



(11) **EP 2 327 817 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
01.06.2011 Bulletin 2011/22

(51) Int Cl.:
D01D 4/02 (2006.01) D01D 5/098 (2006.01)
D04H 3/00 (2006.01) B29C 47/30 (2006.01)

(21) Application number: **10192653.3**

(22) Date of filing: **26.11.2010**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

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(30) Priority: **27.11.2009 JP 2009270011**

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(54) **Spinning apparatus and process for manufacturing nonwoven fabric**

(57) Provided are a spinning apparatus capable of stably spinning fibers having a small fiber diameter with a high productivity, an apparatus comprising the same for manufacturing a nonwoven fabric, a process for manufacturing a nonwoven fabric using the nonwoven fabric manufacturing apparatus, and a nonwoven fabric produced by the process.

The spinning apparatus of the present invention comprises one or more exits for extruding liquid, which are capable of extruding a spinning liquid, and one or more exits for ejecting gas, which extend linearly and are located upstream of each of the exits for extruding liquid

and which are capable of ejecting a gas, wherein a shearing force by the gas and its accompanying airstream can be single-linearly exerted on the spinning liquid extruded. The apparatus of the present invention for manufacturing a nonwoven fabric comprises a fibers collection means as well as the spinning apparatus. The process of the present invention for manufacturing a nonwoven fabric is a process using the apparatus for manufacturing a nonwoven fabric. The nonwoven fabric of the present invention is a nonwoven fabric produced by the process.

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Description

TECHNICAL FIELD

[0001] The present invention relates to a spinning apparatus, an apparatus comprising the same for manufacturing a nonwoven fabric, a process for manufacturing a nonwoven fabric using the nonwoven fabric manufacturing apparatus, and a nonwoven fabric produced by the process.

BACKGROUND ART

[0002] Fibers having a small fiber diameter can impart various excellent properties, such as a separating property, a liquid-holding capacity, a wiping property, a shading property, an insulating property, or flexibility, to a nonwoven fabric, and therefore, it is preferable that fibers which form a nonwoven fabric have a small fiber diameter.

As a process for manufacturing such fibers having a small fiber diameter, electrospinning is known. In this process, a spinning liquid is extruded from a nozzle, and at the same time, an electrical field is applied to the extruded spinning liquid to thereby draw the spinning liquid and thin the diameter of the spinning liquid, and fibers are directly collected on a fibers collection means to form a nonwoven fabric. According to the electrospinning, a nonwoven fabric consisting of fibers having an average fiber diameter of 1 μm or less can be produced. However, the electrospinning is a method with a poor productivity, because the amount of spinning liquid extruded is limited.

[0003] To improve the productivity, patent literature 1 proposes "an apparatus for forming a non-woven mat of nanofibers by using a pressurized gas stream includes parallel, spaced apart first (12), second (22), and third (32) members, each having a supply end (14, 24, 34) and an opposing exit end (16, 26, 36). The second member (22) is adjacent to the first member (12). The exit end (26) of the second member (22) extends beyond the exit end (16) of the first member (12). The first (12) and second (22) members define a first supply slit (18). The third member (32) is located adjacent to the first member (12) on the opposite side of the first member (12) from the second member (22). The first (12) and third (32) members define a first gas slit (38), and the exit ends (16, 26, 36) of the first (12), second (22) and third (32) members define a gas jet space (20). A method for forming a nonwoven mat of nanofibers by using a pressurized gas stream is also included.", as shown in Figure 2. This apparatus does not require the application of a high voltage, and therefore, can be expected to improve the productivity. However, because flat-shaped first, second, and third members are arranged parallel to each other in the apparatus, and the sheet-like pressurized gas stream is applied to a sheet-like spinning liquid, it is considered that the spinning liquid is difficult to have a fibrous form and the nonwoven fabric contains a lot of droplets, and

that, if fibers can be obtained, the diameter of the fibers would become thick.

[0004] As a similar spinning apparatus, patent literature 2 proposes "an apparatus for forming nanofibers by using a pressurized gas stream comprising a center tube, a first supply tube that is positioned concentrically around and apart from the center tube, a middle gas tube positioned concentrically around and apart from the first supply tube, and a second supply tube positioned concentrically around and apart from the middle gas tube, wherein the center tube and first supply tube form a first annular column, the middle gas tube and the first supply tube form a second annular column, the middle gas tube and second supply tube form a third annular column, and the tubes are positioned so that first and second gas jet spaces are created between the lower ends of the center tube and first supply tube, and the middle gas tube and second supply tube, respectively". This apparatus also does not require the application of a high voltage, and can be expected to improve the productivity. However, because the columnar or annular pressurized gas stream is applied to a spinning liquid annularly extruded, spinning cannot be stably performed, and the spinning liquid is difficult to have a fibrous form and the nonwoven fabric contains a lot of droplets.

CITATION LIST

PATENT LITERATURE

[0005]

[patent literature 1] Japanese Translation Publication (Kohyo) No. 2005-515316 (Abstract, Table 1, and the like)

[patent literature 2] U.S. patent No. 6520425 (Abstract, Figure 2, and the like)

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0006] An object of the present invention is to solve the above problems, that is, to provide a spinning apparatus capable of stably spinning fibers having a small fiber diameter with a high productivity, an apparatus for manufacturing a nonwoven fabric comprising this spinning apparatus, a process for manufacturing a nonwoven fabric using this apparatus for manufacturing a nonwoven fabric, and a nonwoven fabric produced by the process.

SOLUTION TO PROBLEM

[0007] The present invention relates to:

[1] a spinning apparatus comprising one or more exits for extruding liquid, which are capable of extruding a spinning liquid, and one or more exits for ejecting

gas, which extend linearly and are located upstream of each of the exits for extruding liquid and which are capable of ejecting a gas, wherein

- (1) the spinning apparatus comprises a columnar hollow for liquid (H1), in which the exit for extruding liquid forms one end of the columnar hollow for liquid,
- (2) the spinning apparatus comprises a columnar hollow for gas (Hg) of which one end is the exit for ejecting gas,
- (3) a virtual column for liquid (Hv1) which is extended from the columnar hollow for liquid (H1) is located adjacent to a virtual column for gas (Hvg) which is extended from the columnar hollow for gas (Hg),
- (4) a central axis of an extruding direction in the columnar hollow for liquid (H1) is parallel to a central axis of an ejecting direction in the columnar hollow for gas (Hg), and
- (5) when the columnar hollow for gas and the columnar hollow for liquid are cross-sectioned with a plane perpendicular to the central axis of the columnar hollow for gas (Hg), there exists only one straight line having the shortest distance between an outer boundary of the cross-section of the columnar hollow for gas (Hg) and an outer boundary of the cross-section of the columnar hollow for liquid (H1),

[2] an apparatus for manufacturing a nonwoven fabric, comprising the spinning apparatus of [1] and a fibers collection means,

[3] a process for manufacturing a nonwoven fabric, using the apparatus of [2], and

[4] a nonwoven fabric produced by the process of [3].

ADVANTAGEOUS EFFECTS OF INVENTION

[0008] In the spinning apparatus of [1] according to the present invention, the spinning liquid extruded from each exit for extruding liquid is close and parallel to the gas ejected from each exit for ejecting gas, and a shearing force by the gas and its accompanying airstream can be single-linearly exerted on each spinning liquid, and thus, fibers of which the fiber diameter is thinned can be stably spun. Further, because the fibers are spun by the action of the gas, the amount of spinning liquid extruded can be increased, and as a result, the fibers can be spun with a high productivity.

[0009] Because the apparatus for manufacturing a nonwoven fabric of [2] according to the present invention comprises the fibers collection means, in addition to the spinning apparatus, a nonwoven fabric containing fibers having a small fiber diameter can be stably produced with a high productivity, by capturing the fibers spun by the spinning apparatus.

[0010] Because the process of [3] according to the

present invention uses the apparatus for manufacturing a nonwoven fabric, a nonwoven fabric containing fibers having a small fiber diameter can be stably produced with a high productivity.

[0011] The nonwoven fabric of [4] according to the present invention is produced by the process, and thus, is a nonwoven fabric containing fibers having a small fiber diameter.

BRIEF DESCRIPTION OF DRAWINGS

[0012]

[Fig. 1]

(a) Figure 1(a) is a partial perspective view schematically showing an embodiment of the spinning apparatus of the present invention.

(b) Figure 1(b) is a partial cross-sectional view taken along plane C in Figure 1(a).

[Fig. 2] Figure 2 is a cross-sectional view showing a conventional spinning apparatus.

[Fig. 3] Figure 3 is a cross-sectional plane view showing the arrangement of a conventional nozzle.

[Fig. 4] Figure 4 is a partial cross-sectional view showing another embodiment of the spinning apparatus of the present invention.

[Fig. 5] Figure 5 is a partial cross-sectional view showing still another embodiment of the spinning apparatus of the present invention.

[Fig. 6] Figure 6 is a partial cross-sectional view showing still another embodiment of the spinning apparatus of the present invention.

[Fig. 7] Figure 7 is a cross-sectional view schematically showing an embodiment of the apparatus of the present invention for manufacturing a nonwoven fabric.

[Fig. 8] Figure 8 is a partial cross-sectional view schematically showing a die for a melt blowing apparatus used in Comparative Example 2.

DESCRIPTION OF EMBODIMENTS

[0013] The spinning apparatus of the present invention will be explained with reference to Figure 1(a) that is a perspective view schematically showing an embodiment of the spinning apparatus of the present invention, and Figure 1(b) that is a cross-sectional view taken along plane C in Figure 1(a).

[0014] The spinning apparatus shown in Figure 1 contains multiple nozzles for extruding liquid (N₁, N₂, N₃...) which are arranged in a single and straight line and which have, at one end thereof, exits for extruding liquid (E₁, E₂, E₃...) capable of extruding a spinning liquid, and a plate for ejecting gas (Pg) having, at one end thereof, an exit for ejecting gas (Eg) which is capable of ejecting a gas and extends in a single and straight line;

each of the nozzles is directly contacted with the outer wall of one side of the plate (Pg); and the exit for ejecting gas (Eg) of the plate for ejecting gas (Pg) is located upstream of all the exits for extruding liquid (E1₁, E1₂, E1₃...) of the nozzles for extruding liquid (N1₁, N1₂, N1₃...). The nozzles for extruding liquid (N1₁, N1₂, N1₃...) have columnar hollows for liquid (H1₁, H1₂, H1₃...) containing the exits for extruding liquid (E1₁, E1₂, E1₃...) at one end, respectively, and the plate for ejecting gas (Pg) has a columnar hollow for gas (Hg) of which one end is the exit for ejecting gas (Eg). Virtual columns for liquid (Hv1₁, Hv1₂, Hv1₃...) which are extended from the columnar hollows for liquid (H1₁, H1₂, H1₃...), respectively, are located adjacent to a virtual column for gas (Hvg) which is extended from the columnar hollow for gas (Hg), and the distance between each virtual column for liquid and the virtual column for gas corresponds to the sum of the wall thickness of each nozzle for extruding liquid and the wall thickness of the plate for ejecting gas (Pg). All the central axes of the extruding direction (A1₁, A1₂, A1₃...) of the columnar hollows for liquid (H1₁, H1₂, H1₃...) are parallel to the central axis of the ejecting direction (Ag) of the columnar hollow for gas (Hg). When the columnar hollow for gas (Hg) and the columnar hollows for liquid (H1₁, H1₂, H1₃...) are cross-sectioned with plane C perpendicular to the central axis of the columnar hollow for gas (Hg), the outer shape of the cross-section of the columnar hollow for gas (Hg) is rectangular, and the outer shape of the cross-section of each columnar hollow for liquid (H1₁, H1₂, H1₃...) is circular, and only a single straight line (L₁, L₂, L₃...) having the shortest distance between the outer boundary of the cross-section of the columnar hollow for gas (Hg) and the outer boundary of the cross-section of each columnar hollow for liquid (H1₁, H1₂, H1₃...), respectively, can be drawn at any combination thereof (see Figure 1(b)).

[0015] In this spinning apparatus as shown in Figure 1, when a spinning liquid is supplied to each of the nozzles for extruding liquid (N1₁, N1₂, N1₃...) and a gas is supplied to the plate for ejecting gas (Pg), the spinning liquid flows through each of the columnar hollows for liquid (H1₁, H1₂, H1₃...) and is extruded from each of the exits for extruding liquid (E1₁, E1₂, E1₃...) in the axis directions (A1₁, A1₂, A1₃...) of the columnar hollows for liquid (H1₁, H1₂, H1₃...), respectively, and simultaneously, the gas flows through the columnar hollow for gas (Hg) and is ejected from the exit for ejecting gas (Eg) in the axis direction of the columnar hollow for gas (Hg). The ejected gas is adjacent to each extruded spinning liquid, the central axis of the ejected gas (Ag) is parallel to the central axis (A1₁, A1₂, A1₃...) of each extruded spinning liquid at the closest range of each exit for extruding liquid (E1₁, E1₂, E1₃...), and there exists only a single point having the shortest distance between the ejected gas and each of the extruded spinning liquids on plane C at any combination, that is, each spinning liquid is single-linearly subjected to the shearing action of the gas and the accompanying airstream, and therefore, each spinning liq-

uid is spun in each axis direction (A1₁, A1₂, A1₃...) of each columnar hollow for liquid (H1₁, H1₂, H1₃...) while the diameter thereof is thinned, and simultaneously, the spinning liquid is fiberized.

[0016] Each of the nozzles for extruding liquid (N1₁, N1₂, N1₃...) may be any nozzle capable of extruding a spinning liquid, and the outer shape thereof is not particularly limited. The outer shape may be, for example, circular, oval, elliptical, or polygonal (such as triangular, quadrangular, or hexagonal), and is preferably circular, because the shearing action of the gas and the accompanying airstream can be single-linearly exerted on each of the spinning liquids, and generation of droplets can be avoided. That is to say, when the nozzles have a circular outer shape, and the columnar hollow for gas (Hg) and the columnar hollows for liquid (H1₁, H1₂, H1₃...) are cross-sectioned with plane C perpendicular to the central axis (Ag) of the columnar hollow for gas (Hg), it is easy to be arranged that only one straight line (L₁, L₂, L₃...) having the shortest distance between the outer boundary of the cross-section of the columnar hollow for gas (Hg) and the outer boundary of the cross-section of each columnar hollow for liquid (H1₁, H1₂, H1₃...), at any combination of the columnar hollow for gas and each of the columnar hollows for liquid, can be drawn, and as a result, the shearing action of the gas and the accompanying airstream is single-linearly exerted on each of the extruded spinning liquids, and generation of droplets can be avoided. The outer shape of each exit for extruding liquid (E1₁, E1₂, E1₃...) in the nozzles for extruding liquid (N1₁, N1₂, N1₃...) may be the same as, or different from, those of the others, but it is preferable that all the outer shapes are circular.

[0017] When the exits for extruding liquid in the nozzles for extruding liquid have a polygonal shape, it is preferable that these exits are arranged so that one vertex of each polygon is at the side of the plate for ejecting gas, because the shearing action of the gas and the accompanying airstream is single-linearly exerted on each spinning liquid, and generation of droplets can be avoided. That is to say, in a case where the nozzles for extruding liquid are arranged so that, when the columnar hollow for gas (Hg) and the columnar hollows for liquid (H1₁, H1₂, H1₃...), respectively, are cross-sectioned with plane C perpendicular to the central axis (Ag) of the columnar hollow for gas (Hg) (see Figure 6), only one straight line (L₁₁, L₁₂, L₁₃..., L₂₁, L₂₂, L₂₃...) having the shortest distance between the outer boundary of the cross-section of the columnar hollow for gas (Hg) and the outer boundary of the cross-section of each of the columnar hollows for liquid (H1₁₁, H1₁₂, H1₁₃..., H1₂₁, H1₂₂, H1₂₃...), respectively, can be drawn, the shearing action of the gas and the accompanying airstream is single-linearly exerted on each of the spinning liquids, and as a result, stable spinning can be performed, and generation of droplets can be avoided.

[0018] The size of each of the exits for extruding liquid (E1₁, E1₂, E1₃...) in the nozzles for extruding liquid (N1₁,

H1₂, N1₃...) is not particularly limited, but is preferably 0.01 to 20 mm², more preferably 0.01 to 2 mm² in all the exits. When the size is less than 0.01 mm², it tends to become difficult to extrude a spinning liquid having a high viscosity. When the size is more than 20 mm², it tends to become difficult to single-linearly exert the action of the gas and the accompanying airstream on the spinning liquid, and therefore, it tends to become difficult to be stably spun. The size of each exit for extruding liquid (E1₁, E1₂, E1₃...) may be the same as, or different from, those of the others.

When all the sizes thereof are the same, fibers of which the fiber diameter is uniform can be easily spun.

[0019] Each of the nozzles for extruding liquid (N1₁, N1₂, N1₃...) may be formed of any material such as a metal or a resin, and a resin or metal tube may be used as the nozzles. When the nozzles are formed of a metal, an electrical field may be applied to the spinning liquid by applying a voltage to part or the whole of nozzles for extruding liquid. Although Figure 1 shows cylindrical nozzles for extruding liquid (N1₁, N1₂, N1₃...), a nozzle having an acute-angled edge in which a tip portion is slantingly cut away with a plane may be used as the nozzles. This nozzle having an acute-angled edge is advantageous to a spinning liquid having a high viscosity. When the nozzles having an acute-angled edge are used so that the acute-angled edge is arranged at the side of the plate for ejecting gas, each spinning liquid may be effectively subjected to the shearing action of the gas and the accompanying airstream, and therefore, may be stably fiberized.

[0020] Although the nozzles for extruding liquid (N1₁, N1₂, N1₃...) are arranged so that they are directly contacted with the outer wall of only one side of the plate for ejecting gas (Pg) in Figure 1, further nozzles for extruding liquid may be arranged, in addition to the nozzles, so that they are directly contacted with the outer wall of the opposite side of the plate for ejecting gas (see Figure 5). This arrangement results in an increased amount of spinning liquid extruded, and spinning can be carried out with a higher productivity.

[0021] Figure 1 shows the plate for ejecting gas (Pg) in which an exit for ejecting gas (Eg) extends in a single and straight line, but it is not necessary that the exit for ejecting gas extends in a single and straight line. The same effects are obtained when the exit for ejecting gas linearly extends in, for example, a curved line, a wavy line, a circular line, an X-shaped line, a U-shaped line, a spiral line, a triangular line, a quadrangular line, and a combination thereof. Figure 1 shows the plate for ejecting gas (Pg) with only one exit for ejecting gas (Eg), but a plate for ejecting gas (Pg) with two or more exits for ejecting gas, or two sets of plates for ejecting gas (Pg), may be used, so long as these exits for ejecting gas extend linearly. The plate for ejecting gas (Pg) may be a member which surrounds the columnar hollow for gas (Hg), as shown in Figure 1, or may be formed by combining two

(columnar hollow for gas (Hg)) between the plane members. The latter has an excellent flexibility, because the width of the slit (the distance in the direction perpendicular to the direction that the slit extends linearly) may be freely changed by appropriately selecting the size of the spacer.

[0022] The length in the direction that the slit (exit for ejecting gas Eg) extends linearly is not particularly limited, but is preferably 3 cm or more in terms of the productivity, and is preferably 4 m or less in terms of the uniformity of the amount of gas ejected in the length direction. The width of the slit is not particularly limited, but is preferably 10 mm or less, more preferably 2 mm or less, and most preferably 0.5 mm or less, so that the spinning can be carried out using a smaller amount of gas. The length in the gas-ejecting direction of the columnar hollow for gas (Hg) in the plate for ejecting gas (Pg) (the length in the vertical direction in Figure 1(a)) is not particularly limited, but is preferably 0.5 mm or more, more preferably 1 mm or more, and most preferably 5 mm or more, in terms of a stable ejection of gas. The structure upstream of the columnar hollow for gas (Hg) is not particularly limited. Figure 1 shows that the exit for ejecting gas of the plate for ejecting gas (Pg) forms a plane perpendicular to the center axis of ejecting direction of gas (Ag) of the plate for ejecting gas (Pg), but the plane may be inclined.

[0023] The plate for ejecting gas (Pg) may be formed of any material such as a metal or a resin, and the material is not particularly limited.

[0024] Because the plate for ejecting gas (Pg) is arranged so that the exit for ejecting gas (Eg) is located upstream (i.e., at the side where a spinning liquid is supplied) of each of the exits for extruding liquid (E1₁, E1₂, E1₃...) of the nozzles for extruding liquid (N1₁, N1₂, N1₃...), each spinning liquid can be prevented from rising around each nozzle for extruding liquid. As a result, the exits for extruding liquid (E1₁, E1₂, E1₃...) are not soiled with the spinning liquid, and spinning may be carried out over a long period. The distance between the exit for ejecting gas (Eg) and each of the exits for extruding liquid (E1₁, E1₂, E1₃...) is not particularly limited, but is preferably 10 mm or less, more preferably 5 mm or less. When this distance is more than 10 mm, the shearing action of the gas and the accompanying airstream is not sufficiently exerted on the extruded spinning liquid, and it tends to become difficult to be fiberized. The lower limit of the distance between the exit for ejecting gas (Eg) and each of the exits for extruding liquid (E1₁, E1₂, E1₃...) is not particularly limited, so long as the exit for ejecting gas (Eg) does not accord with each of the exits for extruding liquid (E1₁, E1₂, E1₃...).

[0025] The distance between the exit for ejecting gas (Eg) and each of the exits for extruding liquid (E1₁, E1₂, E1₃...) may be the same as, or different from, those of the others. When this distance is the same, the shearing action can be equally exerted on each spinning liquid to perform stable spinning, and therefore, it is preferable.

[0026] The columnar hollows for liquid ($H1_1$, $H1_2$, $H1_3...$) in the nozzles for extruding liquid are passages which the spinning liquid flows through, and form the shape of each spinning liquid when extruded. The columnar hollow for gas (Hg) is a passage which the gas flows through, and forms the shape of the gas when ejected.

[0027] The virtual columns for liquid ($Hv1_1$, $Hv1_2$, $Hv1_3...$), which are extended from the columnar hollows for liquid ($H1_1$, $H1_2$, $H1_3...$), respectively, are flight routes of the spinning liquids immediately after being extruded from the exits for extruding liquid ($E1_1$, $E1_2$, $E1_3...$), respectively. The virtual column for gas (Hvg), which is extended from the columnar hollow for gas (Hg), is an ejection route of the gas immediately after being ejected from the exit for ejecting gas (Eg). The distance between each of the virtual columns for liquid ($Hv1_1$, $Hv1_2$, $Hv1_3...$) and the virtual column for gas (Hvg) corresponds to the sum of the wall thickness of each nozzle for extruding liquid and the wall thickness of the plate for ejecting gas (Pg). These distances are preferably 2 mm or less, more preferably 1 mm or less. When the distance is more than 2 mm, the shearing action of the gas and the accompanying airstream is not sufficiently exerted on the spinning liquid, and it tends to become difficult to be fiberized.

[0028] Because each of the central axes of the extruding directions ($A1_1$, $A1_2$, $A1_3...$) of the columnar hollows for liquid ($H1_1$, $H1_2$, $H1_3...$) is parallel to the central axis of the ejecting direction (Ag) of the columnar hollow for gas (Hg), the gas and the accompanying airstream can be single-linearly exerted on each of the extruded spinning liquids, and thus, fibers can be stably formed. When these central axes coincide with each other, for example, in a case where a cylindrical hollow portion for liquid is covered with a hollow-cylindrical hollow portion for gas, or in a case where a cylindrical hollow portion for gas is covered with a hollow-cylindrical hollow portion for liquid, the shearing action of the gas and the accompanying airstream cannot be single-linearly exerted on the spinning liquid, and as a result, the spinning liquid is not sufficiently fiberized, and a lot of droplets occur. Alternatively, when these central axes are skew, or intersect with each other, the shearing action of the gas and the accompanying airstream is not exerted, or is not uniform if exerted, and thus, each spinning liquid is not stably fiberized. The term "parallel" means that the central axes of the extruding directions ($A1_1$, $A1_2$, $A1_3...$) of the columnar hollows for liquid ($H1_1$, $H1_2$, $H1_3...$) and the central axis of the ejecting direction (Ag) of the columnar hollow for gas (Hg) are coplanar and parallel. The term "central axis of the extruding (or ejecting) direction" means a line perpendicular to the centroid of a cross-section taken along a plane perpendicular to the outer wall of a virtual column.

[0029] In the spinning apparatus of the present invention, when the columnar hollow for gas (Hg) and the columnar hollows for liquid ($H1_1$, $H1_2$, $H1_3...$) are cross-sectioned with plane C perpendicular to the central axis (Ag) of the columnar hollow for gas (Hg), only a single

straight line (L_1 , L_2 , $L_3...$) having the shortest distance between the outer boundary of the cross-section of the columnar hollow for gas (Hg) and the outer boundary of the cross-section of each of the columnar hollows for liquid ($H1_1$, $H1_2$, $H1_3...$) can be drawn, at any combination. Because the gas ejected from the columnar hollow for gas (Hg) and the accompanying airstream single-linearly act on each of the spinning liquids extruded from the columnar hollows for liquid ($H1_1$, $H1_2$, $H1_3...$), the shearing action is single-linearly exerted on each of the spinning liquids to thereby perform stable spinning without generation of droplets. For example, when two straight lines can be drawn, because the shearing action is not stably exerted, for example, on one point and on another point by turns, droplets occur and stable spinning cannot be carried out.

[0030] Although not shown in Figure 1, in a case where the spinning liquid is prepared by dissolving a polymer in a solvent, the nozzles for extruding liquid ($N1_1$, $N1_2$, $N1_3...$) are connected to a reservoir for a spinning liquid (for example, a syringe, a stainless steel tank, a plastic tank, or a bag made of a resin, such as a vinyl chloride resin or a polyethylene resin), and the plate for ejecting gas (Pg) is connected to a gas supply equipment (for example, a compressor, a gas cylinder, or a blower). In a case where the spinning liquid is prepared by heat-melting a polymer, the nozzles for extruding liquid ($N1_1$, $N1_2$, $N1_3...$) are connected to a supply equipment such as an extruder, or a metal syringe heated by a heater, and the plate for ejecting gas (Pg) is connected to a gas supply equipment (for example, a compressor, a gas cylinder, or a blower) which is connected to a heater.

[0031] Although Figure 1 shows a set of spinning apparatus, two or more sets of spinning apparatus can be arranged in series or parallel. The productivity can be improved by arranging two or more sets of spinning apparatus. Figure 1 shows the use of the nozzles for extruding liquid ($N1_1$, $N1_2$, $N1_3...$), but it is not necessary to use two or more nozzles for extruding liquid in the present invention, the present invention includes an embodiment using one nozzle for extruding liquid. In terms of the productivity, it is preferable to use 8 or more of the nozzles for extruding liquid. The distance between adjacent nozzles for extruding liquid (the distance between the central axes of the extruding direction of adjacent nozzles for extruding liquid) is not particularly limited, because it is dependent on the outer shape of each nozzle for extruding liquid, but it is preferably 30 mm or less, more preferably 5 mm or less, and most particularly 2.5 mm or less, in terms of the productivity. When adjacent nozzles for extruding liquid are too close to each other, there is a possibility that a sufficient spinnability cannot be obtained because the extruded spinning liquids are contacted with each other, and thus, the distance between the outer walls of adjacent nozzles for extruding liquid is preferably 0.1 mm or more. Each distance between adjacent nozzles for extruding liquid may be regular or irregular, but it is preferable that the nozzles for

extruding liquid are arranged at regular intervals because fibers can be spun in a uniformly dispersed state and, as a result, a nonwoven fabric having an excellent uniformity can be produced.

[0032] Figure 1 shows an embodiment in which the nozzles for extruding liquid ($N1_1$, $N1_2$, $N1_3...$) are fixed on the plate for ejecting gas (Pg), but the present invention may comprise a means capable of freely adjusting the positions of the nozzles for extruding liquid ($N1_1$, $N1_2$, $N1_3...$), so long as these nozzles comply with the relations as described above. As shown in Figure 4 which is a cross-sectional view taken along a plane perpendicular to the central axis of the columnar hollow for gas (Hg), a plate for extruding liquid in which holes for extruding liquid (HI_1 , HI_2 , $HI_3...$) are bored may be used, instead of the nozzles for extruding liquid (NI_1 , NI_2 , $NI_3...$) as shown in Figure 1.

[0033] As shown in Figure 5 which is a cross-sectional view taken along a plane perpendicular to the central axis of the columnar hollow for gas (Hg), the first nozzles for extruding liquid (NI_{11} , NI_{12} , $NI_{13}...$) and the second nozzles for extruding liquid (NI_{21} , NI_{22} , $NI_{23}...$) can be directly contacted to each of both outer walls, respectively, of the plate for ejecting gas (Pg). As shown in Figure 6 which is a cross-sectional view taken along a plane perpendicular to the central axis of the columnar hollow for gas (Hg), the shapes of the first exits for extruding liquid ($E1_{11}$, $E1_{12}$, $E1_{13}...$) of the first nozzles for extruding liquid (NI_{11} , NI_{12} , $NI_{13}...$) and the second exits for extruding liquid ($E1_{21}$, $E1_{22}$, $E1_{23}...$) of the second nozzles for extruding liquid (NI_{21} , NI_{22} , $NI_{23}...$) are not necessary to be circular, but may be polygonal, such as triangular or quadrangular. As described above, it is not necessary that all the exits for extruding liquid ($E1_{11}$, $E1_{12}$, $E1_{13}...$, $E1_{21}$, $E1_{22}$, $E1_{23}...$) have the same shape, and nozzles for extruding liquid having extruding exits with different shapes may be regularly or irregularly arranged. In the spinning apparatus shown in Figure 5 or Figure 6, each of the first nozzles for extruding liquid (NI_{11} , NI_{12} , $NI_{13}...$) are opposite to each of the second nozzles for extruding liquid (NI_{21} , NI_{22} , $NI_{23}...$), respectively, but it is not particularly limited to this arrangement, and the first nozzles and the second nozzles may be regularly or irregularly arranged in a staggered format. When the nozzles for extruding liquid are arranged in a staggered format, the fibers spun from the first nozzles for extruding liquid ($N1_{11}$, $N1_{12}$, $N1_{13}...$) do not completely overlap with those spun from the second nozzles for extruding liquid ($N1_{21}$, $N1_{22}$, $N1_{23}...$), and thus, the fibers can be easily spun in a more dispersed state and, as a result, a nonwoven fabric having a more excellent uniformity can be easily produced.

[0034] The apparatus of the present invention for manufacturing a nonwoven fabric comprises a fibers collection means as well as the spinning apparatus as described above, and thus, a nonwoven fabric can be produced by collecting fibers. The apparatus of the present invention manufacturing a nonwoven fabric will be explained with reference to Figure 7 which is a cross-sectional view schematically showing an embodiment there-

of.

[0035] The apparatus for manufacturing a nonwoven fabric shown in Figure 7 contains a spinning apparatus (1), as shown in Figure 5, in which the first nozzles for extruding liquid (NI_{11} , NI_{12} , $NI_{13}...$) and the second nozzles for extruding liquid (NI_{21} , NI_{22} , $NI_{23}...$) are arranged on both outer walls of the plate for ejecting gas (Pg), a fibers collection means (3) capable of capturing fibers spun from the spinning apparatus, and a suction apparatus (4) which is located downstream of the fibers collection means (3) and which is capable of suctioning the fibers spun from the spinning apparatus. To the spinning apparatus (1), a first supply equipment for spinning liquid capable of supplying a spinning liquid to the first nozzles for extruding liquid (NI_{11} , NI_{12} , $NI_{13}...$) and a second supply equipment for spinning liquid capable of supplying a spinning liquid the same as or different from the first spinning liquid to the second nozzles for extruding liquid (NI_{21} , NI_{22} , $NI_{23}...$), as well as a gas supplying equipment capable of supplying a gas to the plate for ejecting gas (Pg), are connected.

[0036] In this apparatus for manufacturing a nonwoven fabric, each spinning liquid is supplied from the first supply equipments for spinning liquid and the second supply equipment for spinning liquid to the first nozzles for extruding liquid (NI_{11} , NI_{12} , $NI_{13}...$) and the second nozzles for extruding liquid (NI_{21} , NI_{22} , $NI_{23}...$), respectively, and simultaneously, a gas is supplied from the gas supplying equipment to the plate for ejecting gas (Pg). Each spinning liquid extruded from the first nozzles for extruding liquid ($N1_{11}$, $N1_{12}$, $N1_{13}...$) and the second nozzles for extruding liquid ($N1_{21}$, $N1_{22}$, $N1_{23}...$) is drawn and fiberized by the shearing action of the gas ejected from the plate for ejecting gas (Pg), and simultaneously, these fibers are flown to the fibers collection means (3) while being uniformly mixed, and directly accumulated on the fibers collection means (3) to form a nonwoven fabric.

[0037] In the apparatus for manufacturing a nonwoven fabric shown in Figure 7, because many nozzles for extruding liquid are arranged with respect to one plate for ejecting gas (Pg), the amount of the ejected gas can be reduced, the scattering of the accumulated fibers can be avoided, and a nonwoven fabric having an excellent uniformity can be produced with a high productivity. Further, this apparatus is energy-efficient, because the amount of the gas can be reduced, and a high-capacity suction apparatus (4) is not required.

[0038] When the fibers are accumulated, because the suction apparatus (4) is arranged downstream of the fibers collection means (3), the gas ejected from the plate for ejecting gas (Pg) is rapidly exhausted, and thus, a nonwoven fabric is not disturbed by the action of the gas.

[0039] Although the fibers collection means (3) shown in Figure 7 is a conveyor, the fibers collection means (3) may be any support capable of directly accumulating fibers thereon, for example, a nonwoven fabric, a woven fabric, a knitted fabric, a net, a drum, a belt, or a flat plate.

Because the gas is ejected in the present invention, it is preferable that an air-permeable fibers collection means (3) is used and a suction apparatus (4) is arranged on the opposite side of the fibers collection means (3) from the spinning apparatus, so that fibers are easily accumulated and the collected fibers are not disturbed by suction of the gas. In a case where the suction apparatus (4) is not used, it is not necessary that the fibers collection means is air-permeable.

[0040] Figure 7 shows that the fibers collection means (3) is arranged downstream in the extruding direction of the first nozzles for extruding liquid ($N1_{11}$, $N1_{12}$, $N1_{13}$...) and the second nozzles for extruding liquid ($N1_{21}$, $N1_{22}$, $N1_{23}$...) (i.e., the direction of gravity), and that the extruding direction of each spinning liquid is perpendicular to the surface for capturing fibers of the fibers collection means (3). In the present invention, however, the extruding direction of the first nozzles for extruding liquid ($N1_{11}$, $N1_{12}$, $N1_{13}$...) and the second nozzles for extruding liquid ($N1_{21}$, $N1_{22}$, $N1_{23}$...) may be parallel to the surface for capturing fibers of the fibers collection means (3), or may intersect with the surface for capturing fibers of the fibers collection means (3). The extruding direction of the first nozzles for extruding liquid ($N1_{11}$, $N1_{12}$, $N1_{13}$...) and the second nozzles for extruding liquid ($N1_{21}$, $N1_{22}$, $N1_{23}$...) is not particularly limited, and may be the same as, opposite to, or perpendicular to, the direction of gravity, or may intersect with the direction of gravity.

[0041] When the fibers collection means (3) is arranged so that the surface thereof for capturing fibers is opposite to (in particular, perpendicular to) the exit for ejecting gas (Eg) of spinning apparatus (1), the distance between the fiber-capturing surface of the fibers collection means (3) and each of the exits for extruding liquid ($E1_{11}$, $E1_{12}$, $E1_{13}$...) of the first nozzles for extruding liquid ($N1_{11}$, $N1_{12}$, $N1_{13}$...) and the exits for extruding liquid ($E1_{21}$, $E1_{22}$, $E1_{23}$...) of the second nozzles for extruding liquid ($N1_{21}$, $N1_{22}$, $N1_{23}$...) in the spinning apparatus (1) varies in accordance with the amount of a spinning liquid extruded or the gas velocity, and is not particularly limited. Each distance is preferably 50 to 1000 mm in a case where the spinning liquid is prepared by dissolving a polymer in a solvent, and each distance is preferably 10 to 1000 mm in a case where the spinning liquid is prepared by heat-melting a polymer. In the case where the spinning liquid is prepared by dissolving a polymer in a solvent and the distance is less than 50 mm, a nonwoven fabric sometimes cannot be obtained, because fibers are accumulated, while the solvent contained in the spinning liquid does not completely evaporate and remains, and the shape of each fiber accumulated cannot be maintained. In the case where the spinning liquid is prepared by heat-melting a polymer and the distance is less than 10 mm, the heated gas or the like sometimes affects the fibers accumulated on the fibers collection means, and thus the fibers is liable to be melted or fused with each other. In the case where the spinning liquid is prepared by dissolving a polymer in a solvent or by heat-melting a

polymer and the distance is more than 1000 mm, the gas flow is liable to be disturbed, and therefore, the fibers are liable to be broken and scattered.

[0042] The suction apparatus (4) is not particularly limited, but it is preferable that the gas velocity conditions can be controlled in accordance with the amount of the gas supplied from a gas supply equipment or the thickness of a nonwoven fabric to be produced.

[0043] The first or second supply equipment for spinning liquid may be, for example, a syringe, a stainless steel tank, a plastic tank, or a bag made of a resin, such as a vinyl chloride resin or a polyethylene resin in the case where the spinning liquid is prepared by dissolving a polymer in a solvent, and may be, for example, an extruder, or a mental syringe heated by a heater in the case where the spinning liquid is prepared by heat-melting a polymer. The gas supply equipment may be, for example, a compressor, a gas cylinder, or a blower in the case where the spinning liquid is prepared by dissolving a polymer in a solvent, and may be, for example, a compressor, a gas cylinder, or a blower of which each is connected to a heater in the case where the spinning liquid is prepared by heat-melting a polymer.

[0044] Although a set of spinning apparatus (1) is arranged in the apparatus for manufacturing a nonwoven fabric shown in Figure 7, the spinning apparatus arranged is not limited to one set, and two or more sets of spinning apparatus can be arranged. The productivity can be improved by arranging two or more sets of spinning apparatus. In the apparatus for manufacturing a nonwoven fabric shown in Figure 7, the spinning apparatus (1) in which the first nozzles for extruding liquid ($N1_{11}$, $N1_{12}$, $N1_{13}$...) and the second nozzles for extruding liquid ($N1_{21}$, $N1_{22}$, $N1_{23}$...) are arranged on both outer walls of the plate for ejecting gas (Pg), respectively, is used, but a spinning apparatus in which the nozzles for extruding liquid are arranged on either of the outer walls of the plate for ejecting gas (Pg) may be used.

[0045] The apparatus for manufacturing a nonwoven fabric shown in Figure 7 does not contain an apparatus for bonding fibers in a nonwoven fabric, but such an apparatus for bonding fibers in a nonwoven fabric, for example, an apparatus for adding a binder to a nonwoven fabric and drying the nonwoven fabric, an apparatus for heat treatment capable of fusing fibers to each other, or an apparatus for entangling fibers, may be arranged.

[0046] In the apparatus for manufacturing a nonwoven fabric shown in Figure 7, the spinning liquid is fiberized only by the action of gas ejected from the plate for ejecting gas (Pg), but the fiberization may be promoted by applying an electrical field to the spinning liquid, as well as the action of gas. For example, when a voltage is applied to the first nozzles for extruding liquid ($N1_{11}$, $N1_{12}$, $N1_{13}$...) and the second nozzles for extruding liquid ($N1_{21}$, $N1_{22}$, $N1_{23}$...) and the fibers collection means (3) is grounded, to generate an electrical field between the first nozzles for extruding liquid ($N1_{11}$, $N1_{12}$, $N1_{13}$...) and the second nozzles for extruding liquid ($N1_{21}$, $N1_{22}$, $N1_{23}$...) and the

fibers collection means (3), the spinning liquid which is liable to become droplets without extension by the shearing action of gas may be drawn and fiberized by the action of the electrical field. Further, the fibers are electrified by the action of the electrical field and the fibers repel each other, and, as a result, no fiber bundles in which fibers are adhered to each other are formed and the fibers can be captured in a state where each fiber is dispersed, and thus, a nonwoven fabric composed of fibers having a uniform fiber diameter can be easily produced. When a voltage is applied to the first nozzles for extruding liquid (N1₁₁, N1₁₂, N1₁₃...) and the second nozzles for extruding liquid (N1₂₁, N1₂₂, N1₂₃...), a nonwoven fabric which is bulkier than that formed by electrospinning can be produced, because a lower voltage may be used in comparison with conventional electrospinning.

[0047] As a power supply capable of applying a voltage to the first nozzles for extruding liquid (N1₁₁, N1₁₂, N1₁₃...) and the second nozzles for extruding liquid (N1₂₁, N1₂₂, N1₂₃...), for example, a DC high voltage generator or a Van De Graaff generator, may be used. The applied polarity may be positive or negative. The voltage may be applied to, instead of the first nozzles for extruding liquid (N1₁₁, N1₁₂, N1₁₃...) and the second nozzles for extruding liquid (N1₂₁, N1₂₂, N1₂₃...), wires or the like which are inserted into each nozzle for extruding liquid. The voltage may be applied to the fibers collection means (3), and the first nozzles for extruding liquid (N1₁₁, N1₁₂, N1₁₃...) and the second nozzles for extruding liquid (N1₂₁, N1₂₂, N1₂₃...) may be grounded. The voltage may be applied to both the first nozzles for extruding liquid (N1₁₁, N1₁₂, N1₁₃...) and the second nozzles for extruding liquid (N1₂₁, N1₂₂, N1₂₃...) and the fibers collection means (3) so that an electrical field may be generated between the first and second nozzles and the fibers collection means. A counter electrode may be arranged downstream of the opposite side of the conveyor from the exit for ejecting gas (Eg), and the counter electrode may be grounded or a voltage may be applied to the counter electrode, and an electrical field may be generated between the counter electrode and the first nozzles for extruding liquid (N1₁₁, N1₁₂, N1₁₃...) and the second nozzles for extruding liquid (N1₂₁, N1₂₂, N1₂₃...).

[0048] The electric potential difference between the first nozzles for extruding liquid (N1₁₁, N1₁₂, N1₁₃...) and the second nozzles for extruding liquid (N1₂₁, N1₂₂, N1₂₃...) and the fibers collection means (3) varies in accordance with spinning conditions, such as the type of spinning liquid, the distance between the first nozzles for extruding liquid (N1₁₁, N1₁₂, N1₁₃...) and the second nozzles for extruding liquid (N1₂₁, N1₂₂, N1₂₃...) and the fibers collection means (3), and the like, and thus, is not particularly limited, but is preferably 0.05 to 1.5 kV/cm. In a case where the potential difference is higher than 1.5 kV/cm, a spinning by the electrical field similar to electrospinning is dominant to a spinning by the shearing action of gas, but the uniformity of the nonwoven fabric tends to become poor due to the action of gas. In a case

where the potential difference is lower than 0.05 kV/cm, the nonwoven fabric tends to contain many component other than fibers, such as balls of fiber, fiber bundles, shots, particles, or the like, because the fibers are insufficiently or weakly electrified.

[0049] Although the apparatus for manufacturing a nonwoven fabric shown in figure 7 is an open system, the apparatus of the present invention for manufacturing a nonwoven fabric may be a closed system, for example, by housing the spinning apparatus (1), the fibers collection means (3), and the suction apparatus (4) in a spinning container. In a case where the spinning liquid is prepared by dissolving a polymer in a solvent and the solvent is evaporated during spinning, the closed system can avoid the diffusion of the solvent, and the solvent can be sometimes recycled.

[0050] In this case where the members are housed in a spinning container, it is preferable that a ventilator capable of exhausting a gas in the spinning container is connected to the spinning container. In a case where the spinning liquid is prepared by dissolving a polymer in a solvent, the solvent vapor concentration in the spinning container becomes progressively higher during spinning and results in an inhibition of evaporation of the solvent, and as a result, the unevenness of fiber diameters is easily generated and it tends to become difficult to be fiberized. The ventilator is not particularly limited, but may be a fan located at an exhaust vent. In a case where a gas is supplied from a gas supply equipment for a container to the spinning container, such a ventilator is not necessarily required, because the same amount of gas as the amount supplied can be exhausted only by arranging an exhaust vent. In a case where a gas is exhausted by a ventilator, it is preferable that the same amount of gas as the total amount of gas supplied from the gas supply equipment and the gas supply equipment for container is exhausted. When the total amount supplied is different from the amount exhausted, a change in pressure in the spinning container affects the evaporation rate of the solvent, and the unevenness of fiber diameters is easily generated. The suction apparatus (4) may be used as the ventilator, as well as the suction apparatus.

[0051] In a case where a gas supply equipment for container capable of supplying a gas of which the temperature and humidity are controlled is connected to the spinning container, the solvent vapor concentration in the spinning container can be stabilized, and fibers in which the unevenness of fiber diameters is small can be spun. As the gas supply equipment for container, for example, a propeller fan, a sirocco fan, an air compressor, or a blower, may be used.

[0052] The process of the present invention for manufacturing a nonwoven fabric is a process using the above-mentioned apparatus for manufacturing a nonwoven fabric. In particular, it is preferable that a gas having a gas velocity of 100 m/sec. or more is ejected from the exit for ejecting gas (Eg) of the spinning apparatus (1). Generation of droplets can be avoided, and a nonwoven

fabric containing fibers of which the diameter is uniform and thinned can be efficiently produced by ejecting the gas having a gas velocity of 100 m/sec. or more from the exit for ejecting gas (Eg). The gas is ejected at a gas velocity of, preferably 150 m/sec. or more, more preferably 200 m/sec. or more. The upper limit of the gas velocity is not particularly limited, so long as spinning can be stably carried out.

[0053] A gas having such a gas velocity can be ejected by, for example, supplying the gas to the columnar hollow for gas (Hg) from a compressor. The gas is not particularly limited, but air, a nitrogen gas, an argon gas, or the like may be used, and use of air is economical. The temperature of the gas varies in accordance with the type of spinning liquid, and is not particularly limited. In a case where the spinning liquid is prepared by dissolving a polymer in a solvent, ordinary temperature is economically preferable. In a case where the spinning liquid is prepared by heat-melting a polymer, the temperature of the gas at the space where the spinning liquid is contacted with the gas is preferably from a temperature 100°C lower than the temperature of the heat-melted polymer to a temperature 100°C higher than the temperature of the heat-melted polymer. When the gas has a temperature lower than that of the heat-melted polymer, the solidification of the fibers can be promoted by the cooling action. When the gas has a temperature higher than that of the heat-melted polymer, the solidification of the polymer can be inhibited, and the shearing action of the gas can be applied to the spinning liquid over a long distance in the flight space (2).

[0054] To the flight space of fibers (2) between the first nozzles for extruding liquid (N1₁₁, N1₁₂, N1₁₃...) and the second nozzles for extruding liquid (N1₂₁, N1₂₂, N1₂₃...) and the fibers collection means (3), a cooling gas or the like may be supplied to cool the fibers, and as a result, the solidification of the fibers may be promoted. To the flight space of fibers (2) between the first nozzles for extruding liquid (N1₁₁, N1₁₂, N1₁₃...) and the second nozzles for extruding liquid (N1₂₁, N1₂₂, N1₂₃...) and the fibers collection means (3), a heated gas may be supplied to heat the fibers or maintain their temperature, and as a result, the solidification of the fibers may be inhibited.

[0055] A spinning liquid which may be used in the process of the present invention is not particularly limited, and may be any liquid prepared by dissolving a desired polymer in a solvent or by heat-melting a desired polymer.

[0056] For example, as the spinning liquid prepared by dissolving a polymer in a solvent, a liquid prepared by dissolving one polymer, or two or more polymers selected from, for example, polyethylene glycol, partially saponified polyvinyl alcohol, completely saponified polyvinyl alcohol, polyvinylpyrrolidone, polylactic acid, polyester, polyglycolic acid, polyacrylonitrile, polyacrylonitrile copolymer, polymethacrylic acid, polymethylmethacrylate, polycarbonate, polystyrene, polyamide, polyimide, polyethylene, polypropylene, polyethersulfone, polysulfone, fluorocarbon resins (polyvinylidene fluoride, polyvinylidene fluoride copolymer, and the like), polyurethane,

para- or meta-aramid, or celluloses, in one solvent, or two or more solvents selected from, for example, water, acetone, methanol, ethanol, propanol, isopropanol, tetrahydrofuran, dimethylsulfoxide, 1,4-dioxane, pyridine, N,N-dimethylformamide, N,N-dimethylacetamide, N-methyl-2-pyrrolidone, acetonitrile, formic acid, toluene, benzene, cyclohexane, cyclohexanone, carbon tetrachloride, methylene chloride, chloroform, trichloroethane, ethylene carbonate, diethyl carbonate, or propylene carbonate, may be used.

[0057] The viscosity (when spinning is carried out) of the spinning liquid prepared by dissolving a polymer in a solvent is preferably 10 to 10000 mPa·s, more preferably 20 to 8000 mPa·s. When the viscosity is less than 10 mPa·s, the spinning liquid exhibits a poor spinnability due to a low viscosity, and it tends to become difficult to have a fibrous form. When the viscosity is more than 10000 mPa·s, the spinning liquid is difficult to be drawn, and it tends to become difficult to have a fibrous form. Therefore, even if the viscosity at room temperature is more than 10000 mPa·s, such a spinning liquid may be used, provided that the viscosity falls within the preferable range by heating the spinning liquid per se or the columnar hollows for liquid (H1₁₁, H1₁₂, H1₁₃..., H1₂₁, H1₂₂, H1₂₃...). By contrast, even if the viscosity at room temperature is less than 10 mPa·s, such a spinning liquid may be used, provided that the viscosity falls within the preferable range by cooling the spinning liquid per se or the columnar hollows for liquid (H1₁₁, H1₁₂, H1₁₃..., H1₂₁, H1₂₂, H1₂₃...). The term "viscosity" as used herein means a value measured at the temperature same as that when spinning is carried out, using a viscometer, when the shear rate is 100 s⁻¹.

[0058] As a polymer which may compose the spinning liquid prepared by heat-melting a polymer, for example, polyolefins (polypropylene, polyethylene, polypropylene-polyethylene copolymer, polymethylpentene, and the like), polyesters (aliphatic polyesters and aromatic polyesters), acrylic resins (polyacrylonitrile and polyacrylonitrile copolymer), celluloses, polyvinyl alcohol, ethylene-vinyl alcohol copolymer, polyvinyl chloride, polyvinylidene chloride, polycarbonate, polystyrene, polyurethane, polylactic acid, polyamides (nylon 6, nylon 66, nylon 12, and nylon 610), polyacetal, aramids, polyether sulfone, polysulfone, fluorocarbon resins (polyvinylidene fluoride, polyvinylidene fluoride copolymer, and the like), polyphenylene sulfide, poly ether ether ketone, or the like, may be used alone, or as a combination of two or more of these polymers.

[0059] The temperature of the spinning liquid prepared by heat-melting a polymer when spinning is preferably from the melting point of the polymer to a temperature 200°C higher than the melting point, more preferably from a temperature 20°C higher than the melting point to a temperature 100°C higher than the melting point. With respect to a temperature-dependent polymer, when the temperature is higher than a temperature 200°C higher than the melting point, a thermal decomposition of poly-

mer occurs, and the spinning becomes difficult. The shearing rate to the polymer when spinning is preferably 1 to 10000 s⁻¹, more preferably 50 to 5000 s⁻¹. With respect to a pressure-dependent polymer, when the shearing rate is less than 1 s⁻¹, stable extrusion is difficult, and when the shearing rate is more than 10000 s⁻¹, it tends to become difficult to extrude the polymer because a high extrusion pressure is required. Within the temperature range and the shearing rate range, the viscosity of the spinning liquid when spinning of the polymer is preferably 10 to 10000 mPa·s, more preferably 20 to 8000 mPa·s. When the viscosity is less than 10 mPa·s, the spinning liquid exhibits a poor spinnability due to a low viscosity, and it tends to become difficult to have a fibrous form. When the viscosity is more than 10000 mPa·s, the spinning liquid is difficult to be drawn, and it tends to become difficult to have a fibrous form. Therefore, even if the viscosity in melting is more than 10000 mPa·s, such a spinning liquid may be used, provided that the viscosity falls within the preferable range by heating the spinning liquid per se or the columnar hollows for liquid (H1₁₁, H1₁₂, H1₁₃..., H1₂₁, H1₂₂, H1₂₃...). By contrast, even if the viscosity in melting is less than 10 mPa·s, such a spinning liquid may be used, provided that the viscosity falls within the preferable range by cooling the spinning liquid per se or the columnar hollow for liquid (H1₁₁, H1₁₂, H1₁₃..., H1₂₁, H1₂₂, H1₂₃...).

[0060] The amount of each spinning liquid extruded from the exits for extruding liquid (E1₁₁, E1₁₂, E1₁₃...) of the first nozzles for extruding liquid (N1₁₁, N1₁₂, N1₁₃...) and the exits for extruding liquid (E1₂₁, E1₂₂, E1₂₃...) of the second nozzles for extruding liquid (N1₂₁, N1₂₂, N1₂₃...) is not particularly limited, because it varies depending on the viscosity of each spinning liquid or the gas velocity. Each amount is preferably 0.1 to 100 cm³/hour. The amount of the spinning liquid extruded from each nozzle for extruding liquid may be the same as, or different from, that of the other nozzles for extruding liquid. When the amounts are the same, fibers having a more uniform fiber diameter may be spun.

[0061] In the process of the present invention, a nonwoven fabric in which different types of fibers are mixed can be produced by extruding spinning liquids from the exits for extruding liquid (E1₁₁, E1₁₂, E1₁₃...) of the first nozzles for extruding liquid (N1₁₁, N1₁₂, N1₁₃...) and the exits for extruding liquid (E1₂₁, E1₂₂, E1₂₃...) of the second nozzles for extruding liquid (N1₂₁, N1₂₂, N1₂₃...) under two or more different extruding conditions to be fiberized. Because the extruding conditions of the first nozzles for extruding liquid (N1₁₁, N1₁₂, N1₁₃...) and the second nozzles for extruding liquid (N1₂₁, N1₂₂, N1₂₃...) in the spinning apparatus (1) as shown in Figure 7 are different, and the gas that acts on these extruded spinning liquid is the same, different types of fibers can be spun, and as a result, a nonwoven fabric having an excellent uniformity in which different types of fibers are mixed can be produced.

[0062] The term "two or more different extruding con-

ditions" as used herein means that each condition is not completely the same as the other condition(s), that is, each condition is different from the other condition(s) in one condition, or two or more conditions. For example, the shape of the exit for extruding liquid, the size of the exit for extruding liquid, the distance between the exit for extruding liquid and the exit for ejecting gas, the amount of a spinning liquid extruded, the concentration of a spinning liquid, polymers contained in a spinning liquid, the viscosity of a spinning liquid, solvents contained in a spinning liquid, the ratio of polymers contained in a spinning liquid when the spinning liquid contains two or more polymers, the ratio of solvents contained in a spinning liquid when the spinning liquid contains two or more solvents, the temperature of a spinning liquid, the method for preparing a spinning liquid (for example, a spinning liquid prepared by dissolving a polymer in a solvent and a spinning liquid prepared by heat-melting), or the type and/or the amount of an additive contained in a spinning liquid.

[0063] In the present invention, in addition to the production of a nonwoven fabric by spinning fibers using the spinning apparatus (1) as described above and accumulating the fibers, one or more functions can be imparted to the nonwoven fabric by adding powder, fibers, and/or a fiber aggregate to fibers which are spun and flown and mixing them.

[0064] Examples of the powder include activated carbon (for example, steam activated carbon, alkali-treated activated carbon, acid-treated activated carbon, or the like), inorganic particles (for example, manganese dioxide, iron oxide, copper oxide, nickel oxide, cobalt oxide, zinc oxide, titanium-containing oxide, zeolite, catalyst supported with ceramics, silica, or the like), ion exchange resins, and plant seeds.

[0065] Examples of the fibers include regenerated fibers such as rayon, polynosic, and cupra; semi-synthetic fibers such as acetate fibers; synthetic fibers such as nylon fibers, vinylon fibers, vinylidene fibers, polyvinyl chloride fibers, polyester fibers, acrylic fibers, polyethylene fibers, polypropylene fibers, and polyurethane fibers; inorganic fibers such as glass fibers and carbon fibers; plant fibers such as cotton and hemp; and animal fibers such as wool and silk.

[0066] Examples of the fiber aggregate include any aggregate containing the same or different types of these fibers. The aggregation state of the fiber aggregate is not particularly limited, but may be a state in which fibers are entangled, a state in which fibers are adhered to each other, a state in which fibers are fused to each other, a state of strands produced by twisting fibers, or the like.

[0067] The nonwoven fabric of the present invention is a nonwoven fabric prepared by the process as described above. Therefore, its fiber diameter is small and it can be stably produced with a high productivity. The average fiber diameter of fibers which form the nonwoven fabric is not particularly limited, but may be 50 to 5000 nm. The average fiber diameter as used herein is the arithmetic mean of the fiber diameters of 200 fibers. Each

fiber diameter is determined from photographic images of the surface of a nonwoven fabric, taken using a scanning electron microscope (SEM), with reference to the scale.

[0068] The mass per unit area of the nonwoven fabric of the present invention may be 0.1 to 100 g/m², and the thickness thereof may be 1 to 1000 μm. The mass per unit area as used herein means a value obtained by converting the weight of a nonwoven fabric sample of 10 cm square into the weight per 1 m². The thickness as used herein means a value measured using a compressive elasticity thickness gauge, more particularly, a value when 100 gf of load is applied to 5cm² of load area at a rate of 3 mm/s.

EXAMPLES

[0069] The present invention now will be further illustrated by, but is by no means limited to, the following Examples.

Example 1

(Preparation of spinning liquid)

[0070] Polyacrylonitrile (manufactured by Aldrich) was dissolved in N,N-dimethylformamide so as to become a concentration of 10 mass% to prepare a spinning liquid (viscosity (temperature: 25°C): 970 mPa·s.

(Preparation of apparatus for manufacturing nonwoven fabric)

[0071] A manufacturing apparatus as shown in Figure 1 comprising the following parts was prepared.

- (1) Supply equipment for spinning liquid: syringe
- (2) Gas supply equipment: compressor
- (3) Nozzles for extruding liquid (N1₁ to N1₁₉): metal nozzle
- (3) -1 Exits for extruding liquid (E1₁ to E1₁₉): circular, 0.3 mm in diameter (cross-sectional area: 0.07 mm²)
- (3) -2 Columnar hollows for liquid (H1₁ to H1₁₉): cylindrical, 0.3 mm in diameter
- (3) -3 Outer diameter of nozzles: 0.55 mm each
- (3) -4 Number of nozzles: 19
- (4) Plate for ejecting gas (Pg): metal plate
- (4) -1 Exit for ejecting gas (Eg): rectangular, 0.5 mm in width and 50 mm in length
- (4) -2 Columnar hollow for gas (Hg): rectangular parallelepiped, 0.5 mm in width, 50 mm in length, and 20 mm in height
- (4) -3 Thickness of plate members which form the plate for ejecting gas (Pg): 1 mm
- (4) -4 Number of plate for ejecting gas (Pg): 1 set
- (4) -5 Positions: All the exits for extruding liquid (E1₁ to E1₁₉) were located 2.5 mm downstream of the exit for ejecting gas (Eg), each outer wall of the nozzles

for extruding liquid was directly contacted with the outer wall of one side of the plate for ejecting gas (Pg), and the nozzles for extruding liquid were arranged at regular intervals so that the distance between adjacent nozzles (distance between the central axes of an extruding direction) was 2.5 mm.

(5) Distance between each of virtual columns for liquid (Hv1₁ to Hv1₁₉) and virtual column for gas (Hvg) : 1.125 mm each

(6) Central axes of extruding direction of liquid (A1₁ to A1₁₉) and central axis of ejecting direction of gas (Ag):

parallel to each other

(7) Number of straight lines having the shortest distance between the outer boundary of the cross-section of the columnar hollow for gas (Hg) and each outer boundary of the cross-sections of the columnar hollows for liquid (H1₁ to H1₁₉) when the columnar hollow for gas and the columnar hollows for liquid are cross-sectioned with a plane perpendicular to the central axis of the columnar hollow for gas (Hg): 1 each

(8) Fibers collection means: net (30 mesh), which was arranged so that the surface thereof for capturing fibers was perpendicular to the center axis of the ejecting direction of gas (Ag).

(8) -1 Distance between each of the exits for extruding liquid (E1₁ to E1₁₉) and the surface for capturing fibers: 300 mm

(9) Suction apparatus: suction box (size of suction opening: 80 mm x 350 mm)

(10) Container for spinning: acrylic case having a volume of 1 m³

(10) -1 Gas supply equipment: precision air generator (manufactured by Apiste, 1400-HDR)

(Manufacture of nonwoven fabric)

[0072] Fibers were accumulated on the fibers collection means (net) under the following conditions to produce a nonwoven fabric having a mass per unit area of 5 g/m² and a thickness of 50 μm. The average fiber diameter of the fibers which formed this nonwoven fabric was 300 nm, and the nonwoven fabric composed of such thin fibers could be stably produced with a high productivity without generation of droplets.

(a) Amount of spinning liquid extruded from each nozzle for extruding liquid (N1₁ to N1₁₉): 3 cm³/hour/nozzle

(b) Air velocity of air ejected: 250 m/sec.

(c) Moving speed of net: 10 mm/sec.

(d) Conditions for suctioning fibers: 30 cm/sec.

(e) Conditions for supplying gas: 25°C, 27% RH, 1 m³/min.

Comparative Example 1

(Preparation of spinning liquid)

[0073] The same spinning liquid as that described in Example 1 was prepared.

(Preparation of apparatus for manufacturing nonwoven fabric)

[0074] A spinning apparatus comprising the following parts, which had the arrangement of a nozzle for extruding liquid (N1) and a nozzle for ejecting gas (Ng) as shown in Figure 3, was prepared.

- (1) Supply equipment for spinning liquid: syringe
- (2) Gas supply equipment: compressor
- (3) Nozzle for extruding liquid (N1): metal nozzle
- (3) -1 Exit for extruding liquid (E1): circular, 0.3 mm in diameter (cross-sectional area: 0.07 mm²)
- (3) -2 Columnar hollow for liquid: cylindrical, 0.3 mm in diameter
- (3) -3 Outer diameter of nozzle: 0.55 mm
- (3) -4 Number of nozzles: 1
- (4) Nozzle for ejecting gas (Ng): metal nozzle
- (4) -1 Exit for ejecting gas (Eg): circular, 0.8 mm in diameter (cross-sectional area: 0.27 mm²)
- (4) -2 Columnar hollow for gas: Cylindrical, 0.8 mm in diameter
- (4) -3 Outer diameter of nozzle: 1.0 mm
- (4) -4 Number of nozzles: 1
- (4) -5 Positions: The nozzles were arranged so that the exit for ejecting gas was located 5 mm upstream of the exit for extruding liquid, and the nozzle for ejecting gas and the nozzle for extruding liquid were concentrically located. As a result, the exit for ejecting gas has an annular shape having an inner diameter of 0.55 mm and an outer diameter of 0.8 mm (see Figure 3).
- (5) Distance between virtual column for liquid and virtual column for gas: 0.125 mm
- (6) Central axis of extruding direction of liquid and central axis of ejecting direction of gas: coaxial
- (7) Number of straight lines having the shortest distance between the inner boundary of the cross-section of the columnar hollow for gas and the outer boundary of the cross-section of the columnar hollow for liquid when the columnar hollows are cross-sectioned with a plane perpendicular to the central axis of the columnar hollow for gas: infinite
- (8) Fibers collection means: net (30 mesh), arranged so that the surface thereof for capturing fibers was perpendicular to the center axis of the ejecting direction of gas (8)-1 Distance from exit for extruding liquid (E1): 300 mm
- (9) Suction apparatus: suction box (size of suction opening: 80 mm x 350 mm)
- (10) Container for spinning: acrylic case having a

volume of 1 m³

(10) -1 Gas supply equipment: precision air generator

(manufactured by Apiste, 1400-HDR)

(Manufacture of nonwoven fabric)

[0075] Spinning was carried out under the following conditions to produce a nonwoven fabric, but almost all of extruded spinning liquids did not have a fibrous form, and a nonwoven fabric was not obtained.

- (a) Amount of spinning liquid extruded from nozzle for extruding liquid (N1): 3 g/hour
- (b) Air velocity of air ejected: 250 m/sec.
- (c) Moving speed of net: 0.65 mm/sec.
- (d) Conditions for suctioning fibers: 30 cm/sec.
- (e) Conditions for supplying gas: 25°C, 27% RH, 1 m³/min.

Example 2

[0076] As a resin, a polypropylene resin [(MI = 1500), Shear rate at a temperature of 200°C: 3145 s⁻¹, viscosity: 5000 mPa·s] was prepared.

[0077] A spinning apparatus comprising a plate for ejecting gas (Pg), which contained a columnar hollow for gas (Hg), and a plate for extruding liquid, in which columnar hollows for liquid (H1₁ to H1₆₇) were bored, with the cross-section as shown in Figure 4 when the columnar hollows are cross-sectioned with a plane perpendicular to the central axis of the columnar hollow for gas (Hg), was prepared. More particularly, this spinning apparatus contained the following members.

- (1) Resin supply equipment: extruder
- (2) Heated gas supply equipment: compressor (compressed air was heated by a heater)
- (3) Plate for extruding liquid: a set of metal plates having a wall thickness of 1 mm
- (4) Exits for extruding resin liquid (E1₁ to E1₆₇): 67 circular exits (E1₁ to E1₆₇) having a diameter of 0.15 mm were arranged in a single and straight line at intervals of 5 mm, as the distance between the central axes of an extruding direction.
- (5) Columnar hollows for liquid (H1₁ to H1₆₇): cylindrical, 0.15 mm in diameter each
- (6) Plate for ejecting gas: metal plate having a wall thickness of 10 mm
- (7) Exit for ejecting gas (Eg): rectangular, 0.6 mm in width and 420 mm in length
- (8) Columnar hollow for gas (Hg): rectangular parallelepiped, 0.6 mm in width, 420 mm in length, and 5 mm in height
- (9) Positions: The exit for ejecting gas (Eg) was located 5 mm upstream of all the exits for extruding liquid (E1₁ to E1₆₇), and the plate for extruding liquid

was directly contacted with the plate for ejecting gas.
(10) Distance between each of virtual columns for liquid (Hv1₁ to Hv1₆₇) and virtual column for gas (Hvg) : 0.3 mm each

(11) Central axes of extruding direction of liquid (A1₁ to A1₆₇) and central axis of ejecting direction of gas (Ag):

parallel to each other

(12) Number of straight lines having the shortest distance between the outer boundary of the cross-section of the columnar hollow for gas (Hg) and each outer boundary of the cross-sections of the columnar hollows for liquid (H1₁ to H1₆₇) when the columnar hollows are cross-sectioned with a plane perpendicular to the central axis of the columnar hollow for gas (Hg): 1 each

(13) Fibers collection means: suction cylinder (punch metal plate), arranged so that the surface thereof for capturing fibers was perpendicular to the center axis of the extruding direction of liquid; distance between each exit for extruding resin liquid (E1₁ to E1₆₇) and the surface for capturing fibers: 200 mm

(14) Equipment for suctioning fibers: suction cylinder

[0078] After the polypropylene resin was melted at 200°C, the melted resin liquid was extruded from the exits for extruding resin liquid (E1₁ to E1₆₇) in the direction of gravity, and simultaneously, heated air was ejected from the exit for ejecting gas (Eg) to fiberize the resin liquid, and simultaneously, the formed fibers were suctioned by the suction cylinder to fly the fibers in the direction to the fibers collection means and to accumulate the fibers on the fibers collection means, under the following conditions, to produced a nonwoven fabric (mass per unit area: 4 g/m², thickness: 100 μm, average fiber diameter: 600 nm, CV value: 0.6). The fibers which formed the nonwoven fabric were thin, and the unevenness of fiber diameters was small.

(a) Amount of resin extruded: 2 g/hour/nozzle

(b) Temperature of plate for ejecting gas and plate for extruding liquid: 200°C

(c) Air ejected: temperature 260°C, flow rate 6 Nm³/min., air velocity 397 m/sec.

(d) Suction cylinder: rotation speed 4 m/min., amount suctioned 130 m³/min., gas velocity 28 m/sec.

Example 3

[0079] A nonwoven fabric was produced under the same conditions described in Example 2, except that the amount of resin extruded was 10 g/hour/nozzle. The produced nonwoven fabric had a mass per unit area of 5 g/m², a thickness of 150 μm, an average fiber diameter of 1100 nm, and a CV value of 0.3. The fibers which formed the nonwoven fabric were thick, but the uneven-

ness of fiber diameters was very small.

Comparative Example 2

[0080] As a resin, a polypropylene resin [(MI = 1500), Shear rate at a temperature of 200°C: 3145 s⁻¹, viscosity: 5000 mPa·s] was prepared.

[0081] A die for a melt blowing apparatus, of which the schematical cross-section taken along a plane perpendicular to the columns of the exits for extruding resin is shown in Figure 8, was provided. More particularly, this melt blowing apparatus contained the following members.

(1) Resin supply equipment: extruder

(2) Heated gas supply equipment: compressor (compressed air was heated by a heater)

(3) Die for melt blowing apparatus: metal die

(4) Exits for extruding resin liquid (El₁ to El₃₁): circular exits (El₁ to El₃₁) having a diameter of 0.2 mm were arranged in a single and straight line.

(5) Exit for ejecting gas (Eg): 0.5 mm in width and 300 mm in length

(6) Fibers collection means: suction cylinder (punch metal plate), arranged so that the surface thereof for capturing fibers was perpendicular to the center axis of the extruding direction of resin liquid; distance between each exit for extruding resin liquid and the surface for capturing fibers: 300 mm

(7) Equipment for suctioning fibers: suction cylinder

[0082] After the polypropylene resin was melted at 200°C, the melted resin liquid was extruded from the exits for extruding resin liquid (E1₁ to E1₃₁) in the direction of gravity, and simultaneously, heated air ejected from the exit for ejecting gas (Eg) was blown to the extruded resin liquid to fiberize the resin liquid, and simultaneously, the formed fibers were suctioned by the suction cylinder to fly the fibers in the direction to the fibers collection means and to accumulate the fibers on the fibers collection means, under the following conditions, to produced a nonwoven fabric (mass per unit area: 10 g/m², thickness: 100 μm, average fiber diameter: 2000 nm, CV value: 0.9). The fibers which formed the nonwoven fabric were thick, the unevenness of fiber diameters was large, and the nonwoven fabric contained many shots and beads.

(a) Amount of resin extruded: 0.5 g/hour/nozzle

(b) Temperature of die: 200°C

(c) Air ejected: temperature 280°C, flow rate 2.5 Nm³/min., air velocity 278 m/sec.

(d) Suction cylinder: rotation speed 4 m/min., amount suctioned 50 m³/min., gas velocity 20 m/sec.

INDUSTRIAL APPLICABILITY

[0083] The nonwoven fabric of the present invention can be preferably used as, for example, a filtering mate-

rial for filter (such as air filter, liquid filter, or blood filter), a separator for electrochemical device (such as battery separator or separator for capacitor), an electrode material, a film support, a semiconductor substrate, a substrate for flexible display, a thermal insulating material, a sound insulating material, a carrier for cell culture, a wound dressing material, a material for drug delivery system, a sensor chip, or a smart fabric.

REFERENCE SIGNS LIST

[0084]

N1: Nozzle for extruding liquid
 Nl₁, Nl₂, Nl₃: Nozzle for extruding liquid
 Pg: Plate for ejecting gas
 El, El₁, El₂, El₃: Exit for extruding liquid
 Eg: Exit for ejecting gas
 Hl₁, Hl₂, Hl₃: Columnar hollow for liquid
 Hg: Columnar hollow for gas
 Hvl₁, Hvl₂, Hvl₃: Virtual column for liquid
 Hvg: Virtual column for gas
 Al₁, Al₂, Al₃: Central axis of the extruding direction (liquid)
 Ag: Central axis of the ejecting direction (gas)
 C: Plane perpendicular to the central axis of the columnar hollow for gas
 L₁, L₂, L₃: Straight line having the shortest distance between outer boundaries
 12: First member
 22: Second member
 32: Third member
 14, 24, 34: Supply end
 16, 26, 36: Opposing exit end
 18: First supply slit
 38: First gas slit
 20: Gas jet space
 1: Spinning apparatus
 2: Flight space
 3: Fibers collection means
 4: Suction apparatus

exit for ejecting gas,

(3) a virtual column for liquid (Hvl) which is extended from the columnar hollow for liquid (Hl) is located adjacent to a virtual column for gas (Hvg) which is extended from the columnar hollow for gas (Hg),

(4) a central axis of an extruding direction in the columnar hollow for liquid (Hl) is parallel to a central axis of an ejecting direction in the columnar hollow for gas (Hg), and

(5) when the columnar hollow for gas and the columnar hollow for liquid are cross-sectioned with a plane perpendicular to the central axis of the columnar hollow for gas (Hg), there exists only one straight line having the shortest distance between an outer boundary of the cross-section of the columnar hollow for gas (Hg) and an outer boundary of the cross-section of the columnar hollow for liquid (Hl).

2. An apparatus for manufacturing a nonwoven fabric, comprising the spinning apparatus according to claim 1 and a fibers collection means.
3. A process for manufacturing a nonwoven fabric, using the apparatus according to claim 2.
4. A nonwoven fabric produced by the process according to claim 3.

Claims

1. A spinning apparatus comprising one or more exits for extruding liquid, which are capable of extruding a spinning liquid, and one or more exits for ejecting gas, which extend linearly and are located upstream of each of the exits for extruding liquid and which are capable of ejecting a gas, wherein

(1) the spinning apparatus comprises a columnar hollow for liquid (Hl), in which the exit for extruding liquid forms one end of the columnar hollow for liquid,

(2) the spinning apparatus comprises a columnar hollow for gas (Hg) of which one end is the

Figure 1

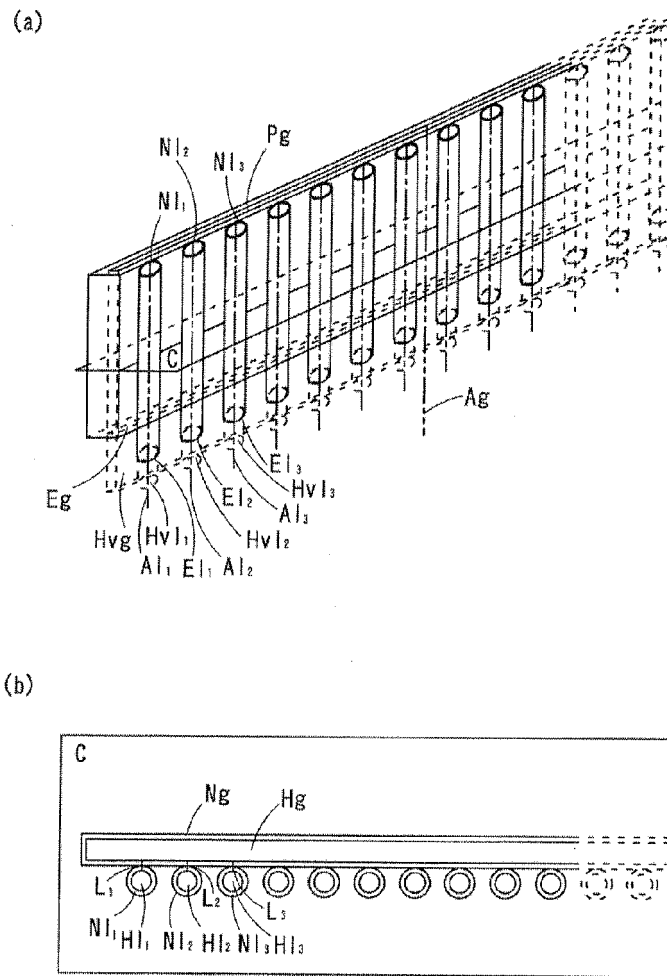


Figure 2

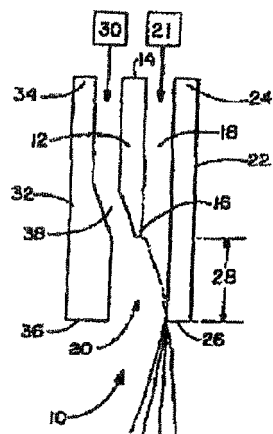


Figure 3

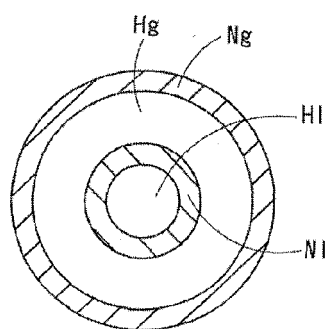


Figure 4

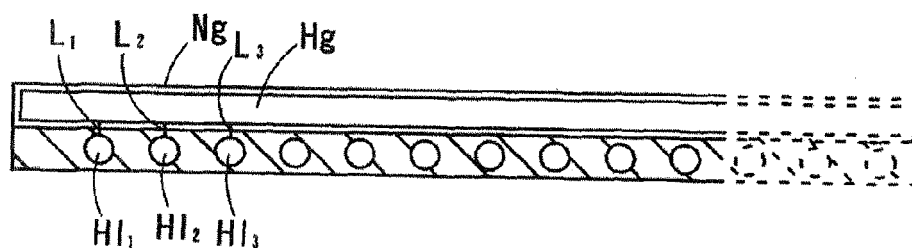


Figure 5

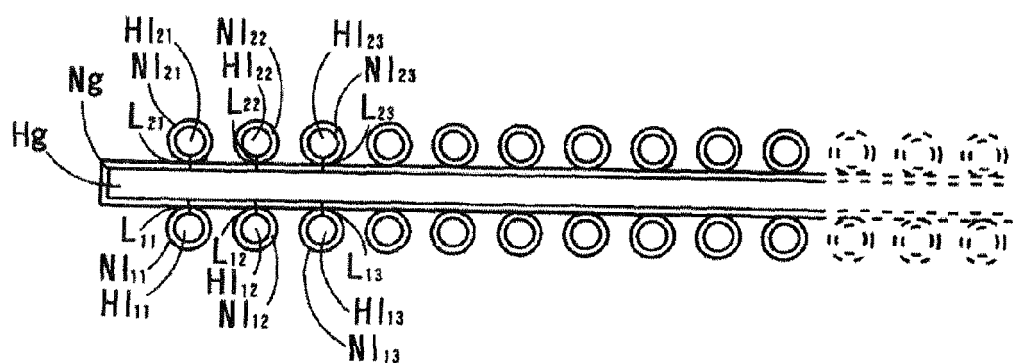


Figure 6

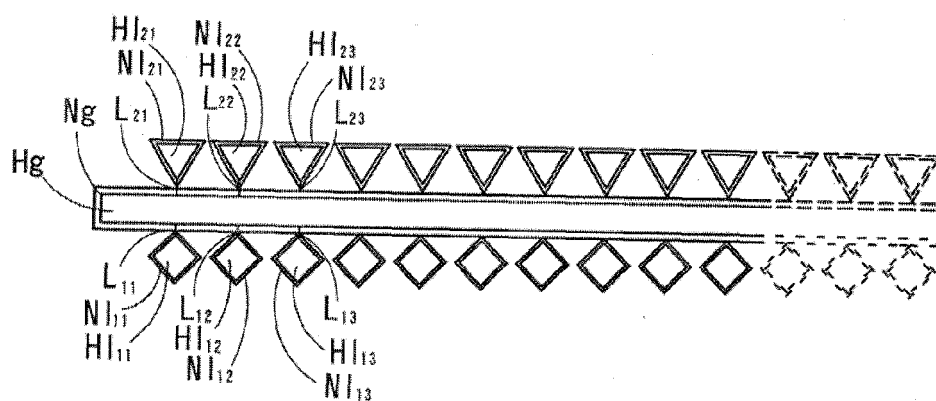


Figure 7

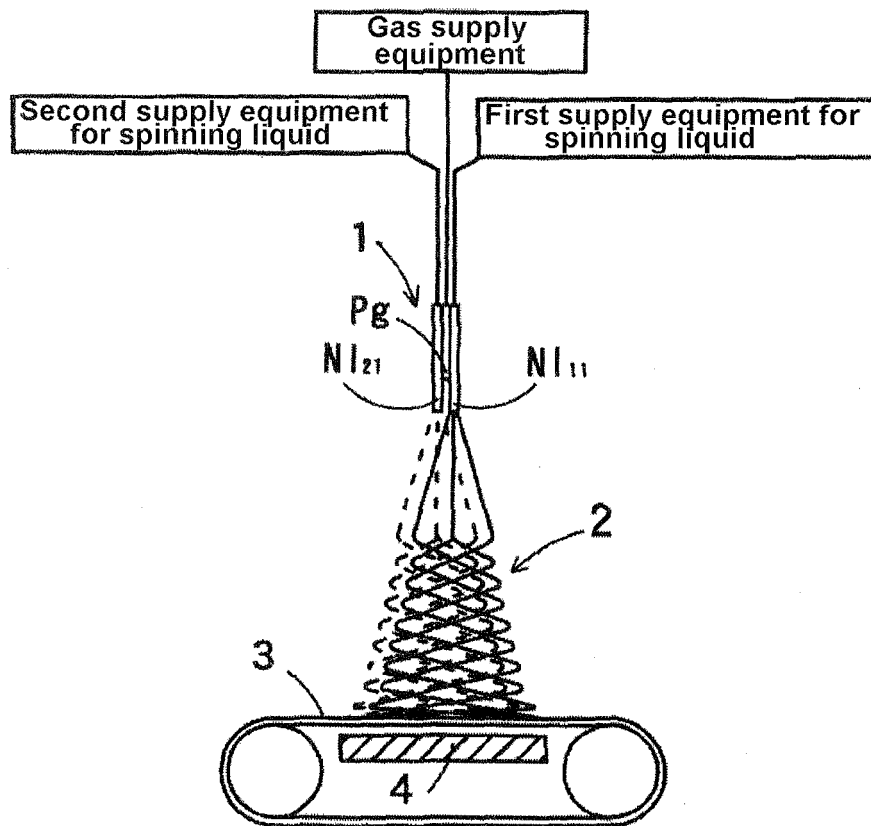
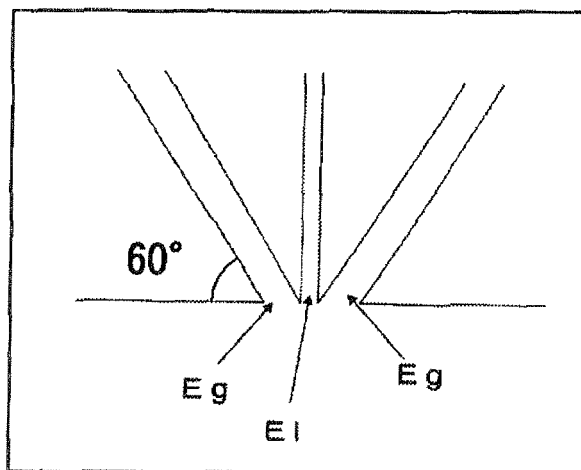


Figure 8





EUROPEAN SEARCH REPORT

Application Number
EP 10 19 2653

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