor used for the spinning apparatus of the present invention,

FIGS. 17A and 17C are explanatory drawings for showing the structure of the twist controller for controlling the twisting operation on the yarn produced by the rotor shown in the proceeding drawings and its operation mechanism, respectively, while FIG. 17B is an explanatory drawing concerning the variation of thickness of the twisted yarn,

FIG. 18 is an explanatory sectional side views of another embodiment of the rotor attached certain twist controller, according to the invention,

FIGS. 19A, 19B and 19C are explanatory sectional side views of another embodiment of the twist controller,

FIGS. 20A and 20B are explanatory sectional side views of certain twist controller of the invention,

FIG. 21A is sectional side view of the embodiment of the spinning rotor wherein the twisting operation is controlled,

FIGS. 21B, 21C, 21D and 21E, are sectional side views of another twist controller of the invention,

FIGS. 22, 23 are explanatory sectional views of the rotor of the invention for showing driving means of the rotor,

FIGS. 24A, 24B, 25, 26A, 26B, 27A and 27B are sectional side views of the rotor having modified inside surface of the rotor of the invention, respectively,

FIG. 28 is a sectional view of the rotor, taken along the line M—M in FIG. 25,

FIGS. 29A, 29B and 29C are explanatory drawings for showing the twisting behavior of a bundle of fibers within the spinning rotor of the apparatus of the invention, respectively,

FIGS. 30A, 30B and 30C are sectional side views of another embodiment of the rotor having a roughened inside surface, according to the invention,

FIG. 30D is an enlarged side view of the roughened surface of the rotor shown in FIG. 30C,

FIG. 31 is an explanatory drawing for showing the doubling behavior by the rotor of the apparatus of the present invention,

FIG. 32 is an explanatory diagram for showing the relation between the amplitude of the variation of yarn thickness and the spinning condition of the apparatus of the present invention,

FIGS. 33 and 34 are the diagrams for showing the irregularity of yarn thickness of the conventioned yarn and the yarn produced by the method of the present invention, respectively,

FIG. 35 is a spectrogram showing the wave length distribution in variation of thickness of the yarn produced by the method of the present invention,

FIGS. 36 and 37 are drafting devices for stretching the yarn produced by the spinning method and apparatus of the present invention, respectively.

GENERAL DESCRIPTION OF THE SPINNING METHOD AND APPARATUS UTILIZING PNEUMATICS AND CENTRIFUGAL FORCE

Referring to FIGS. 1 and 2, a typical embodiment of the spinning apparatus utilizing pneumatics and centrifugal force of the present invention is shown, wherein the roving **2** is supplied to the conventional drafting equipment from the roving bobbin **1**. The drafting equipment, which is of the pendulum arm type and resembles closely the conventional drafting equipment of that type, comprises a pendulum arm **4** supported by the shaft **3**, a trumpet **5**, a pair of back rollers **6**, **6'**, a pair of front rollers **9**, **9'**, and a pair of apron type draft controlling members **8**, **8'** which are supported by a pair of cradles **7**, **7'** between the pair of back rollers **6**, **6'** and the pair of front rollers **9**, **9'**. After it is drafted by this drafting equipment, the bundle of fibers is supplied directly to the spinning apparatus of the present invention, and is taken upon a cheese **21**. The spinning apparatus of the present invention is characterized by supplying a bundle of fibers successively from the supply source to the spinning rotor provided with a cylindrical axis through a transfer pipe by means of air flow transportation, depositing the shredded fibers onto the inside wall of the spinning rotor in a separated condition, taking them successively off from the inside wall, twisting them while conducting them out of the rotor in order to form a yarn, and taking the yarn up on the cheese **21**. As shown in the drawing, the bundle of fibrous material **2'** is supplied to the guide inlet of the supply pipe **10'** disposed to the feeding device **12** positioned close to the pair of front rollers **9**, **9'**. Compressed air is supplied into the supply pipe **10'** through the air conduit **11** in such a manner that the compressed air is ejected in a direction parallel to the passage of the bundle of fibers and creates a negative pressure within the pipe **10**. The air conduit **11** should be terminated adjacent to the top end of pipe **10** at a position within a distance which is shorter than the average length of the produced fibers from the nip point of the front rollers **9**, **9'** as hereinafter described. The negative pressure within the pipe **10'**, which is created by the injection effect of the high speed fluid of the supplied compressed air, prevents the undesirable sticking of the bundle of fibers onto the surface of the front rollers **9**, **9'** due to the sucking effect caused by the negative pressure within the pipe **10'**. After passing the guide inlet of the pipe **10'**, the bundle of fibers is exposed to the stronger compressed air flow streaming in a direction parallel to the bundle of fibers, and consequently, a force is produced for drawing out fibers from the bundle in the direction of the running passage of the bundle caused by the viscous resistance between the ejected air and fibers in the bundle. As a result of this, fibers in the bundle are separated from the bundle individually by the air force just after leaving the nip point of the front rollers **9**, **9'**, and fed to a spinning rotor **13** through the delivery pipe **10** by means of air flow transportation. The outlet portion of the delivery pipe **10** should point toward the inside wall of the rotor **13**, as shown in FIG. 2. The rotor **13**, which is preferably formed in a pot-like shape having the upper and the lower side walls connected to each other with an obtuse angle between them, is supported rotatably by a vertical cylindrical axis or hub **16** and is rotated at a high rotating speed by means of the driving belt **15**. As already described, the shredded fibers are ejected against the inside wall of the rotor **13**, deposited successively upon it by centrifugal force, and rotated at a high rotating speed together with the rotor **13** on whose wall it coheres. The shredded fibers thus deposited upon the inside wall of the rotor **13** are collected to form a bundle of yarn and twisted in a form of a complete spinning yarn **17** and are taken up on a cheese **21** by a pair of take-up rollers **18**, **18'**. In the spinning apparatus of the present invention, the feeding device **12** of shredded fibers and the rotor **13** are disposed independently so as to avoid interference between the two. This is one of the great advantages of the spinning system of the present invention. In the feeding device **12** of the present invention, the bundle of fibers is transferred pneumatically in a completely separated condition without damaging the individual fibers contained in the bundle of fibers, and furthermore, they receive combining action at the outlet portion of the delivery pipe to provide improved orientation of fibers. This is another great advantage of the spinning system of the present invention. While it was possible to expect advantages in case of cotton fibers on account of their short staple length, cohesion property and high Young's modulus, it was quite difficult up to the present to expect such advantages in case of synthetic fibers or synthetic fibers blended with natural fibers. However, in case of the spinning system of the present invention, even such synthetic fibers or synthetic fibers blended with natural fibers can easily be processed by simple modification of the mechanical elements composing the apparatus or slight adjustment of the pneumatic pressure. Furthermore, the shape and the rotating speed of the rotor **13** can be changed as desired according to the requirement in practical production or in the properties of the yarn produced as long as it can maintain the ability to deposit the shredded fibers upon the inside wall of rotating rotor **13**.

THE TWISTING MECHANISM AND THE STRUCTURE OF YARNS OF THE SPINNING METHOD OF THE PRESENT INVENTION

In FIG. 3, the twisting mechanism of the present invention is shown. After coming out of the drafting equipment, the bundle of fibers is led into the delivery pipe **10'**, wherein high speed jet air is flowing, and is shredded into individual fibers. The bundle of fibers thus shredded and floating in the air stream are conducted into the spinning rotor **13** through the delivery pipe **10**, and deposited upon the inside wall of the spinning rotor **13** by the action of centrifugal force and air flow. The deposited fibers are taken off successively from the layer of fibers *2a'* on the inside wall of the spinning rotor **13**, and are conducted out of the spinning rotor **13** through an outlet **13c** positioned at the bottom portion **13b** of the rotor **13** so as to be twisted into a yarn by means of the rotation of the spinning rotor **13** while being taken up on a cheese **21**. The shredded fibers are only deposited on each other while they are cohering on the inside wall **13a** of the spinning rotor **13**. But they are gathered and twisted while they are taken off from the layer of fibers *2a'* at the position *2b* and conducted toward the bottom outlet **13c** while touching the bottom portion **13b** of the rotor **13**. This spinning mechanism is quite different from that of the conventional spinning machine such as the ring or flyer spinning machine. In these conventional spinning systems, one end of the bundle of fibers is held stationary while the other end is turned spirally with respect to the lengthwise direction of the bundle of fibers.

FEEDING DEVICE OF BUNDLE OF FIBERS OF THE PRESENT INVENTION

In the spinning apparatus of the present invention, the bundle of fibers is separated into individual fibers while being transferred pneumatically through a feeding device connected to the fiber supply source, A pneumatic supply area is formed between the fiber supply source and the delivery pipe in such a manner that the length of the pneumatic supply area should not exceed the average length of fed fibers. A compressed air stream is supplied to the pneumatic supply zone of the feeding device in an advancing direction of the shredded fibers so as to provide a sucking action of the bundle of fibers from the fiber supply source.

Referring to FIG. 4, the bundle of fibers **2'** is supplied constantly to the feeding device of the present invention by a pair of front rollers **25, 25'**, which are generally hereinafter called the fiber supply source. A guide inlet of the supply **26** is positioned close to the nip point of the front rollers **25, 25'**, and the other end of the supply pipe **26** is terminated at the outlet portion of an air chamber **28** with a slight superficial clearance. The air chamber **28** is connected to a pneumatic supply cource. In the above-described mechanism, the negative pressure within the supply pipe **26**, which is created by the injection effect of the high speed flow of the supplied compressed air, causes a sucking action on the supplied bundle of fibers so as to conduct them to the fiber separating zone **29**. The above-mentioned pneumatic supply zone refers to the portion between the nip point of the front rollers **25, 25'** and the fiber separating zone **29**. The length of the above-described pneumatic supply zone (designated with L in the drawing) should not exceed the average length of the produced fibers. A compressed air supply nozzle is formed by the combination of the end portion of the supply pipe **26** and an outlet portion of the chamber **28** so as to supply high speed air stream into the fiber separating zone **29** through the small clearance **27** between the outlet portion of the air chamber **28** and the lower end of the supply pipe **26**. The air jet, which is ejected against the bundle of fibers coming out of the supply pipe **26**, produces a strong suction force on the individual fibers within the bundle of fibers on account of viscous resistance between the jet air flow and the fibers. Consequently, individual fibers are drawn out of the bundle of fibers in a separated condition and are transferred pneumatically through the delivery pipe **30**. In order to obtain yarns of high quality, it is necessary to transfer the shredded fibers pneumatically in a uniform condition. Consequently, it is necessary to avoid the formation of floating fibers within the bundle of fibers passing through the supply pipe **26**, in other words, to draw off individual fibers out of the bundle of fibers as soon as they are released from the front rollers **25, 25'**. The pressure of the supplied air should be adjusted so as to cause a drawing force which is strong enough to overcome the cohering force among the individual fibers composing the bundle of fibers, and the length of the above-described pneumatic supply zone should be shorter than the average length of the produced fibers. While, in the embodiment of present case, compressed air is utilized, it is possible to obtain the same result by utilizing other fluids such as water.

Referring to FIG. 5, another embodiment of the feeding device of the present invention is shown, wherein the compressed air is supplied to the equipment in a different manner from that shown in FIG. 4. And almost the same results can be obtained by this equipment whose mechanism is simpler than that of the equipment shown in FIG. 4.

The following examples are illustrative of the present invention, and yarns of high quality with less unevenness are produced.

EXAMPLE

Example	1	2
Components of the yarn produced	(1)	(2)
Count of the yarn produced in English count system	30's	20's
Rotating speed of the spinning rotor, r.p.m.	46,000	27,000
Delivery speed, m./min.	45	38
Pneumatic pressure of supplied air, kg./cm.^{2}	0.2	0.25

[1] Polyester fiber, 65%; cotton fiber blended, 35%.
[2] Polyester fiber, 100%.

The following conditions should be satisfied for the above-described feeding device in order to obtain the desired separation of fibers while being transported in order to obtain yarns having improved uniformity.

(1) The drawing force caused by the supplied compressed air should be strong enough to overcome the cohering force among the fibers composing the bundle of fibers in order to obtain the desired drawing action on fibers.

(2) The conveying speed of the fibers from the feeding device should be lower than the superficial speed of the rotating rotor because the individual fibers are gathered and twisted while the high conveying speed of the fibers is being decelerated.

(3) Bending and tangling of the individual fibers caused by turbulent air flow should be prevented effectively.

The results of the experiments on the feeding device are illustrated in FIGS. 6A, 6B, 6C and 7 wherein FIGS. 6A, 6B and 6C show the type of the passage of fibers within the feeding equipment and FIG. 7 shows the relation between the type of the passage of fibers and the drawing-out force of fibers working on the bundle of fibers respectively. In FIG. 6A, the delivery end of the supply pipe **26** is positioned in the delivery pipe **30** of uniform diameter. Therefore, an injection effect of the high speed flow of the supplied compressed air without eddy current can be obtained. In FIG. 6B, the delivery end of the supply pipe **26** of funnel-shaped outer profile is inserted into the funnel-shaped portion of the delivery pipe **30** with uniform intervened space. Further, the delivery portion of the delivery pipe **30** is provided with the same inside diameter as that of the bottom portion of the funnel portion as shown in the drawing. In this case, slightly higher injection effect of the high speed flow of the supplied compressed air is created as shown in the case of FIG. 6A. However, certain eddy currents may be created in the delivery portion of the pipe **30**. In FIG. 6C, the delivery pipe **30** comprises a funnel-shaped portion wherein the delivery end portion of the supply pipe **26** is inserted in the same manner as in the case shown in FIG. 6B, and an intermediate conduit portion having uniform diameter and an outwardly diverged delivery portion. In this case, the similar injection effect of the high speed flow of the supplied compressed air to that of the case shown in FIG. 6B can be obtained. In the third case shown in FIG. 6C, the speed of the fluid in the pipe **30** is decreased at its delivery portion thereby the entangling of the shredded fibers and hook-formation of the shredded fibers can be prevented. Compressed air with pressure of 0.3 kg./cm.^{2} is supplied to the feeding equipment in every case.

In FIG. 7, the ordinate of the curves represents the drawing force on the fibers in mg. multiplied by 10^2 and measured at different positions adjacent to the end of the supply pipe while the abscissa represents the measuring position of the drawing force on the fibers measured in mm. and represented by the distance from the bottom end of the supply pipe. In the drawing, the vertical line O–O′ corresponds to the position of the end of the supply pipe and the plus region corresponds to a position downstream of the end of the supply pipe. The negative region of the distance refers to the inside portion of the supply pipe, while the positive region of the distance refers to the inside portion of the fiber separating zone or fiber shredding zone. It is well understood that the passage of the fibers shown in FIG. 6C accompanied by the fiber separating zone shown in FIGS. 8 and 9 can satisfy the above-described requirements effectively.

As is shown in FIG. 7, the drawing force on the fibers in the supplied bundle of fibers at the position of −15 mm. is largest in case of the curve (*c*), that is the fiber passage of FIG. 6C. The larger the drawing force, the stronger may be the sucking action upon the bundle of fibers supplied through the front rollers of the drafting equipment into the supply pipe. Thus, by employing the fiber passage of FIG. 6C, unfavorable dispersing of the fibers around the inlet portion of the supply pipe can effectively be prevented. Furthermore, in case of a splicing operation upon a broken bundle of fibers, transfer of the end of the bundle of fibers from the pneumatic clearer (not shown) to the supply pipe can be carried out with less trouble.

Next, the curve (*c*) shows a sudden rise in a region from 0 to 5 mm., that is, the drawing force upon the fibers in the bundle of fibers reaches a maximum value at a moment when the bundle of fibers is released from the nipping action by the front rollers of the drafting equipment. Thus the fibers in the bundle of fibers can be drawn out successively in order and in uniform condition. Furthermore, fibers can be transferred through the feeding device and accumulated upon the inside wall of the spinning rotor in an oriented and straight condition. Besides, no increase in the drawing force in the region beyond 10 mm. is observed. As is already described, fibers in the bundle of fibers are already put in a completely shredded condition in the region from 0 to 5 mm. and no more drawing force is required. In this type of spinning rotor, the smaller the transferring speed of the fibers the larger is the effect of the combing action upon the fibers due to the difference between the peripheral speed of the rotor wall and the rotating speed of the mass of fibers within the rotor and the lesser is the disturbance of the accumulated layer of fibers upon the inside wall of the rotor. Thus the passage of fibers shown in FIG. 6C should preferably be employed in the present invention.

In the embodiment shown in FIGS. 8 and 9, the length of the supply pipe **31** is designed so as to be shorter than the average length of the produced fibers. A straight guide portion **35** of the delivery pipe **34**, whose inside diameter is slightly larger than the diameter of the outlet portion **33** of the supply pipe **31** and whose length is designated by L′, is disposed within the fiber-separating zone. The bottom termination of the straight portion of the delivery pipe **34** is connected to the end of the lower portion of the delivery pipe **34** which is diverged downward with an angle of θ. In the above-described mechanism, the compressed air, which is supplied through a narrow passage **38**, is ejected against the fibers gradually while passing through the fiber-separating zone in a direction parallel to the fiber passage at the position while they are removing toward the outlet portion **36** of the fiber-separating zone through the diverged portion **37** of the delivery pipe **34**, so as to satisfy requirements (2) and (3) described above. As already described, the high speed pneumatic stream conveying shredded fibers must be decelerated in the passageway from the fiber-separating zone to the twisting zone, and this deceleration can effectively be performed by disposing the diverged portion **37** within the fiber separating zone. This decelerating action on the high speed pneumatic stream of fibers is liable to cause bending and tangling of fibers in the stream on account of its disturbing effect on the pneumatic stream, and this results in an inferior quality of the yarn produced. This unfavorable disturbing effect of the decelerating action can be eliminated effectively by disposing the diverged portion **37** within the fiber separating zone and expanding the compressed pneumatic stream of fibers along the diverged portion **37**, thereby enlarging the intervening spaces among fibers in the stream while being conveyed. The diverging angle θ of the pipe must be so designed as to satisfy such requirements as described above, the separating ability of fibers by the drawing force of the supplied compressed air, delivery speed of the pneumatic stream containing shredded fibers at the outlet portion **36** of the fiber separating zone and the degree of fiber orientation within the stream are three important factors in designing the degree of divergence of the diverged portion of the delivery pipe **34**. The length of the straight portion **35**, which is designated by L′, is preferably one-third of the length of the supplied fibers, for instance, in case of embodiment (*c*) in FIG. 7, the length L′ is 13 mm. while the fiber length is 38 mm.

As a result of photographical observation on drawing and conveying actions of fibers during the process, it was found that the above-described diverging angle θ is preferably from 5° to 30°.

An example of a preferable spinning condition when a 100% polyester staple fiber yarn of 30's English count system is to be obtained is shown in the following table.

EXAMPLE

Fed fiber material: 100% polyester staple of 1.5*d* x 38 mm. (cut length)
Count of the yarn produced: 30's (English count system)
Delivery speed of the front roller: 55 m./min.
Rotating speed of the rotor: 30,000 rev./min.
Pressure of compressed air: 0.3 kg./cm.^{2}
Flow rate of the compressed air: 20 l./min.
Dia. of the inlet portion of the fiber separating zone: 3.4 mm.
Diverging angle of the delivery pipe: 20°.

In FIG. 10, another embodiment of the above-described feeding device of the present invention is shown. In this embodiment, the supply pipe **31** is formed as converged in a downstream direction. A plurality of air inlets **39**, **40** and **41** are formed within the above-described fiber separating zone so as to supply air to the passing fibrous materials in multiple stages. The embodiment is also provided with air outlets **42** formed through the wall of the device in the end portion of the fiber separating zone.

In the embodiment shown in FIGS. 11A and 11B, the delivery pipe **43** is provided with a cylindrical guide member **44** disposed thereto. Through the side wall **45** of the cylindrical guide member **44**, shredded fibers are ejected together with the air stream against the inside wall of the spinning rotor **46**. Thus the feeding device may be provided with a controlling function up the direction of the air-fiber suspended stream ejected therefrom.

Still another embodiment of the device of the present invention is shown in FIG. 12, wherein the rovings **47** and **47′** are supplied to independent draft equipments composed of members **48**, **49**, **50** and **48′**, **49′**, **50′** respectively. After being delivered out of the draft equipments through respective front rollers **50** and **50′**, the oriented bundle of fibers are sucked into the respective feeding devices **51** and **51′** which are disposed close to the respective front rollers **50** and **50′**. Passing through the feeding devices **51** and **51′**, the fibers in the bundle are put in a shredded condition and transferred therethrough. The outlet ends of the feeding devices **51** and **51′** are directed to the inside wall of a single spinning rotor **52** in such a manner that the both directions meet at a same point on the wall as apparent from the drawing.

Thus, both fiber streams come together just after coming out of the respective feeding devices and accumulate successively upon the inside wall of the spinning rotor **52** on account of a centrifugal force due to the high speed rotation of the spinning rotor **52**. Then the fibers accumulated on the inside wall of the spinning rotor **52** are stripped successively therefrom, collected again into a bundle of fibers and twisted adequately while taken out of the spinning rotor **52** in the form of a twisted spinning yarn **54** through a cylindrical axis **53**.

Still further embodiment of the feeding device of the present invention is shown in FIG. 13, wherein the mechanical construction of the drafting equipment and the feeding device is almost same as that of the embodiment shown in FIG. 12 with only the exception that the outlet ends of the respective feeding devices **51** and **51′** are directed to the inside wall of the spinning rotor **52** at different points. The advantages of this embodiment over the preceding embodiment are that disturbance of the air flow transferring the fibers around the outlet portion of the feeding devices **51** and **51′** is effectively prevented and that production of a spinning yarn having further uniform quality can be assured on account of this effective elimination of air disturbance.

In the embodiment shown in FIG. 14, the principal mechanical construction is almost same with those shown in FIGS. 12 and 13 with only the exception that the two independent feeding devices are combined so as to form a single unit **56**. After coming out of the spinning rotor, the spinning yarn **54** is taken up on a package **58** by a pair of take-up rollers **57**.

MECHANISM OF THE ROTOR OF THE INVENTION AND ITS FUNCTIONAL FEATURES

In the collecting and twisting method comprising conveying bundle of fibers from a supply source to a rotating rotor by an air stream through a supply conduit continuously, collecting the conveyed shredded fibers on the inside circumferential surface of the rotor, then taking up the cohered fibers from the inside surface of the rotor continuously, and drawing the yarn twisted by the twisting action of the rotating rotor through a central forward portion or bottom portion of the rotating rotor while the fiber bundle which is being taken off from the inside surface of the rotor is provided with a twisting action, a feeding means for feeding a bundle of fibers by a fluid stream, a collecting means of the conveyed shredded fibers on the inside circumferential surface of the rotating rotor and a twisting means are very important factors for obtaining satisfactory quality of yarn and stable spinning condition.

Several attempts of utilizing a rotating rotor as a means for collecting fibers and a means for twisting fiber bundles have been made but a practical method and apparatus of the abovementioned system has not been found as yet, because of the inferior quality of produced yarn and defects in the operation of the apparatus.

The rotor of the apparatus of the present invention has distinguishing functional features when compared with the conventional one, that is, the construction of the rotor is simple and the driving of the rotor can be operated easily, further excellent quality of yarn which is not inferior to that of the conventional yarn can be produced.

Consequently, the above-mentioned features of the rotor of the present invention provide a basis for utilizing the spinning method in which air and centrifugal force are applied practically.

The rotating rotor acocrding to the present invention comprises the following elements: portion of a definite inside surface or surfaces for receiving fibers conveyed by an air stream, a collecting inside surface of the rotor, a bottom or forward surface for guiding fiber bundle taken off from the collecting surface of the rotor, and an aperture for drawing the twisted yarn by the rotation of the rotor.

The receiving surface of the rotor for receiving shredded fibers is defined as a rotating surface for carrying the cohered fibers together with the rotating rotor and for conveying the cohered fibers toward the collecting surface of the rotor continuously by the action of the centrifugal force caused by the high speed rotation of the rotor.

Consequently, the receiving surface of the rotor is restricted only by the discharge end of the delivery pipe of the feeding device.

Next, the collecting surface of the rotor means a zone where fibers carried by the air stream are finally collected on the inside surface of the rotor in a stationary collecting condition, particularly, the collecting surface of the rotor is quantitatively defined as follows: When the feeding of fibers into the rotor is stopped and the apparent thickness of fibers collected on the inside surface of the rotating rotor is twice the actual thickness of the fibers collected on the same inside surface, the zone which is stationally collecting fibers in the rotor is called the collecting surface of the rotor.

A surface composed of a rotating trace of the twsting yarn is called the yarn guide surface of the rotating rotor, when the twisting of yarn is being carried out in a stationary spinning condition while the yarn-like continuous bundle of fibers is being taken up from the abovementioned fiber collecting surface of the rotor. Generally, the yarn guide surface of the rotor coincides with the shape of the forward portion of the rotor, however, in some cases, the bundle of fibers may be free from the some portion of the yarn guide surface, so that the trace of the bundle of fibers or yarn twisted forms a space-curve.

The detailed mechanisms of several embodiments of the rotor of the spinning apparatus according to the present invention are hereinafter explained.

Referring to FIG. 15, bundle of fibers **2′** composed of numerous staple fibers is delivered continuously from a pair of supply rollers **60, 60′** at a constant speed to feeding device **61** provided with a conduit for positively sucking the delivered bundle of fibers **2′** by a suction force of an air stream generated by compressed air and shredding the fibers contained in the bundle of fibers sucked into the supply pipe of the device while the fibers are being conveyed in the device, and then the air stream conveying the shredded individual fibers is blown to the inside circumferential surface of the rotor **62**. In the drawing of FIG. 15, a region of the inside circumferential surface of the rotor **62** designated by the region A forms the receiving surface for receiving fibers conveyed from the feeding device **61**, a region designated by B forms the collecting surface and a region designated by C forms the guide surface. Therefore, the outlet **63** of the feeding device **61** faces the receiving surface A of the rotor **62**.

The fibers deposited upon the receiving surface rotates with a rotating air current in the rotor **62** and are cohered on the receiving surface A of the rotor **62** by the action of the centrifugal force caused by the rotation of the rotor **62**.

According to the present invention, the diameter of the fiber-receiving surface A is smaller than the diameter of the maximum diametrical portion of the rotor **62** and the fiber-receiving surface A converges outwardly with converged angle d as shown in the drawing. Consequently, the fibers cohered on the receiving surface A are displaced toward the maximum diametrical portion B of the rotor **62** by the action of the centrifugal force. It is an essential condition that the frictional resistance between the fibers and the receiving surface A is much weaker than the component force of the centrifugal force working on the cohered fibers on the receiving surface A along the surface, by which a smooth displacement of the fibers from the receiving surface A to the collecting surface B of the rotor **62** can be obtained. Thus, the fiber bundle collected on the collecting surface B, which corresponds to the maximum diametrical portion of the rotor **62** is taken off from the collecting surface B successively, and the fiber bundle in a yarn form is drawn out through a hollow hub **64** disposed to the forward central portion of the rotor **62** while providing twist by the rotation of the rotor **62**. To provide the yarn with a preferable twist construction and also to prevent ballooning of yarn in the rotor by the rotation of the rotor **62** at high speed, it is essential to provide a yarn guide surface C by which the trace of the yarn is controlled while turning on the yarn guide surface. The fiber-receiving surface, fiber-collecting surface and yarn guide surface of the rotor **62** of the present invention are arranged in such a way that the fiber-collecting surface is disposed between the other two surfaces. Thus, the yarn **65** which has finished its formation is taken out by a pair of drawing rollers **66** and then forms a package by a suitable winding device so as to complete the spinning operation.

Referring to FIGS. 16A, 16B and 16C, other embodiments of the rotor of the invention are shown. As it is clearly shown in the drawing, the receiving surface and the collecting surface respectively have different upward converging angles, the upward converging angle of the receiving surface is smaller than that of the collecting surface, and consequently, a clear boundary **67** is formed at the connecting position of both surfaces.

In FIG. 16A, the receiving surface is composed of a single cylindrical surface converged upward while a stepped receiving surface composed of several cylindrical surfaces with different diameters is shown in FIG. 16B, and a receiving surface composed of an inward convex surface is shown in FIG. 16C.

When using the rotor having the above-mentioned construction, the fiber-receiving action and collecting action by the rotor can be performed in a more uniform and stationary condition, moreover, the displacement of fiber bundle cohered on the receiving surface to the fiber collecting surface of the rotor and its held time can be adjusted easily.

In FIG. 16D, the rotor is characterized by numerous small holes **68** disposed in the fiber-receiving surface. The small holes **68** are effective for cohering the conveyed fiber from the feeding device **63** in a shorter time than that of the other embodiments shown in FIGS. 16A, 16B and 16C. Further, when the circumferential speed of the receiving surface of the rotor **62** is set higher than that of the fluid speed of air containing shredded fibers discharged from the outlet of the feeding device of the invention, fibers cohered on the receiving surface are straightened and their relative arrangement along the circular receiving surface of the rotor **62** is improved. To have a better understanding of the several embodiments of rotor of the invention, some of the main problems of the twisting mechanism of the present invention are hereinafter described.

Referring to FIG. 17A in which a model diagram of the twisting mechanism of the present invention is shown, the shredded fibers **2′** conveyed by an air stream are led to the rotating rotor **62** through a delivery pipe **63** and the conveyed fibers are cohered on the receiving surface **69** of the rotor **62** by the fluid force and the centrifugal force caused by the high speed rotation of the rotor **62**. When an auxiliary yarn **71** is inserted into the rotor **62** through a bottom aperture **62′**, the end of the auxiliary yarn **71** is turned toward the inside surface of the rotor **62** by the centrifugal force working on the end portion of the yarn **71** and contacts with the maximum diametrical portion **70** of the rotor which forms the collecting surface. Once the end of leading yarn contacts with the bundle of yarn collected on the collecting surface of the rotor **62**, the twist caused by the rotation of the rotor **62** is transmitted to the yarn **71** as the auxiliary yarn rotates at almost the same rotation speed. As the end portion of the leading yarn **71** gathers fibers collected on the region adjacent to the maximum diametrical portion **70** of the rotor **62**, when the formed yarn **71** is drawn without shock by a pair of drawing rollers **66**, **66′**, the formed yarn is provided with twisting while the yarn collected on the collected surface of the rotor is gathering by the leading end of the formed yarn.

In the above-mentioned yarn forming mechanism, the distribution of twist of yarn between taking-off point of fibers collected on the collecting surface which corresponds to the maximum diametrical portion **70** of the rotor **62** and the rollers **66** and **66′** is considered. When the twist controller **72** is omitted, the twist distribution of yarn is illustrated by the distribution curve A shown in FIG. 17B. That is, in this case, the twisting action is not transmitted to the aggregated fiber at the taking-off position on the collecting surface of the rotor, while in an ideal twisting operation, the above-mentioned twist distribution is shown by the imaginary curve C in FIG. 17B, where the twisting action is transmitted to the position adjacent to the taking-off position.

Again, the mechanism of the twisting operation of the present invention is shown in FIG. 3. In FIG. 3, the conveyed fibers from the delivery pipe **10** are cohered on the receiving surface **13*a*** of the rotor **13**, the bundle of fibers **2*d*** taken off from the inside surface of the rotating rotor **13** is turned toward the W direction as shown in the drawing, that is, the bundle of fibers **2*d*** is twisted in the W direction.

In the formation of yarn, the twisting operation between the taking-off portion **2*b*** of the maximum diametrical portion of the rotor **13** which forms the collecting surface and the outlet **13*c*** is shown in the drawing, that is, the bundle of fibers at the taking-off position **2*b*** is not provided with sufficient twist, and a sufficient transmission of the twisting action of the bundle of fibers stops at the position **2*c*** adjacent to the taking-off position **2*b***.

Consequently, if the drawing speed of the yarn from the rotor is increased, when insufficient twist is given to the bundle of fibers before forming a complete form of yarn, the insufficient twisting causes yarn breakage during the spinning operation. To prevent yarn breakage during the spinning operation, it is essential to provide an excess twist to the yarn, particularly in case the spinning speed is increased.

The above-mentioned defect can be eliminated sufficiently by the yarn formation of the present invention, consequently the spinning speed can be increased without an increase in yarn breakage.

An improved embodiment of the rotor of the invention shown in FIG. 17A comprises a rotor **62** and a hollow shaft **73** supporting the rotor **62** rotatably, and a twist controller **72** rigidly disposed in the hollow shaft **73** in such a way that the yarn **71** always contacts with the twist controller **72** while passing through the controller **72**. Further, it is an essential condition that the twist controller **72** does not disturb the free passing of the yarn **71** through the twist controller **72**, but controls twist transmission from one side to the other side of the twist controller. The twist controller **72** is made of elastic material such as natural rubber, silicone rubber, the polyurethane rubber and some synthetic resin products having elasticity, and it is preferable to use an elastic substance having a hardness of 60–95° (Japanese Industrial Standard), so as to increase the twist density of yarn **71** between the taking-off point of the collecting surface of the rotor **62** and the discharging aperture **62′** of the rotor **62**. However, a twist controller made of non-elastic material can also be used without decreasing the effect of the device of the present invention.

In FIG. 17C, the curve designated with B corresponds to the case employing the twist controller of the present invention corresponding to the case shown in FIG. 17B while the curve A corresponds to the case without such twist controller.

As is well known, most of the uneveness in the thickness of a spinning yarn manufactured by a roller drafting system is of a pitch larger than twice the fiber length. Particularly in case of the system of the present invention, wherein a self doubling effect can be expected as is later explained in detail, formation of unevenness of relatively smaller pitch can remarkably be prevented. It is also well known that, in case of imparting twists to a yarn, a relatively larger number of twists are bestowed on the portion of relatively smaller thickness and a relatively smaller number of twists are bestowed on the portion of relatively larger thickness.

In accordance with the above-described well known facts, the functional effect of the twist controller of the present invention is as hereinafter explained.

As is shown in FIG. 17B, the pitch of the most of the unevenness possessed by a spinning yarn manufactured by the method of the present invention is far larger than a distance P between the fiber collecting position and the twist controller. Provided that a spinning yarn having the unevenness shown in FIG. 17B is manufactured and an effective control action is presented by the twist controller **72**, the actual lengthwise distribution of the number of twists imparted to the yarn is as shown by the curve B in FIG. 17C, while the curve A represents the case wherein no twist controller is employed. Thus, the distribution of the number of twists of the yarn within the twisting zone, that is the distance P, corresponds to that of the thickness of the yarn shown in FIG. 17B but is not dependent upon the thickness itself. After passing through the twisting zone, the distribution of the number of twists shown a tendency contrary to that of the thickness of the yarn within a zone between the twist controller **72** and a pair of take-up rollers **66** and **66'** as shown by the curve B in the drawing. As is clearly seen from the results shown in FIG. 17C, the number of twists imparted to the yarn of the present invention at the position where the bundle of fibers is stripped from the inside wall of the spinning rotor is substantially equal to the designed number of twists to be imparted to the yarn and the yarn breakage can be remarkably prevented because of the above-mentioned control action of the twist controller **72** which causes the increasing of the twist between the maximum diametrical portion **70** of the rotor **62** and the twist controller **72**.

As the preferable condition of the controller **72**, it is preferable to set the controller as close as possible to the taking-off position of the fiber bundle from the collecting surface of the rotor **62**.

The other embodiment of the rotor **62** of the invention is shown in FIG. 18. The rotor **62** is rotatably supported by a hollow shaft **75** secured to a machine frame **81** through a bearing **76**. The downward projected hub always contacts with a driving belt **80**. The top end of the rotor **62** is opened so as to receive the bottom end of the delivery pipe **63** of the feeding device of the invention, thereby the air from the delivery pipe **63** is easily discharged from the open end portion of the rotor **62**, which prevents disturbance of air current in the rotor **62**. The yarn twisted by the rotor **62** is drawn through an axial conduit of the hollow shaft **75** from the rotor **62**. At one end of the hollow shaft **75**, an elastic member **79** is disposed, by which the density of twist of the bundle of yarn in the rotor can be increased. Several types of elastic members disposed in the hollow shaft are shown in FIGS. 19A, 19B and 19C. The elastic member **79** shown in FIG. 19A forms a zig-zag passage of yarn, the elastic member **79** shown in FIG. 19B forms a curved passage of yarn, while the last one shown in FIG. 19C forms a straight passage of yarn, however, in every embodiment, it is essential that the yarn **71** contact with the elastic member **79**. It is preferable to use a rubber-like elastic member produced by bonding several kinds of materials having the different hardness, or covered with a material having superior resistance to abrasion, for forming an elastic and durable yarn passage. As it can be understand from the drawing, the elastic member **79** disturbs the free transmission of twist to the fiber of bundle in the rotor **62**, further the elastic member **79** works on the yarn **71** in such a way that the turning motion of the yarn **71** is stopped by the elastic member **79** while the yarn **71** passes through the yarn passage in the hollow shaft **75**. Consequently, formation of fluffy yarn and yarn having irregular thickness can be prevented.

In FIGS. 20A and 20B, other embodiments of the hollow pipe secured to the machine frame are shown. The hollow pipe **85** is provided with a funnel shaped top **86** made of elastic material to obtain the twist controlling action as shown in the former embodiment of FIG. 18.

In FIGS. 21A, 21B, 21C, 21D and 21E, other embodiments of the twist control member are shown. In these types of rotor, the twist control member is disposed to the top end of the hollow shaft which is secured to the machine frame and rotatably supports the rotor. The twist control member contacts with the yarn guide surface of the rotor. To obtain a stable condition of twist control, the contact surface of the member, which contacts with the yarn, is made as a roughened surface. That is, in FIG. 21A, a twist control member **87** provides with a funnel portion having a roughened inside surface is disposed to the yarn passage defined by L, the yarn **71** is given a sliding friction by the roughened surface while the yarn slides in the forward direction to the outlet of the hollow shaft **75**, and is provided with stable twist by its turning motion along its axis by the rotation of the rotor **62**.

The following table shows the effect of a certain twist control member showing the spinning tension of yarn and spinning condition.

Roughness of the inside surface of the rotor	Yarn tension in grams	Spinning condition
50–70×10^{-6} in H.r.m.s.	25.0	Good.
90–120×10^{-6} in H.r.m.s.	27.6	Excellent.
130–150×10^{-6} in H.r.m.s.	36.7	A little unstable.
Without roughened surface		Impossible to spin.
For comparison, a twist control member made of Urethan Rubber (Hardness: Japanese Industrial Standard 85) was attached to the top end of the hollow shaft 83.	43.5	Good.

The spinning tension of the yarn **71** was measured at the passage between the twist control member and the drawing rollers **66**, **66'**. The passage is designated by Y in FIG. 21A. Measurements were made at a spindle speed of 30,000 r.p.m., that is 40–55 m./min.

In FIG. 21B, another embodiment of twist control member **87** is provided with a combination of two different surfaces having different diverging angle, consequently, the yarn can be provided with strong friction at the three boundaries of *a*, *b*, and *c* formed on the inside surface of the twist control member **87**. Other types of funnel control member such as, that with several step boundaries, jagged circular grooves and convex surface are shown in FIGS. 21C, 21D and 21E, respectively.

In FIG. 22, an embodiment of twist control means provided with a hollow pipe **88** rotatably supported by a cylindrical holder secured to the machine frame is shown. The rotor **62** is also rotatably supported by the cylindrical holder. The hollow pipe **88** is disposed in the cylindrical holder in such a way that the top end portion of the hollow pipe **88** is positioned at an aperture **62'** of the rotor **62**, as shown in the drawing. When the rotor **62** is driven by a belt **80**, the yarn **71** is drawn from the aperture **62'** and the yarn **71** contacts with the inside surface of the hollow pipe **88**, the hollow pipe **88** is negatively rotated in the same rotating direction of the rotor **62** by the frictional force between the yarn and the hollow pipe **88**.

Consequently, the desired twist control action can be obtained. Further, it is very easy to control the rotation of the hollow pipe **88** by applying certain control means such as an electromagnet, etc.

In FIG. 23, another embodiment of the twist control member is shown. The twist control hollow pipe **96** is rotatably supported by a holder **93** through a bearing **95**, while the rotor **62** is also rotatably supported by a holder **93** through a bearing **94** in such a way that the top portion of the hollow pipe **96** passes through the shaft holder of the rotor **62**, the rotor **62** is driven by a belt **80** and the twist control pipe **96** is driven by a belt **92**. Consequently, the twist control pipe **96** can be driven positively without any relation with the rotor **62**. The twist control pipe **96** can be rotated positively in the clockwise direction or counterclockwise direction so as to provide a temporary twist to the yarn positioned at the rotor **62** and the hollow cylindrical member. By the above-mentioned action of the elements, the twist control pipe **96** is rotated in the opposite direction to the rotor **62**, or the twist control pipe **96** is rotated in the same direction as the rotor **62**, but rotational speed is very slow when compared with that of the rotor **62**. As described above, the rotation speed or direction of the twist control pipe **96** can be suitably selected to obtain the desired twist control effects. To have more effective false twisting by the hollow pipe **96**, the rotor **62** having the shape shown in FIG. 23 can be used so as to float the yarn **71** upon the inside surface of the rotor **62**, and to make the contact of the yarn **71** with the top end of the hollow pipe **96** strong. In the above-mentioned embodiment, the shape of the hollow pipe **96** is very simple, but modified hollow pipe **96** having zig-zag passage or surface-treated passage, etc. can be used for increasing the frictional force caused by the contact of yarn **71** with the hollow pipe **96**. The yarn produced by the rotor **62** having the twist control pipe **96** is drawn by the drawing rollers **66** and **66'** in a stable condition and then wound into a package by a conventional winding means.

Other embodiments for controlling the twisting yarn by the rotor of the invention are shown in FIGS. 24A, 24B. In FIG. 24A, a doughnut-shaped portion **100** projected upward is formed in the rotor **62** in such a way that the position of the projected portion **100** is adjacent to the lower position of the maximum diametrical position **70** of the rotor **62**. Thus, in the yarn-forming operation, the yarn **71** passes over the projected portion **100** in such a way that the yarn **71** pushes toward the projected portion **100** by the centrifugal force caused by the high speed rotation of the rotor **62**, while the yarn **81** slides on the projected portion **100** by the drawing action of the drawing roller **66**, and **66'**. Consequently, pertinent tension control of the bundle of fibers between the taking-off position on the maximum diametrical portion **70** of the rotor **62** and the projected portion **100** and stable transmission of twist to the taking-off position can be obtained. In the above-mentioned embodiment, more than two projected portions having the same functional feature as the doughnut-shaped projection can be used. In FIG. 24B, another embodiment of the rotor **62** having a projection **100'** of different shape is shown.

In FIGS. 25, 28 the doughnut-shaped projected portion **101** of the rotor **62** is provided with a plurality of lateral apertures **102** passing through the portion **101** in such a way that the apertures **102** are arranged radically. In this embodiment, the bundle of fibers passing over the projected portion **101** is pushed to the portion **101** by a stronger force caused by the air flow passing through the apertures **102**. One example of the arrangement and shape of the aperture **102** is shown in FIG. 28, wherein, the rotor **62** rotates toward V direction and the intervened angle of the two adjacent apertures **102** is given by a constant angle β so as to increase the pushing force toward the projected portion **101**.

Further, to increase the twist control effect by the projected portion, a grooved ring **103** having a semicircular cross section is disposed at the arranged position of the apertures **102**, as shown in FIG. 26A. The rotor **62** shown in FIG. 26B is a modified embodiment in which the shape of the inside surface of the rotor **62** is changed so as to increase the length of the apertures **102**. It is necessary for the yarn **71** to contact with the yarn guide surface of the rotor **62** firmly to control the transmission of twist when the shape of the rotor **62** has been decided.

In the above-mentioned embodiments, the projected portion disposed on the inside wall of the rotor **62** bestows a pushing action to the yarn, thereby the pertinent transmission of twist to the taking-off position of the maximum diametrical portion **70** of the rotor **62** can be obtained by the frictional contact of yarn **71** with the projected portion. That is, the tension of the yarn from the contacting position of yarn with the projected portion **100**, **100'**, **101** can be controlled, further, the density of twist of bundle of the fibers between the taking-off position on the maximum diametrical portion **70** of the rotor **62** and the projected portion can be increased, thereby, the spinning speed of yarn can be increased remarkably.

The preferable shapes and positions of the projected portion are shown in FIGS. 27A and 27B. In these embodiments, the yarn **71** contacts with the inside wall between the maximum diametrical portion **70** of the rotor **62** and the projected portion **100**.

Referring to FIGS. 26A, 26B, 27A and 27B, at least one group of apertures **104** disposed to a position beside the projected portion increases the effectiveness of the twist control by the projected portion. This additional effect is explained hereinafter by the plan view shown in FIGS. 29A, 29B and 29C. In FIG. 29A, the trace of yarn **71** is represented by an imaginary straight line *f* (dotted line) extending between the aperture **62'** and the maximum diametrical portion **70** of the rotor without any projected portion. In this case, the spinning condition is unstable. On the other hand, the rotor **62** is provided with the above-mentioned projected portion **100** and apertures **104** for discharging air, the yarn **71** turns toward the rotational direction of the rotor **62** as shown by a curved line *h*, and a stable spinning condition at increased spinning speed can be obtained. When the rotor **62** provided with the projected portion **100** but without the apertures **104** is used, the trace of yarn **71** is represented by a curve *g* as shown in the enlarged drawing of FIG. 29B. When the aperture **104** is further added to the rotor **62** as shown in FIG. 29C, the trace of yarn **71** is represented by a curve *h* which turns further towards the rotational direction of the rotor **62** at the disposed position of the aperture **104**. Consequently, it is clear that the aperture **104** improves the twist control effect of the projected portion **100**.

The position of the aperture **104** is so chosen that it is close to the maximum diametrical portion **70** of the rotor **62** so that a good twist control effect can be obtained, and it is preferable to dispose the aperture **104** at a position slightly above the projected portion **100**. It is also preferable that the projected portion **100** has sufficient magnitude to provide the yarn **71** with frictional contact.

FIGS. 30A, 30B, 30C, and 30D show sectional views of other embodiments of the rotor **62** of the invention. In these embodiments, a control surface provided with roughened surface or frictional surface is disposed on the inside surface of the rotor **62**.

In FIGS. 30A and 30B, a control surface **105** composed of frictional substances is disposed on a part of the receiving surface closely adjacent to the maximum diametrical portion **70** of the rotor **62**. The receiving surface comprises two different tapered portions, that is, the upper portion **107** and the lower portion **108**, as shown in the drawing. The conveyed shredded fibers are cohered on the upper portion **107** of the receiving surface and then the cohered fibers are displaced toward the lower portion **108** by the centrifugal force caused by the high speed rotation of the rotor **62**, while doubling of delivered fibers is taking place. In this embodiment, tapered portions **107** and **108** are provided with roughened surface. The roughened surface may be restricted only to the lower portion **108**. As the receiving surface of the rotor **62**, comprises two portions having different tapers, and each of the two portions **107** and **108** is provided with roughened surface, disturbance of the cohered fibers on the receiving surface can be prevented by smooth displacement of the cohered fibers from the upper portion **107** to the lower portion **108**, while preventing the direct blowing of air to the lower portion **108**. Any number of tapered portions may be provided on the rotor of the invention. As described above, by using the duplicate tapered receiving surface provided on the rotor **62**, the coherence of conveyed fibers on the receiving surface is improved and the fly phenomenon of fibers cohered on the receiving surface can be eliminated. Further, the delivered fibers are straightened by a combing-like action caused by the speed difference between the higher surface speed of the receiving surface of the rotor **62** and the lower conveying speed of shredded fibers by the feeding device, consequently, the cohered fibers on the receiving surface are provided with improved parallel arrangement of individual fibers.

FIG. 30C shows a sectional view of a modified rotor provided with roughened surface at an adjacent position **106** to the maximum diametrical portion **70** and FIG. 30D is an enlarged view of the roughened surface of the rotor shown in FIG. 30*C*.

MECHANICAL CONDITIONS REQUIRED FOR THE SPINNING APPARATUS OF THE PRESENT INVENTION

Evenness of yarn produced is due to periodical and random elements in the spinning process of the present invention, the same as in the case of the traditional spinning technique, and is the most important factor affecting the quality of the yarn produced. The spinning technique of the present invention is characterized by the elimination of the periodical unevenness of the yarn thickness caused mainly by the eccentric deviation of the front rollers by means of selecting suitable diameter and rotating speed of the spinning rotor, thereby obtaining yarns having improved evenness. The mechanical principle and the experimental results are disclosed in the following description, wherein M designates the rotating speed of the spinning rotor in rev./min., R designates the inside radius of the spinning rotor (in case the diameter is not equal throughout the circle, it designates the radius of the collecting surface whereon the separated fibers are deposited, in other words, the largest inside radius of the rotor), *r* designates the radius of the front top roller of the drafting equipment, U designates the delivery speed of the bundle of fibers from the drafting equipment, V designates the superficial speed of the inside wall of the spinning rotor and is equal to 2πRM, and W designates the separating speed of the bundle of fibers from the inside wall of the rotor which is nearly equal to the take-up speed of the yarn produced.

The bundle of fibers, which is delivered from the drafting equipment at the delivery speed U, is conveyed pneumatically through the supply pipe and ejected against the inside wall of the rotor from the bottom outlet portion of the delivery pipe in order to be deposited upon the inside wall of the rotor in an oriented condition by the pneumatic action of the compressed air and the centrifugal action of the spinning rotor. Now, if the thickness of the bundle of fibers delivered from the drafting equipment changes in a sine curve shape having a wave

length λ and relative amplitude a (equal to the value of amplitude divided by the average thickness), the thickness of the bundle of fibers $S_1(X)$ at the position X taken on the lengthwise axis of the bundle is expressed as follows, wherein $\overline{S}$ refers to the average value of $S_1(X)$;

$$S_1(X)=\overline{S}\left(1+a\sin\frac{2\pi}{\lambda}X\right) \tag{1}$$

The bundle of fibers delivered from the drafting equipment is drafted at a draft ratio of V/U and converted into a bundle of fibers having average thickness of $\overline{S}U/V$ on account of the subtracted speed between the delivery speed from the drafting equipment and the superficial speed of the inside wall of the spinning rotor. The thickness $S_2(X)$ of the converted bundle of fibers is as follows:

$$S_2(X)=\frac{U}{V}\overline{S}\left\{1+a\sin\frac{2\pi}{\lambda'}X\right\} \tag{2}$$

wherein

$$\lambda'=\frac{\lambda V}{U}$$

The trace of the bundle of fibers deposited spirally on the inside wall of the spinning rotor before being separated therefrom is shown in FIG. 31.

The total thickness S′(X) of the bundle of fibers at the point P on the inside wall of the rotor is generally expressed by the following equation, wherein Q refers to the number of the winding of the bundle of fibers or the inside wall of the spinning rotor, and l refers to the circular length of the inside wall of the spinning rotor which is equal to $2\pi R$;

$$S'(X)=\sum_{K=0}^{Q-1}S(X+kl) \tag{3}$$

inserting Equation 2 into Equation 3

$$S'(X)=Q\frac{U}{V}\overline{S}\left\{1+a\frac{\sin\pi 1Q}{Q\sin\frac{\pi 1}{\lambda'}}\sin\frac{2\pi}{\lambda'}\left(X+\frac{(Q-1)}{2}\right)\right\} \tag{4}$$

in case

$$\pi 1\ll\lambda',\ \sin\frac{\pi 1}{\lambda'}\doteqdot\frac{\pi 1}{\lambda'}$$

then

$$S'(X)=Q\frac{\overline{U}}{V}\overline{S}\left\{1+a\frac{\lambda'}{Q\pi 1}\sin\frac{\pi 1Q}{\lambda}\sin\frac{2\pi}{\lambda}\left(X+\frac{(Q-1)}{2}1\right)\right\} \tag{5}$$

The bundle of fibers is separated successively from the inside wall of the spinning rotor while it is being deposited upon the wall successively. Formation of fibers deposited upon the inside wall is shown in FIG. 3. If a portion of the bundle is separated from the inside wall at the point **2***b*, a time of $2\pi R/W$ is required for the next portion of the bundle to be separated from the inside wall at the same point. Meanwhile, the spinning rotor is rotated $M\cdot 2\pi R/W=V/W$ turns and V/W layers of bundles are deposited upon at the point **2***b* when the next separation of the bundle takes place again at the point. The above-described process is the same at all points on the inside wall. Therefore, the above-described Q is equal to V/W.

Inserting the relation $Q=V/W$ and $\lambda'=\lambda V/U$ into Equation 5,

$$S'(X)=\frac{\overline{S}U}{W}\left\{1+aA\sin\frac{2\pi}{\lambda'}\left(X+\frac{(Q-1)l}{2}\right)\right\} \tag{6}$$

Referring to Equation 6, the thickness S′(X) of the yarn produced bears a sine curve-shaped variation having the wave length $\lambda'=\lambda V/U$ and the relative amplitude aA.

The value of A is always smaller than 1 and is expressed by the following equation.

$$A=\frac{\lambda W}{\pi lU}\sin\frac{\pi lU}{\lambda W} \quad (7)$$

As already described, the unevenness of the yarn caused by the eccentric variation of the front top roller is the largest of the periodical unevenness produced during the drafting process which affects the resulting quality of the yarn produced. The sine curve-shaped unevenness thus produced in the yarn has a wave length which is equal to the circular length $2\pi r$ of the front top roller and an amplitude which is proportional to the degree of eccentricity and to (draft ratio—1). Therefore, Equation 7 can be rewritten as follows by using the relation $\lambda=2\pi r$ and $1=2\pi R$

$$A=\frac{rW}{\pi RU}\sin\frac{\pi RU}{rW} \quad (8)$$

It is apparent from the above Equation 8, that the value of A is dependent on the value RU/rW as shown in FIG. 32.

Referring to FIG. 32, A is aproximately equal to 1 when the value of RU/rW is very small, and decreases gradually toward zero as RU/rW increases. And A is equal to zero when the value of RU/rW is an integer. Generally, the degree of variation is expressed mathematically by variance, especially in case of appreciating the unevenness of the spinning yarn, it is convenient to apply relative variance instead of usual variance. Here, the relative variance is obtained by dividing variance by the mean value squared and is equal to the squared value of the percent of variation divided by 10^4. Using the Equation 6, relative variance c^2 of the thickness of yarn is expressed as follows;

$$c^2=\tfrac{1}{2}a^2A^2 \quad (9)$$

On the other hand, the relative variance of the thickness of the bundle of fibers just after being delivered from the drafting equipment is equal to $\tfrac{1}{2}a^2$. Therefore, the relative variance of the thickness of the yarn delivered from the spinning rotor of the present invention is A^2 times larger than that of the bundle of fibers delivered from the drafting equipment. By selecting the values of R, U, r and W so as to make the value of RU/rW an integer, it is possible, irrespective of how large the eccentric variation of the front top roller is, to eliminate the periodical unevenness of the thickness of the yarn produced completely, which is caused by the eccentric variation of the front top roller. But in practical cases, it is difficult to make A zero on account of the variation in fiber length and wave length. Although it is most preferable to make the value of RU/rW an integer, it is possible to make the percent of increase in the variance caused by the periodical unevenness below 5 but larger than 0.83, that is $|A|<0.224$ and $A^2<0.05$, by making the value of RU/rW larger than 0.83. If the degree of increase in the variance being limited to this value, the eliminating effect of the unevenness can be considered as being sufficient in practical case. And it is not always necessary for the value of RU/rW to be an integer.

On the other hand, it is necessary to increase the value of R or U in order to increase the value of RU/rW. But the increased R results in increased distance between spindles requiring increased power consumption and increased results in sticking of the fibers onto the surface of rollers. It is therefore not desirable to increase the value of R or U too much.

Referring to FIG. 32, sufficient degree of eliminating effect can be expected by making the value of RU/rW approximately equal to 4 or 5. It is therefore not necessary to make the value of RU/rW larger than 5 because this results in increased power consumption, floor space and difficulty in operation. Consequently, the value of RU/rW should be preferably chosen between 0.83 and 5 in practical cases.

Furthermore, the periodical unevenness of the thickness of the yarn is also caused by draft waves. While, in most cases, the wave length of the draft waves is from 2 to 2.5 times larger than the length of fibers fed to the apparatus, the circular length of the front top roller **2** is from 2 to 3 times larger than the length of fibers fed to the apparatus in case of cotton spinning or synthetic fiber spinning. Therefore, the wave length of the draft wave is approximately equal to that of the periodical unevenness caused by the eccentric variation of the front top roller. The approximately periodical unevenness called draft wave can be completely or almost eliminated by selecting the value of RU/rW between 0.83 and 5. Furthermore, by selecting the value of R so as to satisfy the above-described mechanical condition, the circular length of the inside wall of the spinning rotor becomes sufficiently large compared with the length of fibers fed to the apparatus, and this results in easy separation of fibers from the deposited layers on the inside wall of the rotor. As described repeatedly, it is almost possible to eliminate periodical unevenness of yarn thickness caused by the eccentric deviation of the front top rollers and by draft waves by proper selection the values of R, r, W and U so as to satisfy the relation

$$0.83<\frac{RU}{rW}<5$$

in the spinning apparatus of the present invention.

EXAMPLE

A drawing sliver of 200 grain/6 yds. produced by passing through a double drawing process is fed to the 4-line-double apron type super high draft equipment and a yarn of 20's (English count system) is obtained. The fed sliver is composed of polypropylene fibers of 1.5d x 38 mm. (cut length). An eccentric front top roller which is covered with synthetic rubber is used. The outside diameter of the roller is 31 mm., width is 27 mm., and the degree of eccentricity is 0.5 mm. The delivered bundles of fibers are supplied to the traditional ring and traveller type spinning machine and to the spinning apparatus of the present invention respectively. In the present case the value of RU/rW is set to 2.3. The unevenness of yarn thickness produced by the traditional spinning machine is shown in FIG. 33, wherein a remarkable periodical unevenness having 10 cm. of wave length is observed. The unevenness of yarn thickness produced by the spinning rotor of the present invention is shown in FIG. 34, wherein the periodical unevenness whose wave length is equal to the circular length of the front top roller can hardly be observed. This is also proved by the spectrograph shown in FIG. 35.

The mechanical conditions in the embodiment shown in FIG. 34 is as follows;

U=64 m./min.
W=43 m./min.
R=25 mm.
r=16 mm.

By applying the spinning apparatus of the present invention, it is possible to eliminate almost all of the unevenness of yarn thickness produced during spinning operation, and to obtain a yarn having superior evenness which comprises only an unevenness having longer wave length produced in the process preceding the spinning process and random unevenness.

AUXILIARY EQUIPMENT ATTACHED TO THE SPINNING APPARATUS OF THE PRESENT INVENTION

Generally speaking, yarns produced by the conventional spinning apparatus utilizing pneumatics and centrifugal force were characterized by their bulky and slacked structure caused by twisting operation which was performed while the individual fibers are in a slacked condition after eliminating internal stress on individual fibers by transferring pneumatically. This bulky and slacked structure of the yarn produced is not ordinarily desired, although there are some cases in which they are prepared. In order to obtain yarn of tight structure such as that of the conventional spinning yarns, it is effective to give a definite degree of drafting to the yarn produced by the spinning apparatus of the present invention in the passageway from the delivery rollers to the yarn package. When thermoplastic synthetic fibers are contained in the fibrous materials supplied to the spinning apparatus of the present invention, it is also desirable to dispose heat-setting equipment within the stretch zone in order to heat-setting the yarn produced. According to the results of a mill test, the stretch ratio should be chosen between 1.05 and 1.20 in order to obtain preferable results.

Referring to FIGS. 36 and 37, an embodiment of the stretch equipment disposed between the delivery rollers and the yarn package is shown, wherein the same type of spinning apparatus as shown in FIG. 2 is applied.

In FIG. 36, the superficial speed of a pair of rollers **110, 110'** is higher than that of the pair of delivery rollers **18, 18'** so as to perform stretching operation within the zone between them. In FIG. 37, heat-setting equipment **112** is disposed within the draft zone formed between the pair of rollers **110, 110'** and a pair of rollers **111, 111'**. By applying above-described drafting equipment, the twist constant and the elongation of the produced yarn are decreased and the bulkiness of the yarn produced is suitably controlled, thereby a tight structure of the yarn produced can be obtained. Consequently, yarn breakage during the take-up operation is avoided and this results in increased production speed.

What is claimed is:

1. In a method for manufacturing a yarn from textile fibers utilizing a pneumatic fluid stream on a rotating hollow rotor having an inlet and an outlet and connected with a given supply source of a bundle of said textile fibers; the improvement comprising advancing said bundle of fibers from said given supply source towards said hollow rotor by a pneumatic suction flow, positively shredding individual fibers from said advanced bundle of fibers at a given position between said supply source and said inlet of said hollow rotor by ejecting a pneumatic flow produced by compressed air on said bundle of fibers which is directed to a given position on an inside peripheral wall of said hollow rotor, supplying said shredded fibers successively through said inlet of said hollow rotor onto said inside peripheral wall of said hollow rotor together with said pneumatic flow, accumulating said shredded fibers in longitudinally successive layers on said inside peripheral wall of said hollow rotor, releasing said accumulated layers of fibers successively and longitudinally from said inside peripheral wall concurrently with rebundling and rolling said fibers, further advancing said rebundled fibers outside of said rotor through said outlet of said rotor and taking up said bundle of fibers onto a package; thereby providing said rebundled fibers with twist by rolling said rebundled fibers while releasing and further advancing.

2. An improvement according to claim **1**, in which inside pressure of said hollow rotor is maintained at a value at least approximately atmospheric pressure.

3. An improvement according to claim **1**, in which said rebundled fibers, after said releasing, are advanced along a curved path in a region from said inside peripheral wall to said outlet of said rotor.

4. An improvement according to claim **1**, in which said rebundled fibers are subjected to positive external resistance while advancing, after releasing said rebundled fiber from said inside peripheral wall towards the outside of said rotor through said outlet of said rotor, thereby increasing the number of twists imparted to a unit length of said rebundled fibers.

5. An improvement according to claim **1**, in which said rebundled fibers are stretched in a region between said bottom of said rotor and said package.

6. An improvement according to claim **5**, in which said rebundled fibers are subjected, concurrently with stretching, to heating at a temperature high enough to heat set a configuration of said rebundled fibers.

7. In a spinning apparatus having a hollow rotor having an inlet and an outlet, a feeding device for advancing a bundle of fibers from a given supply source towards said hollow rotor, means for shredding individual fibers from said bundle of fibers by pneumatic fluid stream, means for driving said rotor at a high rotating speed and means for taking up fibers in a rebundled condition from said hollow rotor concurrently with imparting twists to said rebundled fibers, the improvement comprising means for advancing said bundle of fibers from said given supply source towards said hollow rotor by a pneumatic suction flow produced by compressed air and means for positively shredding individual fibers from said advanced bundle of fibers at a given position between said supply source and said inlet of said hollow rotor by ejecting a pneumatic flow on said bundle of fibers which is directed to a given position on an inside peripheral wall of said hollow rotor; both of said advancing means and said shredding means being disposed in said feeding device and a delivery end portion of said shredding means being received by said inlet of said rotor.

8. An improvement according to claim **7**, in which said feeding device comprises, in combination, a supply pipe with its inlet positioned close to said given supply source of said bundle of fibers, a delivery pipe with its outlet closely directed to an inside peripheral wall of said hollow rotor and a jet conduit located in between said supply pipe and said delivery pipe; said jet conduit introducing a flow of compressed air along an advancing direction of said fibers within said feeding device.

9. An improvement according to claim **8**, in which said feeding device comprises a pneumatic supply zone and a fiber separating zone following said pneumatic supply zone; said pneumatic supply zone including said supply pipe and at least a part of said jet conduit.

10. An improvement according to claim **9**, in which an effective length of said pneumatic supply zone is shorter than an average length of said fibers composing said supplied bundle fibers.

11. An improvement according to claim **8**, further comprising a cylindrical guide member disposed coaxially of said inlet of said rotor; a delivery end of said delivery pipe being disposed through said cylindrical guide member and forming an opening facing said inside peripheral wall of said hollow rotor.

12. An improvement according to claim **7**, further comprising at least one additional feeding device located independently from said feeding device of said apparatus; inlets of said two or more feeding devices being located closely and independently to respective supply sources of bundles of fibers and outlets of said two or more feeding devices being directed independently and closely to given positions on said inside peripheral wall of said hollow rotor; whereby two or more bundles of fibers supplied from said respective supply sources are blended uniformly within said hollow rotor.

13. An improvement according to claim **8**, in which said delivery pipe is composed of a conduit having a constant diameter which is slightly larger than that of a termination of said supply pipe and a subsequently diverged conduit having a diversion angle in a range from 5° to 30°.

14. An improvement according to claim **9**, in which said separating zone includes a plurality of annular steps and a plurality of apertures formed between adjacent steps for introducing a jet air stream into said separating zone along said advancing directions of said fibers.

15. An improvement according to claim 7, in which said hollow rotor comprises, on an inside wall thereof, an annular fiber receiving surface, an annular yarn guide surface and an annular fiber bundle collecting surface between said fiber receiving surface and said yarn guide surface, said three surfaces successively arranged and said yarn guide surface being provided with an aperture for permitting discharge of said rebundled fibers out of said hollow rotor.

16. An improvement according to claim 15, in which the mechanical construction of said hollow rotor is defined by:

$$0.83<\frac{RU}{rw}<5$$

wherein

R=radius of said fiber collecting surface of said rotor in cm.,

U=supplying speed of said bundle of fibers from said given supply source in cm./sec.,

r=radius of a delivery roller of said given supply source in cm.,

w=take-up speed of a yarn acquired in cm./sec.

17. An improvement according to claim 15, in which said fiber receiving surface diverges towards said fiber collecting surface.

18. An improvement according to claim 15, in which said fiber receiving surface includes at least two surfaces diverging towards said fiber collecting surface with different diverging angles.

19. An improvement according to claim 15, in which said fiber receiving surface includes at least two annular stepped surfaces.

20. An improvement according to claim 15, in which said fiber receiving surface includes more than one annular roughened portions.

21. An improvement according to claim 15, in which said yarn guide surface has an annular diverged portion formed toward said fiber collecting surface.

22. An improvement according to claim 15, in which said yarn guide surface has more than one annular projections formed as one body.

23. An improvement according to claim 22, in which said annular projections are provided with a plurality of apertures passing therethrough.

24. An improvement according to claim 22, in which said yarn guide surface is provided with a plurality of apertures formed adjacent to said annular projections.

25. An improvement according to claim 15, in which said rotor is rotatably supported by a hollow shaft secured to a frame of said apparatus.

26. An improvement according to claim 15, in which said rotor is supported by a hollow shaft, an upper end of which is connected to said outlet of said hollow rotor, said hollow shaft being rotatably supported by a hollow bracket secured to a frame of said apparatus.

27. An improvement according to claim 15, further comprising a hollow shaft disposed at said outlet of said rotor and a twist controller disposed within said hollow shaft.

28. An improvement according to claim 27, in which said twist controller is made of elastic materials.

29. An improvement according to claim 27, in which said twist controller is disposed at a head portion of said hollow shaft.

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