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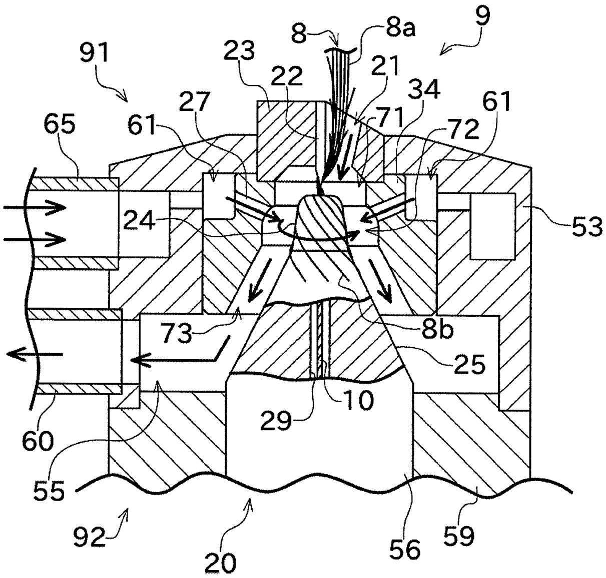
(54) **Pneumatic spinning device and spinning machine**

(57) A pneumatic spinning device includes a hollow guide shaft (20) , and a nozzle block (34). A portion of the hollow guide shaft (20) is located within a whirling chamber. A whirling chamber is formed in the nozzle block (34). Four air injecting nozzles (27) that inject compressed air from a nozzle opening (27a) opening into the whirling chamber to generate whirling airflow in the whirling chamber are formed in the nozzle block (34). The whirling chamber has a columnar portion formed as a substantially columnar shape having a constant diameter (D2). A height (H1) of the whirling chamber is equal to or smaller than the diameter (D2) . A flow path cross-sectional area at a downstream end of the whirling chamber in a fiber feeding direction (a position A2) is formed smaller than a flow path cross-sectional area of the whirling chamber at a position where the nozzle opening (27a) is formed.

FIG. 5



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Description

1. Field of the Invention

[0001] The present invention mainly relates to a pneumatic spinning device. More particularly, the present invention relates to a shape of a space in which whirling airflow is generated in the pneumatic spinning device.

2. Description of the Related Art

[0002] Conventionally, there is known a spinning machine provided with a pneumatic spinning device which applies twists to fibers by utilizing whirling airflow to generate spun yarn. This type of pneumatic spinning device includes a whirling chamber, and an air injecting nozzle that injects compressed air into the whirling chamber to generate whirling airflow in the whirling chamber. The fibers are subjected to an action of the whirling airflow and whirl in the whirling chamber. Accordingly, twists are applied to the fibers and spun yarn is produced.

[0003] As described above, since the fibers are twisted by the whirling airflow to produce the spun yarn, quality of the spun yarn is greatly influenced by a flowing manner of the whirling airflow. Accordingly, there has been conventionally devised a shape of the whirling chamber in which the whirling airflow is generated.

[0004] For example, Japanese Unexamined Patent Publication No. 2003-193337 discloses a spinning device in which a whirling chamber that is a space in which whirling airflow is generated (a portion corresponding to a space formed between wall surfaces of a first circular truncated cone shaped space section and a second circular truncated cone shaped space section, and an outer peripheral wall surface of a first circular truncated cone shaped section of a hollow guide shaft) is formed as a tapered tubular shape. As illustrated in FIG. 5 and the like of the prior art document, the whirling chamber having the tapered tubular shape is formed such that diameter of a wall surface in an outer peripheral side of the whirling chamber (an inner peripheral wall of a nozzle block) and diameter of a wall surface in an inner peripheral side of the whirling chamber (an outer peripheral wall of the hollow guide shaft) are wider towards downstream in a fiber feeding direction. By forming the whirling chamber wider towards the downstream, the whirling airflow may smoothly flow towards the downstream.

[0005] Japanese Unexamined Patent Publication No. 2003-193337 discloses a structure in which the inner peripheral wall surface of the nozzle block has a protruding section serving as a throttle section. This prior art document discloses that a rate adjustment of a whirling component and an axial flow component of the whirling airflow can be carried out by appropriately setting a cross-sectional area of the whirling chamber in the protruding section. By increasing a protruding amount of the protruding section, the whirling airflow hardly flows towards the downstream, and the whirling airflow can strongly whirl in the whirling chamber.

[0006] Japanese Unexamined Patent Publication No. 2008-297688 discloses a spinning device in which a whirling chamber (a whirling airflow generating chamber) is formed as a columnar shape. A width of a flow path of the columnar whirling chamber (an interval between an inner peripheral wall of a nozzle block and an outer peripheral wall of a spindle) is constant within a predetermined height range. This prior art document discloses that spun yarn having predetermined yarn strength can be produced by structuring such that, when the width of the flow path of the whirling chamber is S, an outlet diameter D of an air nozzle (an air injecting nozzle) has a relationship of $0.7D \leq S \leq 1.3D$.

[0007] When the whirling chamber is formed wider towards the downstream as in Japanese Unexamined Patent Publication No. 2003-193337, a whirling diameter of the whirling airflow becomes larger towards the downstream, and there is a problem that the fibers cannot be whirled at high speed in the downstream side. If the whirling chamber is formed wider towards the downstream as in this prior art document and the width of the flow path is constant, a cross-sectional area of the whirling chamber becomes larger towards the downstream of the whirling chamber. As a result, the compressed air expands in the whirling chamber, a flow speed is reduced, and a density of the whirling flow becomes smaller. Accordingly, the structure of this prior art document is limited in spinning speed, and productivity of the spinning device could not be improved.

[0008] Japanese Unexamined Patent Publication No. 2003-193337 describes that spun yarn having desired yarn strength can be produced by setting a cross-sectional area of the whirling chamber (the space) in the protruding section to a range from 7 sqmm to 12 sqmm. However, this prior art document does not describe a relationship between the cross-sectional area and the diameter of the air injecting nozzle (a specific numerical value of the diameter of the air injecting nozzle is not described). Referring to FIG. 5 of this prior art document, the width of the flow path of the whirling chamber (a gap between the inner peripheral surface of the nozzle block and the surface of the hollow guide shaft) is estimated to be about six-fold of the diameter of the air injecting nozzle. As described above, if the width of the whirling chamber is too large with respect to the nozzle outlet, the injected air from the air injecting nozzle expands in the spinning chamber, and the flow speed of the whirling airflow is reduced. Accordingly, high-speed whirling flow is difficult to be maintained. In this point as well, the structure of this prior art document is also limited in spinning speed.

[0009] On the other hand, in the spinning device disclosed in Japanese Unexamined Patent Publication No. 2008-297688, since the whirling chamber is formed as the columnar shape, a whirling radius of the whirling airflow does not become large even in the downstream of the whirling chamber. Therefore, compared with the structure in which the whirling chamber is formed wider towards the downstream as in Japanese Unexamined Patent Publication No. 2003-193337, the whirling speed of the fiber can be maintained even in the downstream of the whirling chamber. However, the structure of Japanese Unexamined Patent Publication No. 2008-297688 does not include the protruding section (the throttle section) in Japanese Unexamined Patent Publication No. 2003-193337. Therefore, in the structure of Japanese Unexamined Patent Publication No. 2008-297688, the whirling airflow in the whirling chamber is prone to flow towards the downstream without whirling sufficiently. Accordingly, in order to sufficiently whirl the fibers in the whirling chamber, a countermeasure is required such as enlarging a dimension in a height direction of the whirling chamber (a dimension in a fiber flowing direction) so as to increase a distance in which the whirling airflow is acted upon the fibers. In fact, referring to FIG. 2 of Japanese Unexamined Patent Publication No. 2008-297688, the height of the whirling chamber is formed larger than the diameter of the whirling chamber.

[0010] By forming the whirling chamber high as described above, the distance in which the compressed air whirls at high speed in the whirling chamber becomes long, and consumed energy (a consumed flow rate) for flowing the whirling airflow becomes large. In other words, in the structure of Japanese Unexamined Patent Publication No. 2008-297688, it is difficult to maintain the whirling speed of the fiber unless a great amount of energy is consumed. As a result, the speed of the whirling airflow decreases in the downstream side of the whirling chamber, and the fibers cannot be whirled at high speed. As described above, the structure of Japanese Unexamined Patent Publication No. 2008-297688 also had restrictions in improving the productivity by increasing the spinning speed. By making the whirling chamber high as described above, the size of the pneumatic spinning device also becomes large.

[0011] Japanese Unexamined Patent Publication No. 2008-297688 discloses a relationship of $0.7D \leq S \leq 1.3D$, however, if $S = 0.7D$ is set, the diameter of the nozzle outlet becomes larger than the width of the flow path of the whirling chamber. In this case, the air injected from the nozzle outlet expands to an irregular shape in the whirling chamber, and interferes with air injected from another nozzle outlet adjacent thereto. Accordingly, turbulence of air is generated in the whirling chamber. When the width of the flow path of the whirling chamber is smaller than the diameter of the nozzle outlet as described above, the whirling chamber may not allow a great amount of injected air. In this case, the injected air flows out towards a reversing chamber (a suction depressurizing chamber) in upstream of the whirling chamber. As a result, malfunctions occur such that a fiber bundle cannot be guided to the reversing chamber, and that a suction flow rate in the suction depressurizing chamber becomes small. On the other hand, even if $S = 1.3D$ is set, considering that the injected flow expands in the whirling chamber, the flow path width of the whirling chamber is small with respect to the diameter of the nozzle outlet.

SUMMARY OF THE INVENTION

[0012] An object of the present invention is to provide a pneumatic spinning device in which fibers can be whirled at high speed and stably in a whirling chamber.

[0013] According to a first aspect of the present invention, there is provided a pneumatic spinning device for producing spun yarn by whirling fibers of a fiber bundle by whirling airflow in a substantially columnar whirling chamber, wherein the pneumatic spinning device includes a spindle and a whirling chamber section. At least a portion of the spindle is located in the whirling chamber. The whirling chamber is formed in the whirling chamber section. At least one air injecting nozzle is formed in the whirling chamber section for injecting compressed air from a nozzle opening opening into the whirling chamber to generate the whirling airflow in the whirling chamber. The whirling chamber has a columnar portion formed as a substantially columnar shape having a constant diameter. A height of the whirling chamber is equal to or smaller than the diameter of the whirling chamber. A flow path cross-sectional area at a downstream end portion of the whirling chamber in a fiber feeding direction is smaller than a flow path cross-sectional area of the whirling chamber at a downstream end portion of an opening contour of the nozzle opening.

[0014] As described above, by making the diameter of the whirling chamber to be constant, a whirling radius of the whirling airflow does not become large even at the downstream of the whirling chamber, and the whirling flow can be kept at high speed until the whirling airflow is discharged to the downstream of the whirling chamber. Accordingly, since a winding fiber can be whirled at high speed, a yarn strength of the produced spun yarn can be improved. As a result, high speed spinning at 500 m/min or 600 m/min, which has not been conventionally realized, can be realized. Since the flow path cross-sectional area at the downstream end portion of the whirling chamber is formed small, the whirling airflow in the whirling chamber hardly flows out towards the downstream. Accordingly, the whirling airflow in the whirling chamber can flow at high speed while maintaining a blowing angle from the air injecting nozzle and suppressing a decrease in the speed. As a result, the yarn strength of the produced spun yarn can be maintained stably. With the above structure, the whirling airflow can be effectively applied to the fiber bundle even within a short distance, and the height of the whirling chamber can be made low. For example, as described above, the height of the whirling chamber can be made equal to or smaller than the diameter thereof. Accordingly, consumed energy for flowing the whirling airflow can be reduced, and energy saving can be achieved. Thus, the pneumatic spinning device can be formed compact in a height direction.

[0015] In the above pneumatic spinning device, at the downstream end portion of an opening contour of the nozzle opening, an interval between an inner wall surface of the whirling chamber section forming the whirling chamber and an outer peripheral surface of the spindle is at least 1.3 times and less than or equal to 2.5 times a diameter of an opening of the air injecting nozzle. Accordingly, a width of the flow path of the whirling chamber can be appropriately formed with respect to the compressed air injected from the air injecting nozzle. Therefore, the compressed air injected from the air injecting nozzle can be prevented from expanding due to the flow path being too wide, and from warping due to the flow path being too narrow.

[0016] In the above pneumatic spinning device, at the downstream end portion of the opening contour of the nozzle opening, the interval between the inner wall surface of the whirling chamber section forming the whirling chamber, and the outer peripheral surface of the spindle is at least 1.5 times and less than or equal to 2.0 times the diameter of the opening of the air injecting nozzle. Accordingly, the width of the flow path of the whirling chamber can be further appropriately formed with respect to the compressed air injected from the air injecting nozzle.

[0017] In the above pneumatic spinning device, the spindle is preferably formed such that among the portion of the spindle located in the whirling chamber, a diameter of a portion located upstream in a fiber feeding direction is smaller than a diameter of a portion located downstream in the fiber feeding direction. Accordingly, since the width of the flow path in the downstream of the whirling chamber can be prevented from being widened, the whirling airflow in the whirling chamber can be suppressed from flowing out towards the downstream without whirling sufficiently. Therefore, the high-speed whirling airflow in the whirling chamber can be maintained, and as a result, the winding fiber can be wound around core fiber while being sufficiently whirled in the whirling chamber, even in high-speed spinning such as 500 m/min or 600 m/min.

[0018] In the above pneumatic spinning device, a ratio of the height of the whirling chamber with respect to the diameter of the whirling chamber is preferably at least 0.4 and less than or equal to 1.0. By making the height of the whirling chamber to be equal to or smaller than the diameter thereof, the consumed energy for flowing the whirling airflow into the whirling chamber can be reduced, and energy saving can be achieved. Further, the pneumatic spinning device can be formed compact in the height direction. As described above, by setting the height of the whirling chamber to be at least 0. 4 times the diameter thereof, the space of the whirling chamber for applying the whirling airflow to the winding fiber does not become too short. Accordingly, the whirling airflow can be effectively applied to the winding fiber.

[0019] In the above pneumatic spinning device, the air injecting nozzle is preferably formed to inject the compressed air so as to aim the whirling chamber. Accordingly, the compressed air injected from the air injecting nozzle can be discharged after being whirled in the whirling chamber. Therefore, even in the high-speed spinning, the winding fiber can be wound around the core fiber after being sufficiently whirled in the whirling chamber.

[0020] According to a second aspect of the present invention, a spinning machine includes the above pneumatic spinning device, a draft device, a drawing device, and a winding device. The draft device is arranged upstream of the pneumatic spinning device, and drafts the fiber bundle. The drawing device is arranged downstream of the pneumatic spinning device, and draws the spun yarn produced by the pneumatic spinning device from the pneumatic spinning device. The winding device winds the spun yarn drawn out by the drawing device into a package. Accordingly, the spun yarn having high yarn strength can be produced even in high-speed spinning, thereby improving quality and productivity of the package into which the spun yarn is wound.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021]

FIG. 1 is a front view illustrating an entire structure of a spinning machine according to an embodiment of the present invention;
FIG. 2 is a cross-sectional view of the spinning machine;
FIG. 3 is a schematic vertical cross-sectional view of a pneumatic spinning device;
FIG. 4 is a vertical cross-sectional view of a nozzle block;
FIG. 5 is a vertical cross-sectional view illustrating a state during spinning of the pneumatic spinning device; and
FIG. 6 is a schematic vertical cross-sectional view of a pneumatic spinning device according to another embodiment.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0022] Next, a description will be made of a first embodiment with reference to the accompanying drawings. A spinning machine 1 illustrated in FIG. 1 includes a plurality of spinning units 2 which are arranged in line. The spinning machine 1 includes a yarn splicing cart 3, a blower box 4 and a motor box 5. The yarn splicing cart 3 can travel in a direction in which the spinning units 2 are arranged.

[0023] As illustrated in FIG. 1, each of the spinning units 2 mainly includes a draft device 7, a pneumatic spinning device 9, a yarn feeding device (a drawing device) 11 and a winding device 12. The draft device 7 is provided in an upper portion of a frame 6 of the spinning machine 1. The pneumatic spinning device 9 spins a fiber bundle 8 fed from the draft device 7 to generate spun yarn 10. The spun yarn 10 generated by the pneumatic spinning device 9 is drawn out from the pneumatic spinning device 9 by the yarn feeding device 11, and is fed downstream. Thereafter, the spun yarn 10 is wound by the winding device 12 to form a package 45. In FIG. 1, the winding device 12 is illustrated so as to form a cheese winding package. However, the winding device 12 may be structured to form a cone winding package. In the following description, "upstream" or "downstream" respectively means upstream or downstream in a feeding direction of the fiber bundle 8 (or the spun yarn 10).

[0024] The draft device 7 drafts a sliver 13 to form the fiber bundle 8. As illustrated in FIG. 2, the draft device 7 includes four rollers, which are a back roller 14, a third roller 15, a middle roller 17 provided with an apron belt 16, and a front roller 18.

[0025] A draft motor 31 made of an electric motor is installed at an appropriate position in the frame 6. The back roller 14 and the third roller 15 are connected to the draft motor 31 via a belt. Driving and stopping operations of the draft motor 31 are controlled by a unit controller provided in the spinning unit 2. In the spinning machine 1 according to the present embodiment, electric motors for driving the middle roller 17 and the front roller 18 are also provided in the frame 6, however, an illustration thereof will be omitted.

[0026] The pneumatic spinning device 9 is structured by two divided blocks, that is, a first block 91 and a second block 92. The second block 92 is provided downstream of the first block 91.

[0027] The yarn feeding device 11 includes a delivery roller 39 which is supported by the frame 6 of the spinning machine 1, and a nip roller 40 which is arranged so as to make contact with the delivery roller 39. With this structure, the spun yarn 10 can be drawn out from the pneumatic spinning device 9 and fed to the winding device 12 by nipping the spun yarn 10 between the delivery roller 39 and the nip roller 40 and rotating the delivery roller 39 by an electric motor (not illustrated).

[0028] The yarn splicing cart 3 includes a splicer (a yarn splicing device) 43, a suction pipe 44 and a suction mouth 46, as illustrated in FIGS. 1 and 2. As illustrated in FIG. 1, the yarn splicing cart 3 is provided so as to travel on a rail 41 provided on the frame 6 of the spinning machine 1 main body. If a yarn cut or a yarn breakage is generated in a certain spinning unit 2, the yarn splicing cart 3 travels to such a spinning unit 2 and stops. The suction pipe 44 sucks and catches a yarn end fed out from the pneumatic spinning device 9 and guides the yarn end to the splicer 43 while rotating in a vertical direction around an axis. The suction mouth 46 sucks and catches a yarn end from the package 45 rotatably supported by the winding device 12 and guides the yarn end to the splicer 43 while rotating in a vertical direction around an axis. The splicer 43 carries out yarn splicing of the guided yarn ends.

[0029] Next, a description will be made in detail on a structure of the pneumatic spinning device 9 with reference to FIG. 3. As illustrated in FIG. 3, the first block 91 includes a nozzle section casing 53, and a nozzle block 34 and a fiber guide section 23 that are held by the nozzle section casing 53. The second block 92 includes a hollow guide shaft (a spindle) 20, and a shaft holding member 59.

[0030] A fiber guide hole 21 is formed in the fiber guide section 23. The fiber bundle 8 drafted by the draft device 7 is introduced to the fiber guide hole 21. The fiber guide section 23 holds a needle 22 which is arranged on a flow path of the fiber bundle 8 introduced from the fiber guide hole 21.

[0031] The nozzle block (a whirling chamber section) 34 is arranged at a position located downstream of the fiber guide section 23. FIG. 4 illustrates a detailed cross-sectional view of the nozzle block 34. FIG. 4 is a vertical cross-sectional view of the nozzle block 34 cut through the same plane as in FIG. 3 (a plane passing through an axis of the hollow guide shaft 20). As illustrated in FIG. 4, a passage hole 70 is formed in the nozzle block 34. The passage hole 70 is formed such that a cross-sectional shape cut through a plane orthogonal to a center axial line 90 of the hollow guide shaft 20 (a plane orthogonal to a fiber feeding direction) is formed circular.

[0032] As illustrated in FIG. 3, the hollow guide shaft 20 includes a columnar body 56 which is held by the shaft holding member 59. A tapered first taper portion 24 in which a diameter is enlarged towards downstream is formed in one end of the columnar body 56. A second taper portion 25 is formed downstream of the first taper portion 24. The second taper portion 25 is connected to the first taper portion 24. A taper angle of the second taper portion 25 is larger than a taper angle of the first taper portion 24. An inlet hole 28 is formed at a tip end of the first taper portion 24. A fiber passage 29 connected to the inlet hole 28 is formed at an axial center of the columnar body 56. A downstream end portion of the fiber passage 29 forms an outlet hole (not illustrated). The fiber bundle 8 or the spun yarn 10 which has passed through the fiber passage 29 is fed from the outlet hole towards an outer side of the pneumatic spinning device 9 by the yarn feeding device 11 arranged downstream of the pneumatic spinning device 9.

[0033] The first taper portion 24 and the second taper portion 25 of the hollow guide shaft 20 are inserted into the passage hole 70 formed in the nozzle block 34 from a side opposite to the fiber guide section 23 as seen from the nozzle block 34, while bringing an axial line of the hollow guide shaft 20 in line with an inner portion of the passage hole 70. A predetermined interval is set between an outer peripheral surface of the first taper portion 24 and the second taper portion 25 of the hollow guide shaft 20 and an inner wall surface of the nozzle block 34 (a wall surface of the passage hole 70) so that the airflow can pass therethrough.

[0034] A depressurized suction chamber 71, a whirling chamber 72 and a taper chamber 73 are formed in the nozzle block 34 in this order from upstream in the traveling direction of the fiber bundle 8. More precisely, the depressurized suction chamber 71 having a substantially cylindrical shape, the whirling chamber 72 having a substantially columnar shape and the taper chamber 73 having a substantially tapered tubular shape are formed by an outer peripheral surface of the hollow guide shaft 20 and an inner wall surface of the nozzle block 34 (a wall surface of the passage hole 70). In this case, the depressurized suction chamber 71 is formed substantially cylindrical, however, as illustrated in FIG. 3, the tip end of the hollow guide shaft 20 (the tip end of the inlet hole 28 of the fiber passage 29) is actually slightly inserted into the depressurized suction chamber 71 from the downstream side of the depressurized suction chamber 71. As illustrated in FIG. 3, a portion of the hollow guide shaft 20 is inserted into the whirling chamber 72, and a portion of the outer peripheral surface of the first taper portion 24 forms a wall surface in an inner peripheral side of the whirling chamber 72. Accordingly, the wall surface in the inner peripheral side of the whirling chamber 72 having the substantially columnar shape is formed as a taper shape in which a diameter is enlarged towards downstream.

[0035] As illustrated in FIG. 3, the depressurized suction chamber 71 is connected to the fiber guide hole 21 of the fiber guide section 23. The whirling chamber 72 is connected to the depressurized suction chamber 71. The taper chamber 73 is connected to the whirling chamber 72.

[0036] Meanwhile, a supply air accumulating chamber 61 is formed around the nozzle block 34. A compressed air supplying pipe 65 connected to a compressed air source (not illustrated) is connected to the nozzle section casing 53. Accordingly, the compressed air can be supplied to the supply air accumulating chamber 61 from the compressed air source.

[0037] Four air injecting nozzles 27 connecting the whirling chamber 72 and the supply air accumulating chamber 61 are formed in the nozzle block 34. Each of the air injecting nozzles 27 is formed as an elongated round hole which is pierced through the nozzle block 34. Four air injecting nozzles 27 are arranged at an equal interval in a peripheral direction of the whirling chamber 72. The compressed air supplied to the supply air accumulating chamber 61 is injected into the whirling chamber 72 via the air injecting nozzle 27. Accordingly, whirling airflow that whirls in one direction around the axial line of the hollow guide shaft 20 is generated in the whirling chamber 72.

[0038] In order to generate such whirling airflow as described above in the whirling chamber 72, a longitudinal direction of the air injecting nozzle 27 is directed substantially to a tangential direction of the whirling chamber 72 in plan view. FIG. 3 illustrates as if the longitudinal direction of the air injecting nozzle 27 exists in the same plane as the center axial line of the whirling chamber 72. However, FIG. 3 has been simply (conceptually) illustrated for facilitating understanding of the drawing. The air injecting nozzle 27 is actually formed in the tangential direction of the whirling chamber 72 as described above. Therefore, a cross-sectional view more accurately illustrating the air injecting nozzle 27 is illustrated in FIG. 4.

[0039] As illustrated in FIGS. 3 and 4, the longitudinal direction of the air injecting nozzle 27 is slightly inclined towards the downstream side. Accordingly, the compressed air injected from the air injecting nozzle 27 can flow towards the downstream.

[0040] With the above structure, the compressed air injected from the air injecting nozzle 27 flows towards the downstream in the traveling direction of the fiber bundle 8 while whirling in the whirling chamber 72. That is, spiral whirling airflow flowing towards the downstream can be generated in the whirling chamber 72.

[0041] An air discharge space 55 is formed in the nozzle section casing 53. The air discharge space 55 is connected to the taper chamber 73. A negative pressure source (a suction unit) (not illustrated) which is arranged in the blower box 4 is connected to the air discharge space 55 through a pipe 60.

[0042] Next, a description will be made of a state at the time of introducing the fiber bundle 8 to the fiber guide hole 21 in the pneumatic spinning device 9 structured as described above.

[0043] First, under a state in which the fiber bundle 8 is not introduced into the pneumatic spinning device 9 (a state illustrated in FIG. 3), the compressed air is supplied to the supply air accumulating chamber 61 from the compressed air source (not illustrated). The compressed air supplied to the supply air accumulating chamber 61 is injected towards the whirling chamber 72 via the air injecting nozzle 27. Accordingly, the whirling airflow generated in the whirling chamber 72 flows spirally downstream in the whirling chamber 72, and thereafter flows into the taper chamber 73. The whirling airflow further flows to downstream while weakening its flow rate, and is finally discharged from the air discharge space 55.

[0044] Meanwhile, by the generation of the airflow towards the downstream in the whirling chamber 72, the depressurized suction chamber 71 which is adjacent to the upstream of the whirling chamber 72 is depressurized, and the suction airflow is generated in the fiber guide hole 21. The suction airflow flows from the fiber guide hole 21 into the depressurized suction chamber 71. Thereafter, a portion of the suction airflow flows into the fiber passage 29 and flows downstream. The remaining suction airflow flows into the whirling chamber 72 and interflows with the whirling airflow.

[0045] If the fiber bundle 8 is fed from the draft device 7 to the pneumatic spinning device 9 under this state, the fiber bundle 8 is sucked from the fiber guide hole 21, and is guided into the depressurized suction chamber 71. The fiber bundle 8 guided into the depressurized suction chamber 71 is guided downstream through the fiber passage 29 along with the flow of the suction airflow that flows into the fiber passage 29, and is fed outside of the pneumatic spinning device 9 from the outlet hole (not illustrated) .

[0046] An end portion of the fiber bundle 8 or the spun yarn 10 which is fed out of the outlet hole of the pneumatic spinning device 9 is caught by the suction pipe 44 of the yarn splicing cart 3, and is spliced with the yarn end from the package 45 by the splicer 43. Accordingly, the fiber bundle 8 or the spun yarn 10 is continuous from the front roller 18, the fiber guide hole 21, the depressurized suction chamber 71 and the fiber passage 29 to the yarn feeding device 11. Under this state, when a feeding force towards the downstream is applied by the yarn feeding device 11, a tension is applied to the spun yarn 10 and the spun yarn 10 is sequentially pulled out from the pneumatic spinning device 9.

[0047] 1 Next, with reference to FIG. 5, a description will be made of a state in which twists are applied to the fiber bundle 8 to produce the spun yarn 10 in the pneumatic spinning device 9 according to the present embodiment. FIG. 5 conceptually illustrates the airflow within the pneumatic spinning device 9 by thick arrows.

[0048] The fiber bundle 8 is formed of a plurality of fibers. Each of the fibers is introduced into the depressurized suction chamber 71 from the fiber guide hole 21. A downstream end portion of each of the fibers is introduced into the fiber passage 29 along with the flow of the suction airflow flowing from the fiber guide hole 21 towards the fiber passage 29. Accordingly, at least a portion of the fibers introduced into the depressurized suction chamber 71 is continuous between the fiber guide hole 21 and the fiber passage 29. The fibers in this state are referred to as core fibers 8a.

[0049] The core fibers 8a are twisted by being lead by reversal fibers 8b (described below) whirling in the whirling chamber 72. The twists tend to propagate upstream (the front roller 18 side), however, the propagation is prevented by the needle 22. Accordingly, the fiber bundle 8 fed out from the front roller 18 is not twisted by the twist mentioned above. As described above, the needle 22 has a twist propagation preventing function.

[0050] The downstream end portion of each of the fibers introduced into the depressurized suction chamber 71 is twisted into the core fibers 8a which are about to be twisted. However, each of the fibers is not entirely twisted into the core fiber 8a, and the upstream end portion is a free end.

[0051] If the free end (the upstream end portion) of each of the fibers enters into the depressurized suction chamber 71, the free end is separated from the core fibers 8a so as to be opened, and flows towards the whirling chamber 72 (the downstream) by the suction airflow flowing from the depressurized suction chamber 71 into the whirling chamber 72. As described above, the upstream end portion of the fibers flows towards the downstream, whereby the direction of the upstream end portion is "reversed". The fiber in this state is referred to as the reversal fiber 8b. The fiber which has been the core fiber 8a may become the reversal fiber 8b if its upstream end portion enters into the depressurized suction chamber 71.

[0052] The free end of the reversal fiber 8b is introduced into the whirling chamber 72, and is affected by the whirling airflow flowing spirally towards the downstream. Accordingly, as illustrated in FIG. 5, the reversal fiber 8b whirls around the first taper portion 24 of the hollow guide shaft body 20 while being along the surface of the first taper portion 24 of the hollow guide shaft 20. Therefore, the free end of the reversal fiber 8b is swung around the core fiber 8a passing through the fiber passage 29. Accordingly, the reversal fiber 8b is sequentially wound around the core fiber 8a so as to form the wound fiber.

[0053] At this time, the reversal fiber 8b is pushed against the surface of the first taper portion 24 of the hollow guide shaft 20 by a force of the whirling airflow that attempts to flow downstream. Accordingly, the free end of the reversal fiber 8b can be prevented from being disordered on the hollow guide shaft 20, and the reversal fiber 8b can whirl stably around the first taper portion 24 of the hollow guide shaft 20.

[0054] Since the core fiber 8a is fed downstream through the fiber passage 29, the reversal fiber 8b (the wound fiber) wound around the core fiber 8a is sequentially pulled into the fiber passage 29 together with the core fiber 8a. At this time, since the reversal fiber 8b is pushed against the surface of the first taper portion 24 of the hollow guide shaft 20 by the force of the whirling airflow that attempts to flow downstream, an appropriate tension is applied to the reversal fiber 8b when the reversal fiber 8b is pulled into the fiber passage 29. Accordingly, the reversal fiber 8b is strongly wound around the core fiber 8a, and the spun yarn 10 having high yarn strength can be produced.

[0055] Truly twisted spun yarn 10 is produced as described above. The spun yarn 10 advances through the fiber passage 29, and is fed out from the outlet hole (not illustrated) towards the yarn feeding device 11.

[0056] The spun yarn 10 is fed via the yarn feeding device 11 illustrated in FIG. 1 and is wound by the winding device 12 to finally form a package 45. The fiber, which has been cut when being opened and twisted and which has not been twisted into the spun yarn 10, is fed from the whirling chamber 72 via the taper chamber 73 to the air discharge space 55 along with the flow of the airflow, and is discharged via the pipe 60 by the suction of the negative pressure source.

[0057] Next, a description will be made in detail on a structure of the nozzle block 34 in the pneumatic spinning device 9 according to the present embodiment.

[0058] As illustrated in FIG. 4, among the inner wall surface of the nozzle block 34 (the wall surface of the passage hole 70), a portion forming the depressurized suction chamber 71 is a depressurized suction chamber forming surface 81, and a portion forming the whirling chamber 72 is a whirling chamber forming surface 82. The depressurized suction chamber forming surface 81 is facing the depressurized suction chamber 71. The whirling chamber forming surface 82 is facing the whirling chamber 72.

[0059] FIG. 4 is a cross-sectional view illustrating the nozzle block 34 according to the present embodiment, which is cut along a plane passing through the central axis line of the hollow guide shaft body 20. In this cross-sectional view, an upstream portion of the whirling chamber forming surface 82 (near the depressurized suction chamber 71) serves as a curved section 82a having a curved cross-sectional contour. A downstream portion of the whirling chamber forming surface 82 serves as a linear section 82b having a linear cross-sectional contour.

[0060] As illustrated in FIG. 4, a downstream end of the depressurized suction chamber forming surface 81 and an upstream end of the linear section 82b of the whirling chamber forming surface 82 are connected by the curved section 82a. In the cross-sectional view (FIG. 4) cut along the plane passing through the central axis line of the hollow guide shaft 20, the cross-sectional contour of the curved section 82a and the linear section 82b are smoothly connected. By forming a cross-sectional contour of the upstream portion of the whirling chamber forming surface 82 (near the fiber guide section 23) in a curve, an angular portion is not formed in the whirling chamber 72. In the present embodiment, the cross-sectional contour of the curved section 82a is specifically formed as a circular arc.

[0061] By structuring such that the angular portion does not exist in the whirling chamber 72, the turbulence of the airflow in the whirling chamber 72 can be reduced. Accordingly, the behavior of the reversal fiber 8b in the whirling chamber 72 can be stabilized. As a result, the reversal fiber 8b can be prevented from floating from the surface of the first taper portion 24 of the hollow guide shaft 20, and the spun yarn 10 having high quality can be stably produced.

[0062] In the cross-sectional view of FIG. 4, the cross-sectional contour of the linear section 82b is parallel to the center axial line 90. That is, in the portion of the linear section 82b, the diameter of the whirling chamber 72 is constant in the height direction. Accordingly, the portion corresponding to the linear section 82b of the whirling chamber 72 can be a columnar portion having a substantially columnar shape.

[0063] In other words, as in Japanese Unexamined Patent Publication No. 2003-193337, if the diameter of the whirling chamber becomes large towards the downstream, the whirling diameter of the whirling airflow becomes large in the downstream of the whirling chamber, and the fiber cannot be whirled at high speed. By making the diameter of at least a portion of the whirling chamber 72 to be constant as in the present embodiment, the whirling diameter of the whirling airflow does not change even in the downstream of the whirling chamber 72, and the whirling speed of the fibers can be maintained.

[0064] In the present embodiment, a diameter D1 of the depressurized suction chamber forming surface 81 is smaller than a diameter D2 of the whirling chamber forming surface 82 (specifically, a diameter of the linear section 82b). By making the diameter of the depressurized suction chamber 71 to be smaller than the diameter of the whirling chamber 72 as described above, the compressed air hardly flows towards the depressurized suction chamber 71 (the upstream side) even if the compressed air injected into the whirling chamber 72 expands. Accordingly, since the airflow can smoothly flow towards the downstream in the depressurized suction chamber 71, the fiber can be smoothly reversed in the depressurized suction chamber 71.

[0065] Next, a description will be made of the air injecting nozzle 27 in the present embodiment.

[0066] [0062] As described above, the air injecting nozzle 27 is formed such that a longitudinal direction thereof is directed towards a substantially tangential direction of the whirling chamber 72. Accordingly, an opening contour of the portion of the air injecting nozzle 27 opening into the whirling chamber forming surface 82 (the nozzle opening 27a) is formed as a substantially oval shape as illustrated in FIG. 4. In the present embodiment, a peripheral length of the opening contour of the nozzle opening 27a is referred to as an oval peripheral length.

[0067] In the pneumatic spinning device 9 according to the present embodiment, the nozzle opening 27a of the air injecting nozzle 27 is formed in the curved section 82a of the whirling chamber forming surface 82, as illustrated in FIG. 4. Accordingly, compared with the case in which the nozzle opening 27a is formed on the linear section 82b, for example, the oval peripheral length of the nozzle opening 27a can be increased. Therefore, the air injecting nozzle 27 can inject compressed air such that the compressed air spreads towards the downstream. Accordingly, since the whirling airflow can be applied to the fiber in a wider range, the fiber can be efficiently whirled by a great force. The air injecting nozzle 27 can thus inject the compressed air so as to spread towards the downstream. Therefore, even if the compressed air expands in the whirling chamber 72, the compressed air hardly flows towards the upstream (the depressurized suction chamber 71 side). Accordingly, the whirling airflow can more smoothly flow towards the downstream, and the turbulence of the airflow in the whirling chamber 72 can be further reduced.

[0068] For example, in Japanese Unexamined Patent Publication No. 2003-193337, the nozzle opening of the air injecting hole is formed over the angular portion (the connecting portion of the cylindrical space portion and the first circular truncated cone shaped space section). Accordingly, there has been a problem that the opening shape of the nozzle opening is varied greatly just by a slight shift of the position where the nozzle opening is formed. Therefore, the structure of this prior art document has a drawback that the yarn quality tends to be affected by machining precision. In the present embodiment, the opening contour of the nozzle opening 27a is entirely formed on the curved section 82a of the whirling chamber forming surface 82. In other words, in the present embodiment, the nozzle opening 27a is formed at the position where the wall surface does not have the angular portion. According to the structure of the present embodiment, even if the position where the nozzle opening 27a is formed is slightly shifted, the shape of the opening contour of the nozzle opening 27a is not changed so much. Therefore, the quality of the spun yarn 10 can be maintained independently from the machining precision of the air injecting nozzle 27.

[0069] In the present embodiment, the air injecting nozzle 27 is formed to inject the compressed air so as to aim the whirling chamber 72. More specifically, a target position (a position indicated by A1 in FIG. 4) of the air injecting nozzle 27 is formed to be located upstream of a downstream end of the whirling chamber 72 (a position indicated by A2 in FIG. 4). In this case, "target position" means a point at which the center axial line 27b of the air injecting nozzle 27 intersects the center axial line 90 of the hollow guide shaft 20 when projected to a plane which is parallel to the center axial line 27b of the air injecting nozzle 27 and parallel to the center axial line 90 of the hollow guide shaft 20.

[0070] With the above structure, the whirling airflow can be discharged to the taper chamber 73 after being whirled in the whirling chamber 72.

[0071] The target position (the position indicated by A1 in FIG. 4) of the air injecting nozzle 27 is required to be set such that the whirling flow is discharged after being whirled to some degree in the whirling chamber 72. In other words, a structure cannot be adapted in which the target position A1 is set to such a downstream side that the whirling flow cannot be whirled in the whirling chamber 72.

[0072] When a height of the whirling chamber 72 (a length of the whirling chamber forming surface 82 in the fiber feeding direction) is set to H1, the target position A1 of the air injecting nozzle 27 is preferably set to H1 $\times$ 3/8 or more upstream from the downstream end of the whirling chamber 72. More preferably, the target position A1 is set to H1 $\times$ 1/2 or more upstream from the downstream end of the whirling chamber 72. By setting the target position A1 of the air injecting nozzle 27 to a position located close to the upstream end of the whirling chamber 72, a distance can be obtained for the injected air from the air injecting nozzle 27 to flow towards the downstream in the whirling chamber 72. In other words, the injected air can be sufficiently whirled in the whirling chamber 72.

[0073] The target position of the air injecting nozzle 27 (the position indicated by A1 in FIG. 4) is set downstream than the upstream end portion of the hollow guide shaft 20. Accordingly, the whirling airflow can be satisfactorily generated around the hollow guide shaft body 20 to sufficiently whirl the reversal fiber 8b, and the strong spun yarn 10 can be produced.

[0074] In the present embodiment, a flow path cross-sectional area of the whirling chamber 72 at the downstream end of the whirling chamber 72 (a flow path cross-sectional area at the position A2 in FIG. 4) is smaller than a flow path cross-sectional area of the whirling chamber 72 at the position where the nozzle opening 27a of the air injecting nozzle 27 is formed (specifically, the position at the downstream end portion of the opening contour of the nozzle opening 27a) (a flow path cross-sectional area at the position A3 in FIG. 4). In this case, "flow path cross-sectional area" means a cross-sectional area of the whirling chamber 72 cut through a plane orthogonal to the fiber feeding direction (an axial direction of the hollow guide shaft 20).

[0075] More specifically, in the present embodiment, in the columnar portion of the whirling chamber 72, the diameter of the linear section 82b forming the outer peripheral wall surface of the whirling chamber 72 is constant, and the outer peripheral wall surface of the first taper portion 24 of the hollow guide shaft 20 forming the inner peripheral wall surface of the whirling chamber 72 is formed as a taper shape which widens towards the downstream. In other words, in the columnar portion of the whirling chamber 72, the flow path cross-sectional area narrows towards the downstream. Accordingly, the flow path cross-sectional area at the downstream end of the whirling chamber 72 is narrower than the flow path cross-sectional area at the target position of the air injecting nozzle 27.

[0076] The first taper portion 24 of the hollow guide shaft 20 is formed such that the diameter becomes larger towards the downstream in the yarn feeding direction as described above, however, the change of the diameter is preferably gentle. However, the diameter of the hollow guide shaft 20 may be formed to rapidly change in the yarn feeding direction.

[0077] As described above, since the flow path cross-sectional area of the whirling chamber 72 is structured so as to be slightly throttled in the downstream side, the injected air from the nozzle opening 27a can be prevented from flowing out towards the taper chamber 73 without being sufficiently whirled in the whirling chamber 72. Accordingly, the flow rate of the whirling airflow can be kept at high speed until the whirling airflow is discharged from the whirling chamber 72 to the taper chamber 73.

[0078] The inventor of the present application carried out experiments regarding this point, and found out that in order to keep the whirling airflow in the whirling chamber 72 at high speed, it is effective to keep an average flow rate of the airflow around 200 m/sec in the flow path cross-section at the downstream end of the whirling chamber 72 (the flow path cross-section at the position A2 in FIG. 4). In other words, if the average flow rate at this position is not kept at 200 m/sec, a balance is disordered between a suction flow rate of the fiber guide hole 21 and an injection flow rate from the nozzle opening 27a of the air injecting nozzle 27.

[0079] In order to keep the above average flow rate, the flow path cross-sectional area at the downstream end of the whirling chamber 72 (the flow path cross-sectional area at the position A2 in FIG. 4) is preferably at least 7.5 sqmm and less than or equal to 12.0 sqmm. Further, while satisfying the above condition, the compressed air injected from the nozzle opening 27a preferably does not warp or spread too much.

[0080] As a result of the above experiments, the inventor of the present application has found out that, in order to satisfy the above condition, an interval (a passage width of the whirling chamber 72) T1 between the whirling chamber forming surface 82 and the outer peripheral wall of the first taper portion 24 of the hollow guide shaft 20 is preferably set as follows, at the position where the nozzle opening 27a is formed (specifically, the position of the downstream end portion of the opening contour of the nozzle opening 27a). In other words, the interval T1 is preferably at least 1.3 times and less than or equal to 2.5 times a diameter D3 of the opening of the air injecting nozzle 27 (the diameter in the plane orthogonal to the longitudinal direction of the air injecting nozzle 27), and more preferably, at least 1.5 times and less than or equal to 2.0 times.

[0081] In the present embodiment, the interval T1 is at least 1.5 times and less than or equal to 2.0 times the diameter D3 of the opening of the air injecting nozzle 27. Accordingly, the interval between the whirling chamber forming surface 82 and the first taper portion 24 (the width of the whirling chamber 72) is neither too narrow nor too wide with respect to the compressed air injected from the air injecting nozzle 27. Therefore, the compressed air injected from the air injecting nozzle 27 can be prevented from warping in the whirling chamber 72, and from rapidly expanding in the whirling chamber 72. As a result, the turbulence of the air in the whirling chamber 72 can be prevented, and a stable whirling airflow having high speed and high density can be generated. Further, the suction flow rate of the fiber guide hole 21 becomes stable.

[0082] As described above, since the flow rate of the whirling airflow can be kept by the structure according to the present embodiment, the force applied to the reversal fiber 8b in the whirling chamber 72 can be increased, compared to the conventional pneumatic spinning device provided with the whirling chamber having the same height (length in the fiber feeding direction). In other words, according to the structure of the present invention, even if the height of the whirling chamber 72 is reduced than the conventional pneumatic spinning device (even if the length of the space for applying the whirling airflow to the reversal fiber 8b is reduced), the reversal fiber 8b can be whirled by the same level of force as the conventional pneumatic spinning device.

[0083] In the present embodiment, the height H1 of the whirling chamber forming surface 82 (the length in the fiber feeding direction) is formed to be equal to or smaller than the diameter D2 of the whirling chamber forming surface 82 (specifically, the diameter of the linear section 82b). In other words, the height H1 of the whirling chamber 72 is formed to be equal to or smaller than the diameter D2 of the whirling chamber 72.

[0084] Since the height of the whirling chamber 72 can be reduced as described above, energy required for flowing the whirling airflow in the whirling chamber 72 can be reduced. Further, the pneumatic spinning device 9 can be formed compact in the height direction.

[0085] However, if the height of the whirling chamber 72 is too low, the whirling airflow cannot be sufficiently applied to the reversal fiber 8b. Accordingly, the height H1 of the whirling chamber 72 is at least 0.4 times the diameter D2 of the whirling chamber 72.

[0086] As described above, the pneumatic spinning device 9 according to the present embodiment whirls the fibers of the fiber bundle 8 in the substantially columnar whirling chamber 72 by the whirling airflow to produce the spun yarn 10. The pneumatic spinning device 9 includes the hollow guide shaft 20 and the nozzle block 34. A portion of the hollow guide shaft 20 is located within the whirling chamber 72. The whirling chamber forming surface 82 is formed in the nozzle block 34. Four air injecting nozzles 27 are formed in the nozzle block 34 for injecting the compressed air from the nozzle opening 27a opening into the whirling chamber 72 to generate the whirling airflow in the whirling chamber 72. The whirling chamber 72 has the columnar portion formed as the substantially columnar shape having the constant diameter D2. The height H1 of the whirling chamber 72 is equal to or smaller than the diameter D2. The flow path cross-sectional area at the downstream end of the whirling chamber 72 in the fiber feeding direction (the position A2) is formed smaller than the flow path cross-sectional area of the whirling chamber 72 at the downstream end portion of the opening contour of the nozzle 27a (the position A3) .

[0087] As described above, by making the diameter D2 of the whirling chamber 72 to be constant, the whirling radius of the whirling airflow does not become large even at the downstream of the whirling chamber 72. As a result, the whirling flow can be kept at high speed until the whirling airflow is discharged to the downstream of the whirling chamber 72, and an angle of the whirling airflow in the whirling chamber 72 (an injecting angle from the nozzle opening 27a) can be easily maintained. Accordingly, since the winding fiber can be whirled at high speed, the yarn strength of the produced spun yarn can be improved. As a result, high-speed spinning at 500 m/min or 600 m/min which could not be achieved conventionally can be achieved. Further, since the flow path cross-sectional area at the downstream end of the whirling chamber 72 is made small, the whirling airflow in the whirling chamber 72 hardly flows out towards the downstream. Accordingly, the whirling airflow in the whirling chamber 72 can flow at high speed while maintaining the blowing angle from the air injecting nozzle 27 and suppressing the speed reduction. As a result, the yarn strength of the produced spun yarn 10 can be maintained stably. By structuring the pneumatic spinning device 9 as described above, the whirling airflow can be effectively applied to the fiber bundle 8 even within the short distance, and the height H1 of the whirling chamber 72 can be reduced. For example, as described above, the height H1 of the whirling chamber 72 can be equal to or smaller than the diameter D2.

Accordingly, consumed energy for flowing the whirling airflow can be reduced, and energy saving can be achieved. The pneumatic spinning device 9 can be formed compact in the height direction.

[0088] In the pneumatic spinning device 9 according to the present embodiment, at the downstream end portion of the opening contour of the nozzle opening 27a (the position A3), the interval T1 between the whirling chamber forming surface 82 and the outer peripheral surface of the hollow guide shaft 20 is at least 1.5 times and less than or equal to 2.0 times the diameter D3 of the opening of the air injecting nozzle 27. Accordingly, the width of the flow path of the whirling chamber 72 can be appropriately formed with respect to the compressed air injected from the air injecting nozzle 27. Accordingly, the compressed air injected from the air injecting nozzle 27 can be prevented from expanding too much due to the flow path of the whirling chamber 72 being too wide, thereby reducing the flow rate, and prevented from warping due to the flow path of the whirling chamber 72 being too narrow.

[0089] The hollow guide shaft 20 of the pneumatic spinning device 9 according to the present embodiment is formed such that in the first taper portion 24 located within the whirling chamber 72, the diameter of the portion located upstream in the fiber feeding direction is smaller than the diameter of the portion located downstream in the fiber feeding direction. Accordingly, since the width of the flow path at the downstream of the whirling chamber 72 can be prevented from being widened, the whirling airflow in the whirling chamber 72 can be suppressed from flowing out towards the downstream without being sufficiently whirled. Therefore, the high-speed whirling airflow can be maintained in the whirling chamber 72. As a result, even in the high-speed spinning such as 500 m/min or 600 m/min, the winding fiber can be wound around the core fiber while being sufficiently whirled in the whirling chamber 72.

[0090] In the pneumatic spinning device 9 according to the present embodiment, the ratio of the height H1 of the whirling chamber 72 with respect to the diameter D2 of the whirling chamber 72 is at least 0. 4 and less than or equal to 1. 0. As described above, the consumed energy for flowing the whirling airflow into the whirling chamber 72 can be reduced by making the height H1 of the whirling chamber 72 equal to or smaller than the diameter D2, and energy saving can be achieved. The pneumatic spinning device 9 can be formed compact in the height direction. As described above, by making the height H1 of the whirling chamber 72 to be at least 0.4 times the diameter D2, the space of the whirling chamber 72 for applying the whirling airflow to the winding fiber does not become too short. Accordingly, the whirling airflow can be effectively applied to the winding fiber.

[0091] In the pneumatic spinning device 9 according to the present embodiment, the air injecting nozzle 27 is formed to inject the compressed air so as to aim the whirling chamber 72. Accordingly, the compressed air injected from the air injecting nozzle 27 can be discharged after being whirled in the whirling chamber 72. Therefore, even in the high-speed spinning, the winding fiber can be wound around the core fiber after being sufficiently whirled in the whirling chamber 72.

[0092] The spinning machine 1 according to the present embodiment includes the pneumatic spinning device 9, the draft device 7, the yarn feeding device 11, and the winding device 12. The draft device 7 is arranged in the upstream of the pneumatic spinning device 9, and drafts the fiber bundle 8. The yarn feeding device 11 is arranged downstream of the pneumatic spinning device 9, and draws the spun yarn 10 produced by the pneumatic spinning device 9 from the pneumatic spinning device 9. The winding device 12 winds the spun yarn 10 drawn out by the yarn feeding device 11 into a package. Accordingly, the spun yarn 10 having high yarn strength can be produced even in the high-speed spinning, and quality and productivity of the package into which the spun yarn is wound can be improved.

[0093] Next, a description will be made of a second embodiment according to the present invention. In the following description, the same reference numerals are denoted to the structures which are the same or similar to the first embodiment, and descriptions thereof are omitted.

[0094] FIG. 6 illustrates a structure of a pneumatic spinning device 9 provided in the spinning machine according to the second embodiment. As illustrated in FIG. 6, the pneumatic spinning device 9 according to the present embodiment does not have the needle 22 provided in the fiber guide section 23 in the first embodiment. That is, the needle 22 may be omitted. In the first embodiment, the needle 22 serves as the twist propagation preventing function. If the needle 22 is omitted as in the present second embodiment, a downstream end portion of the fiber guide section 23 serves as the twist propagation preventing function.

[0095] The preferred embodiments of the present invention has been described above, however, the above structures can be modified as follows, for example.

[0096] The above embodiments are structured such that the tip end of the hollow guide shaft 20 is slightly inserted into the depressurized suction chamber 71. The hollow guide shaft 20 may not be inserted into the depressurized suction chamber 71 or the tip end of the hollow guide shaft 20 may be located on a boundary line between the depressurized suction chamber 71 and the whirling chamber 72.

[0097] In the above embodiments, four air injecting nozzles 27 are formed, however, any number of the air injecting nozzles may be formed as long as at least one air injecting nozzle 27 is formed. For example, six air injecting nozzles 27 may be formed. When the number of the air injecting nozzles 27 is at least five, in order to appropriately regulate the amount of air supplied to the whirling chamber 72, the diameter D3 of the opening needs to be made smaller than the embodiment in which the number of the air injecting nozzles 27 is four. If the number of the air injecting nozzles 27 is increased, it becomes difficult to improve working precision. Therefore, the number of the air injecting nozzles 27 is preferably four as described above.

[0098] In the above embodiments, although the shape of the depressurized suction chamber 71 is formed substantially cylindrical, the present invention is not limited thereto. Since the whirling airflow is not necessarily required to be generated in the depressurized suction chamber 71, a cross-sectional shape cut along the plane orthogonal to the fiber feeding direction may not be formed as the circular shape.

[0099] The depressurized suction chamber 71 may be omitted (the whirling chamber 72 may be directly connected to the fiber guide hole 21). Since the fiber can be smoothly reversed by the presence of the depressurized suction chamber 71, the depressurized suction chamber 71 is preferably not omitted.

[0100] In the curved section 82a of the whirling chamber forming surface 82, the cross-sectional contour along the plane passing through the axial line of the hollow guide shaft 20 may not be formed as the circular arc, but may be formed in any shape as long as the cross-sectional contour is a smooth curve. In short, it suffices if the angular portion does not exist near the fiber guide section 23 of the whirling chamber 72. By forming the cross-sectional contour of the curved section 82a as the circular arc, the turbulence of the airflow in the whirling chamber 72 can be reduced particularly well.

[0101] If the cross-sectional contour of the curved section 82a may be regarded to be substantially a curve, the cross-sectional contour may be formed by fine broken lines. For example, if the cross-sectional contour of the curved section 82a is formed by a broken line bent a plurality of times at obtuse angles, the cross-sectional contour may be regarded to be substantially a curve.

[0102] The curved section 82a is not necessarily required to be formed on the whirling chamber forming surface 82 as in the above embodiments, and an angular portion may be provided in the whirling chamber 72. For example, the curved section 82a may be omitted, and the whirling chamber forming surface 82 may be formed only by the linear section 82b.

[0103] In the above embodiments, the nozzle block 34 serves as the depressurized suction chamber section and the whirling chamber section in which the whirling chamber is formed, however, the depressurized suction chamber section and the whirling chamber section may be formed as separate members.

[0104] Although the entire opening contour of the nozzle opening 27a of the air injecting nozzle 27 is formed in the curved section 82a in the above embodiments, the present invention is not limited to this structure. For example, only a portion of the opening contour of the nozzle opening 27a may be formed in the curved section 82a, and the remaining portion may be formed in the linear section 82b. The entire opening contour of the nozzle opening 27a may be formed in the linear section 82b. If at least a portion of the opening contour of the nozzle opening 27a is formed in the curved section 82a, the compressed air can be injected while spreading from the nozzle opening 27a towards the whirling chamber 72, and this structure is preferable.

[0105] In the above embodiments, the air discharge space 55 is formed in the nozzle section casing 53. However, the air discharge space 55 may be formed in the shaft holding member 59. The air discharge space 55 may be formed by combining the nozzle section casing 53 and the shaft holding member 59.

[0106] In the above embodiments, the description is made on the spinning machine 1 in which the fiber bundle 8 (or the spun yarn 10) is fed from top towards bottom. However, the present invention is not limited thereto, and may be, for example, a spinning machine in which the fiber bundle is fed from bottom to top. In other words, the pneumatic spinning device according to the above embodiments may be provided in a spinning machine in which a can accommodating the fiber bundle is arranged in a lower part of a machine main body, and a winding device is arranged in an upper part of the machine main body.

[0107] The spinning machine 1 may be structured such that a yarn accumulating device is provided between the yarn feeding device 11 and the winding device 12. Briefly describing, the yarn accumulating device is structured such that the spun yarn 10 is temporarily wound around a rotating yarn accumulating roller so that a prescribed amount of the spun yarn 10 can be accumulated on the yarn accumulating roller. A function of the yarn accumulating device is as follows. In other words, the winding device 12 cannot wind the spun yarn 10 during a yarn splicing operation by the yarn splicing cart 3. In such cases, if the spun yarn 10 is continuously fed from the pneumatic spinning device 9, the spun yarn 10 which is not wound slackens. Therefore, the spun yarn 10 can be prevented from slackening by providing the yarn accumulating device between the winding device 12 and the yarn feeding device 11, and accumulating the spun yarn 10 on the yarn accumulating roller during a period in which the winding device 12 cannot wind the yarn.

[0108] The above yarn accumulating device includes the yarn accumulating roller which rotates while winding the spun yarn 10. The above yarn accumulating device can feed the spun yarn 10 wound around the yarn accumulating roller towards the downstream by rotating the yarn accumulating roller. In other words, the yarn accumulating device has a function of feeding the spun yarn 10 towards the downstream. Accordingly, the spinning machine 1 including the yarn accumulating device as described above may be structured such that the yarn feeding device 11 is omitted and the spun yarn 10 is delivered from the pneumatic spinning device 9 towards the downstream by the yarn accumulating device. In this case, the yarn accumulating device serves as the drawing device.

Claims

1. A pneumatic spinning device (9) for producing spun yarn by whirling fibers of a fiber bundle by whirling airflow in a substantially columnar whirling chamber (72),
a spindle (20) of which at least a portion thereof is located in the whirling chamber (72), and
a whirling chamber section (34) in which the whirling chamber (72) is formed and in which at least one air injecting nozzle (27) is formed to inject compressed air from a nozzle opening (27a) opening into the whirling chamber (72) to generate the whirling airflow in the whirling chamber (72);
wherein the whirling chamber (72) has a columnar portion formed as a substantially columnar shape having a constant diameter,
a height (H1) of the whirling chamber (72) is equal to or smaller than a diameter (D2) thereof, and
a flow path cross-sectional area at a downstream end (A2) of the whirling chamber (72) in a fiber feeding direction is smaller than a flow path cross-sectional area of the whirling chamber (72) at a downstream end portion of an opening contour of the nozzle opening (27a).

2. The pneumatic spinning device (9) according to claim 1, wherein at the downstream end portion of the opening contour of the nozzle opening (27a), an interval (T1) between an inner wall surface of the whirling chamber (72) and an outer peripheral surface of the spindle (20) is at least 1.3 times and less than or equal to 2.5 times a diameter of an opening of the pneumatic spinning nozzle (27).

3. The pneumatic spinning device (9) according to claim 2, wherein at the downstream end portion of the opening contour of the nozzle opening (27a), an interval (T1) between an inner wall surface of the whirling chamber (72) and an outer peripheral surface of the spindle (20) is at least 1.5 times and less than or equal to 2.0 times a diameter of an opening of the pneumatic spinning nozzle (27).

4. The pneumatic spinning device (9) according to any one of claim 1 through claim 3, wherein among the portion of the spindle (20) located within the whirling chamber (72), a diameter of a portion located upstream in the fiber feeding direction is smaller than a diameter of a portion located downstream in the fiber feeding direction.

5. The pneumatic spinning device (9) according to any one of claim 1 through claim 4, wherein a ratio of the height (H1) of the whirling chamber (72) with respect to the diameter (D2) of the whirling chamber is at least 0.4 and less than or equal to 1.0.

6. The pneumatic spinning device (9) according to any one of claim 1 through claim 5, wherein the air injecting nozzle (27) is formed to inject the compressed air so as to aim the whirling chamber (72).

7. A spinning machine (1) comprising:

   the pneumatic spinning device (9) according to any one of claim 1 through claim 6;
   a draft device (7) arranged upstream of the pneumatic spinning device (9) and adapted to draft the fiber bundle;
   a drawing device (11) arranged downstream of the pneumatic spinning device (9) and adapted to draw the spun yarn from the pneumatic spinning device (9); and
   a winding device (12) adapted to wind the spun yarn drawn out from the pneumatic spinning device (9) by the drawing device (11) into a package.

FIG. 1

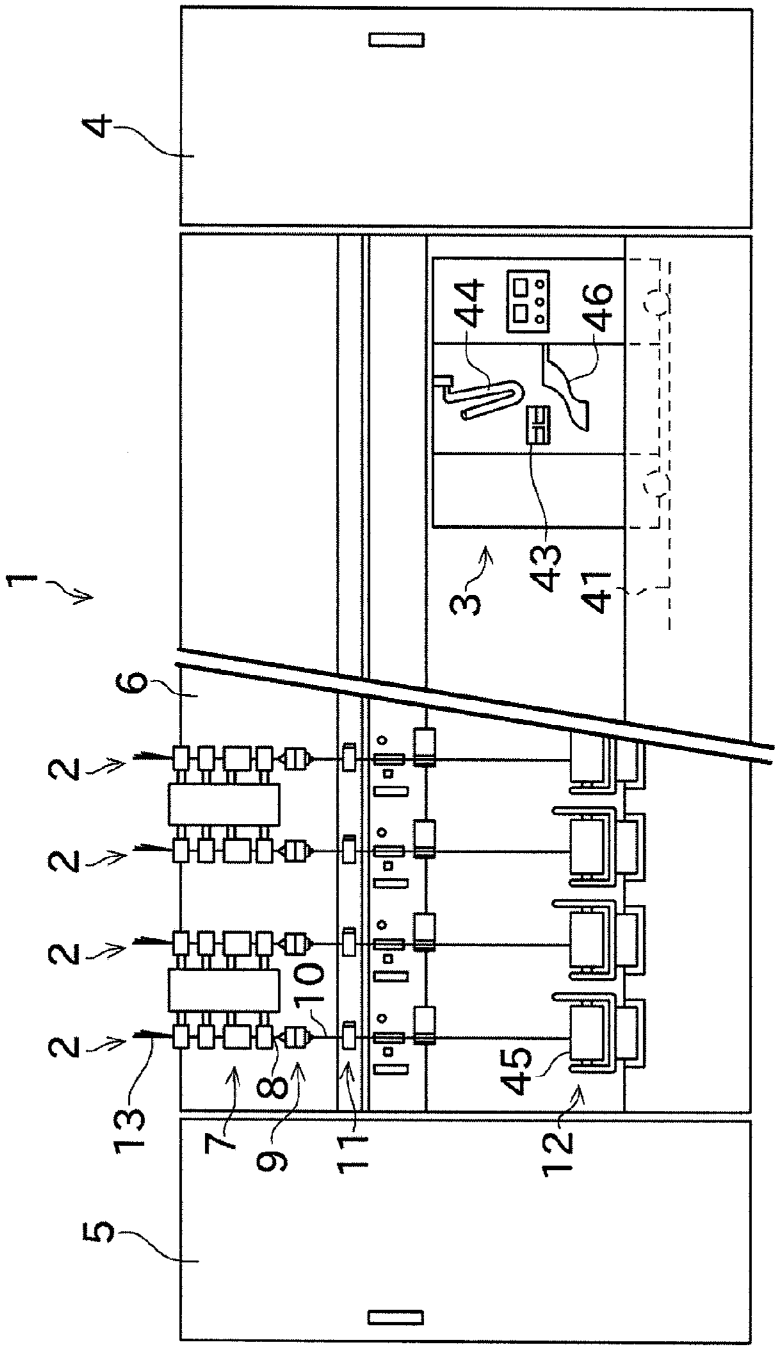


FIG. 2

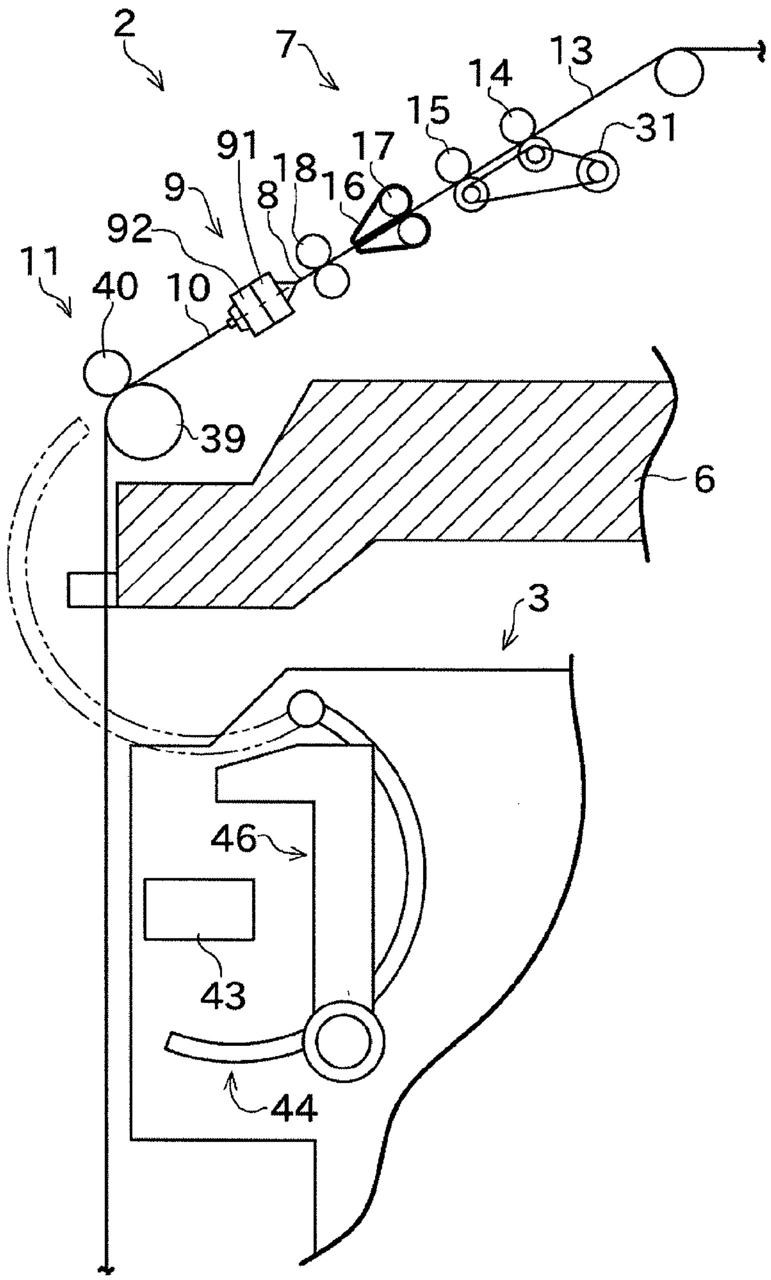


FIG. 3

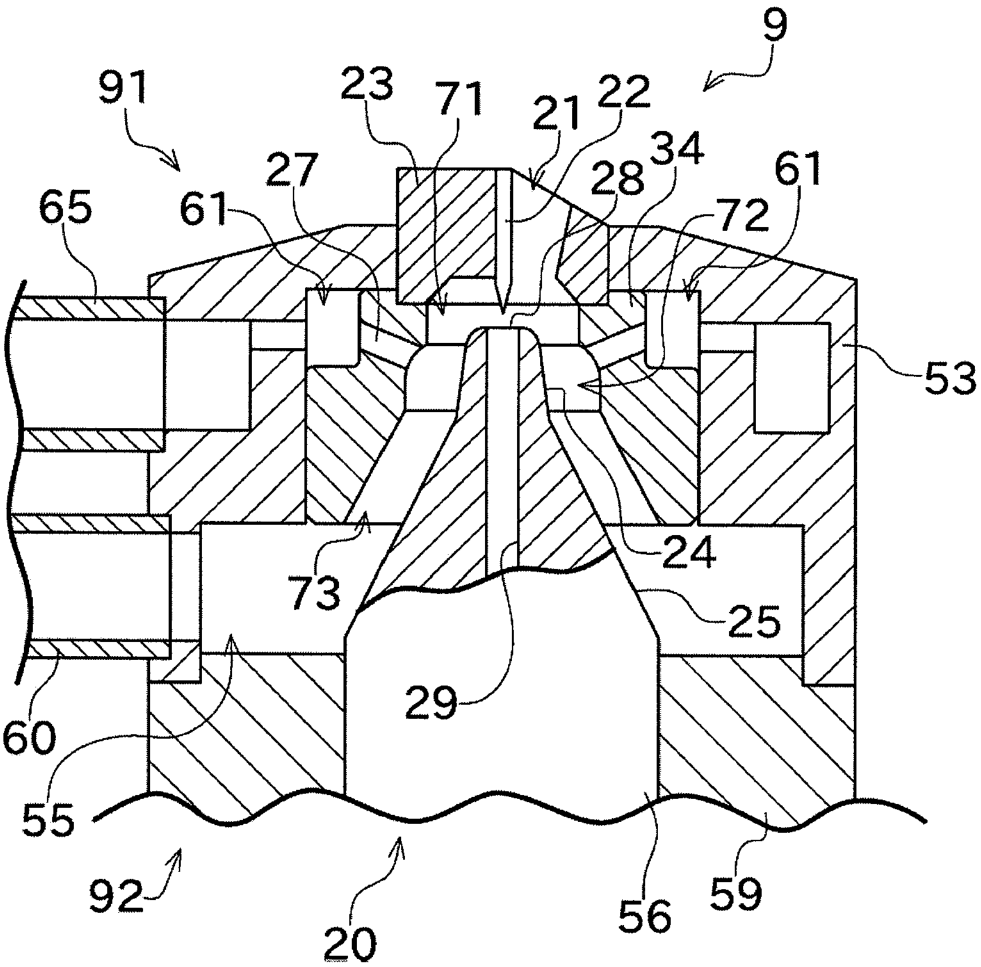


FIG. 4

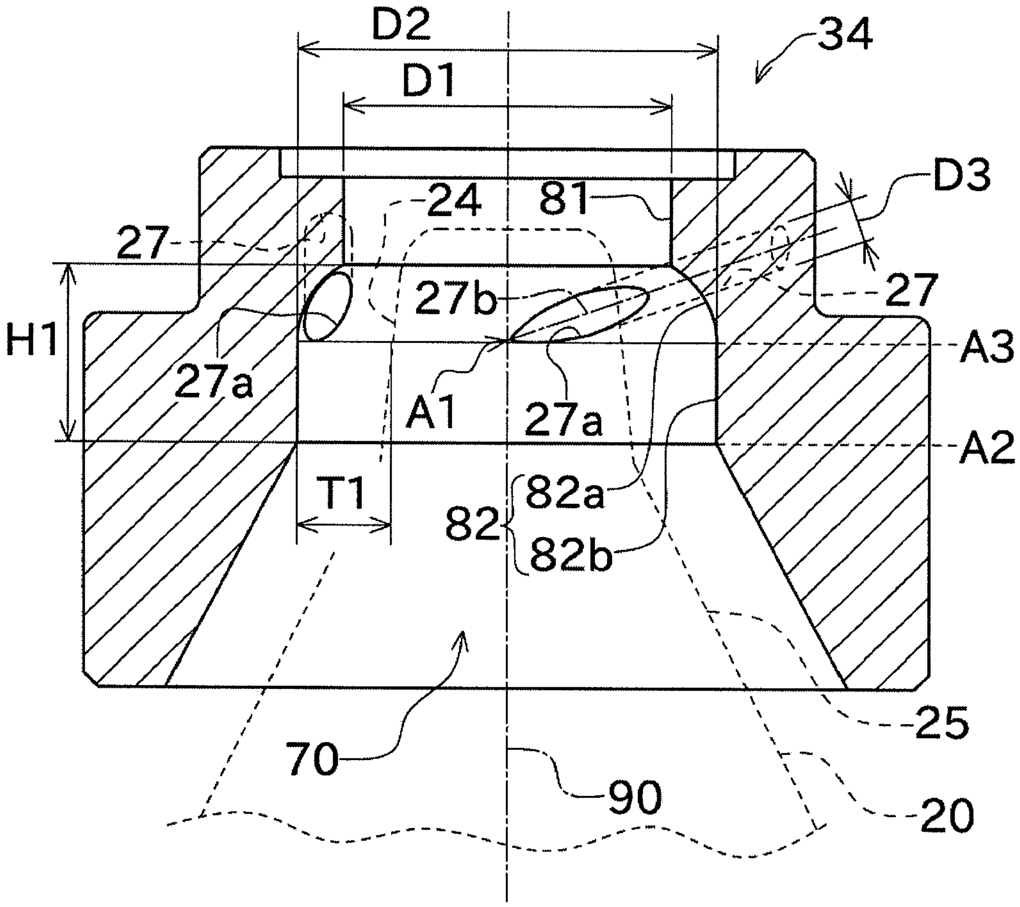

D2
D1
34
24
81
D3
27
27
27b
H1
A3
27a
A1
27a
A2
T1
82a
82
82b
25
70
90
20

FIG. 5

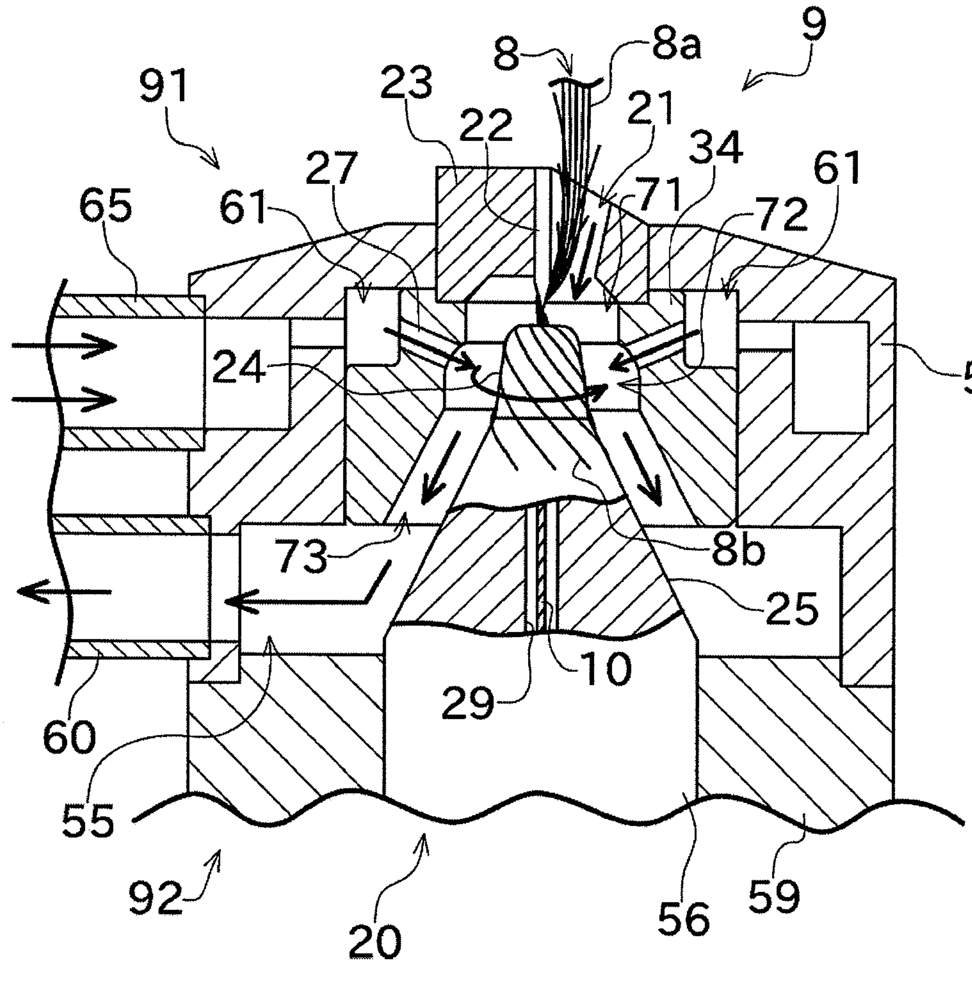
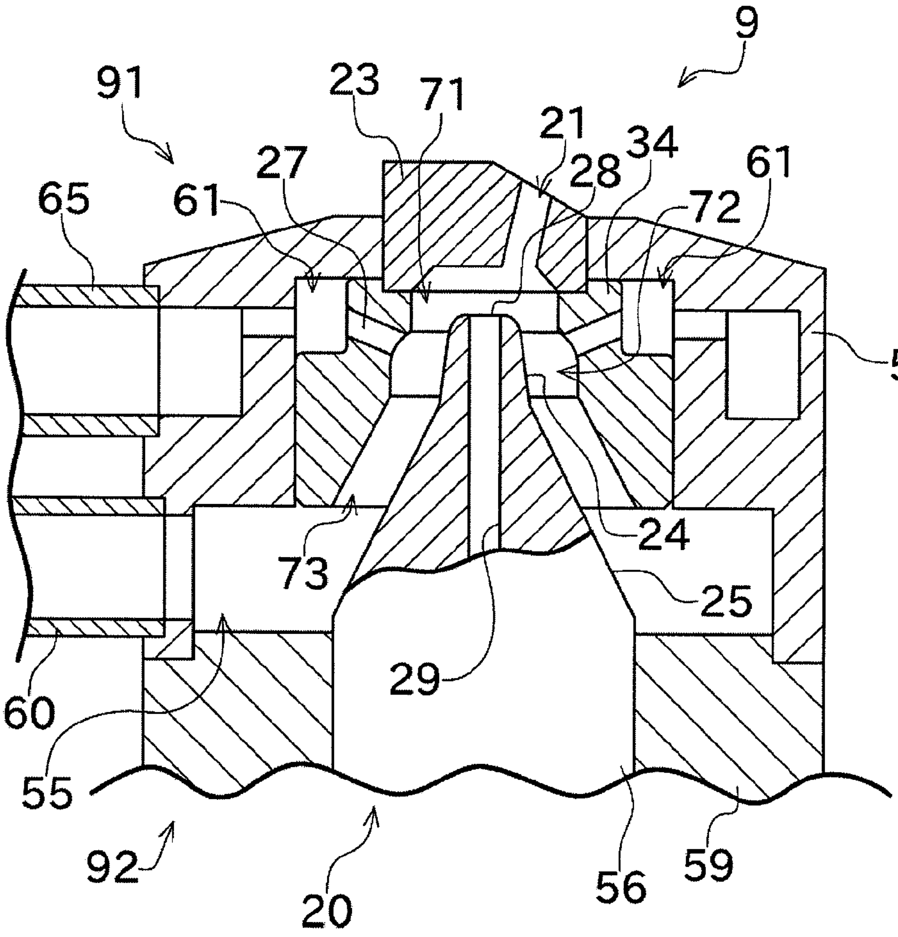

8
8a
9
91
23
22
21
34
61
27
71
72
65
24
53
73
8b
25
10
29
60
55
92
20
56
59

FIG. 6



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- JP 2008297688 A **[0006] [0009] [0010] [0011]**