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(54) **NANOFIBER PRODUCTION DEVICE AND NANOFIBER PRODUCTION METHOD**

(57) An object of the present invention is to provide an apparatus and method for producing a nanofiber by using a melt blown method improving productivity.

A pellet-shaped raw material (resin) fed into a hopper 2 is supplied and melted in a heating cylinder 3 heated by a heater 4, and sent to a front part of the heating cylinder 3 by a screw 5 rotated by a motor 6. The heating cylinder 3 is provided with a head portion 7, and a high-pressure gas is ejected from the gas ejection hole

71 provided at a center of the head portion 7. The molten resin sent to an end of the heating cylinder 3 is discharged from a resin discharge hole 73 having six superfine tubes provided in a downstream side of the resin ejection hole 73 through inside of the head portion 7. The molten resin discharged from the resin discharge hole 73 is elongated and a fiber having nanometer-order diameter can be formed.

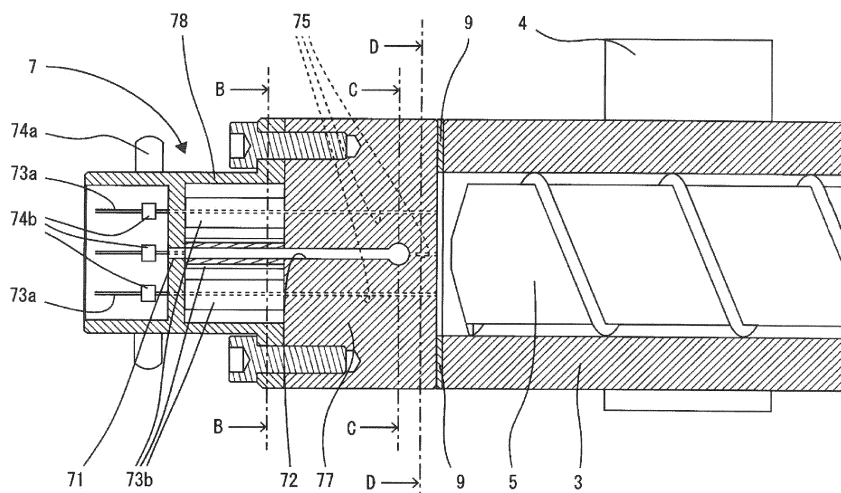


Fig. 4

Description

Technical Field

[0001] The present invention relates to an apparatus and a method for producing a nanofiber, which is capable of providing a high-quality nanofiber in a simple structure.

Background of the Invention

[0002] In recent years, demand of a nanofiber is rapidly increasing in accordance with expansion of use of a fiber having a nanometer-order diameter, namely a nanofiber. In accordance with expansion of use of the nanofiber, a special nanofiber has been required which is high in quality and corresponds to purpose. Regarding a nanofiber producing method, there are conventional methods such as an electrospinning method, a melt blown method or the like, and there are advantages and disadvantages with each method.

[0003] Patent Document 1 as the above-mentioned background of the invention discloses a method for producing a nonwoven fabric consisting of a plurality of kinds of fiber which is made by mixing a solution discharging fiber to a melt blown fiber. Specifically, by using a solution spinning unit which ejects a spinning solution discharged from a liquid discharge portion with a gas ejected from a gas discharge portion, the solution discharge fiber made by discharging and fiberizing the spinning solution is mixed into a fiber flow of a melt blown fiber delivered from a nozzle by the melt blown method.

[0004] Furthermore, Non-Patent Document 1 discloses a nanofiber producing method using an electrospinning method. A conventional electrospinning method for producing the nanofiber requires solvent for swelling resin, however, Non-Patent Document 1 discloses a configuration for preventing flashing and explosion caused by using a solvent by swelling by a heat without using the solvent. Additionally, disadvantages of the nanofiber producing method using the melt blown method are described in detail.

Description of Prior Art

Patent Literature

[0005] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2010-185153

Non-Patent Literature

[0006] Non-Patent Literature 1: WEB-Journal No. 151 Nonwoven Fabric Extra Issue (<http://www.webj.co.jp/index.html>)

Summary of Invention

Problems to be solved by the Invention

[0007] As described in the above-mentioned Non-Patent Literature 1, when a fiber diameter is reduced in the nanofiber producing method of the conventional melt blown method, it is considered to apply a method for ejecting high-temperature air at high speed and a method for suppressing discharge of polymer. When the high-temperature air is ejected at high speed, the fiber diameter is reduced but length of the fiber is shortened and shredded. On the other hand, when discharge of polymer is suppressed, an amount of production per unit time is extremely reduced. Accordingly, it is difficult for either method to achieve mass production of the nanofiber having a good quality. In an electrospinning method, productivity has been improved, however, an apparatus has become complicated, countermeasures is required for preventing flashing and explosion, and cost of manufacture has become expensive.

[0008] The present invention was made in consideration of the above problems, and an object of the present invention is to provide an apparatus and a method for producing a nanofiber which is capable of supplying a large amount of the nanofiber having good quality in nanofiber producing method of a melt blown method, and improving safety by eliminating factor of flashing and explosion.

Means for Solving the Problems

[0009] According to the present invention, there is provided an apparatus for producing a nanofiber comprising a liquid raw material discharge unit for discharging a liquid raw material to a high-pressure gas flow ejected from a high-pressure gas ejection unit, wherein a plurality of the liquid raw material discharge units are provided around the high-pressure gas flow ejected from the high-pressure gas ejection unit.

[0010] According to the present invention, there is provided an apparatus for producing the nanofiber wherein the liquid raw material discharge unit comprises an extruding unit for melting and extruding a raw material.

[0011] According to the present invention, there is provided an apparatus for producing the nanofiber wherein the liquid raw material discharge unit comprises a unit for supplying a dissolved raw material.

[0012] According to the present invention, there is provided an apparatus for producing the nanofiber wherein the high-pressure gas ejection unit is provided with a gas supply unit for supplying a high-pressure and high-temperature gas, and the high-pressure gas ejection unit ejects the high-temperature gas at a high pressure.

[0013] According to the present invention, there is provided an apparatus for producing the nanofiber comprising an angle adjustment unit capable of adjusting an installation angle of the liquid raw material discharge unit

to the high-pressure gas flow ejected from the high-pressure gas ejection unit.

[0014] According to the present invention, there is provided an apparatus for producing the nanofiber wherein at least two or more liquid raw material discharge unit are symmetrically provided to the high-pressure gas ejection unit.

[0015] According to the present invention, there is provided an apparatus for producing the nanofiber wherein the liquid raw material discharge units are equally provided around the high-pressure gas flow ejected from the high-pressure gas ejection unit.

[0016] According to the present invention, there is provided an apparatus for producing the nanofiber wherein the high-pressure gas flow ejected from the high-pressure gas ejection unit is provided in a vertical direction to an installation surface of the nanofiber producing apparatus.

[0017] According to the present invention, there is provided a method for producing a nanofiber by discharging a liquid raw material from a liquid raw material discharge unit to a high-pressure gas flow ejected from a high-pressure gas ejection means, wherein a discharge angle of the liquid raw material discharged from the liquid raw material discharge unit to the high-pressure gas flow is adjusted, when a plurality of the liquid raw material discharge units provided around the high-pressure gas flow ejected from the high-pressure gas ejection unit discharge the liquid raw material.

[0018] According to the present invention, there is provided a method for producing a nanofiber using a nanofiber producing apparatus comprising a heating cylinder to which a raw material is fed, a heating unit for heating the heating cylinder, and an extruding unit for extruding the raw material in the heating cylinder, wherein, an end portion of the heating cylinder is provided with a gas ejection hole for ejecting a high-pressure gas, a plurality of raw material discharge units for discharging the raw material in melting state in the heating cylinder are provided around the gas ejection holes, the raw material fed in the heating cylinder is melted or melting state of the same is maintained by heating the heating cylinder by the heating unit, the raw material is discharged from the raw material discharge unit by using the extruding unit, an air current is generated by the gas ejected from the gas ejection hole, and a fiber having nanometer-order diameter is obtained by elongating the discharged raw material along with the air current of the ejected gas from the periphery.

Effect of the Invention

[0019] According to the present invention, a nanofiber having a smaller diameter and good quality can be safely produced. Furthermore, when the nanofiber is produced, it is not necessary to apply an apparatus using high voltage, and a problem of an amount of production per unit time which is disadvantage for the melt blown method

can be solved by providing a plurality of resin discharge unit.

BRIEF DESCRIPTION OF DRAWINGS

[0020]

Fig. 1 is a partial sectional side view showing an entire structure of an embodiment 1 of a nanofiber producing apparatus according to the present invention. Fig. 2 is an external plan view showing a head portion and a heating cylinder of the nanofiber producing apparatus according to the embodiment 1 of the present invention.

Fig. 3 is an external front view showing an end of the head portion of the nanofiber producing apparatus according to embodiments of the present invention. Fig. 4 is a cross-sectional view of the nanofiber producing apparatus in Fig. 3, taken along the line A-A. Fig. 5 is cross-sectional views of the nanofiber producing apparatus in Fig. 4, taken along the lines B-B, C-C and D-D, respectively.

Fig. 6 is an explanatory diagram showing resin flow and gas flow in the head portion of the nanofiber producing apparatus according to the embodiment 1 of the present invention.

Fig. 7 are explanatory diagrams showing (a) an example of a supporting structure of a resin discharge unit and (b) another example of a supporting structure of the resin discharge unit of the nanofiber producing apparatus according to the embodiment 1 of the present invention.

Fig. 8 is a side view showing the entire structure of an embodiment 2 of a nanofiber producing apparatus according to the present invention.

Fig. 9 is a plan view showing the entire structure of the embodiment 2 of the nanofiber producing apparatus according to the present invention.

Fig. 10 is a front view showing a structure of the head portion of the embodiment 2 of the nanofiber producing apparatus according to the present invention.

Fig. 11 is an explanatory diagram illustrating a basic concept of the apparatus and a method for producing the nanofiber according to the present invention.

Detailed Description of Preferred embodiments

[0021] Hereinafter, the preferred embodiment of the present invention will be described in detail. The present invention is, needless to say, easily applicable to a structure other than the description of embodiments of the present invention within a scope not inconsistent with an object of the invention.

[0022] According to the present invention, a nanofiber is formed by supplying a liquid raw material to fluid (preferably, gaseous fluid) ejected in high pressure. In the description, a term "GAS" without specifying composition means gases consisting of any composition and molec-

ular structure. Additionally, in the description, a term "raw material" means all of materials applicable for forming the nanofiber. In the embodiments hereinafter, an explanation will be made for an example using synthetic resin as the "raw material", but not limited thereto, various kinds of composition material will be usable. The term "liquid raw material" in the description does not limit property of the material to liquid, and includes "molten raw material" applicable for the embodiment 1 forming the nanofiber by melting and extruding a solid raw material from an extruding unit. Moreover, the term "liquid raw material" in the description also includes "dissolved raw material" applicable for the embodiment 2 which forms the nanofiber by dissolving in advance a solid or a liquid raw material in a predetermined solvent so that a predetermined concentration can be obtained, and by feeding by using an appropriate means and discharging or extruding from a discharge holes. The "liquid raw material" of the present invention needs property having viscosity enough to supply (eject, discharge) "raw material" from supplying holes (ejection holes, discharge holes), and "raw material" having such liquid property is described as "liquid raw material" in the present invention.

[0023] While detail description will be made hereafter, basic concept of the present invention is common to an apparatus and method for producing the nanofiber explained as the embodiments 1 and 2 of the present invention, and, as shown in Fig. 11, it is configured to provide a high-pressure gas ejection unit 71 at a center thereof, and to make an installation angle of a plurality of discharge unit 73a variable, which are arranged around a high-pressure gas flow 90 ejected from a high-pressure gas ejection unit 71. In other words, a supply angle θ of the liquid raw material to the high-pressure gas flow 90 is variable. The basic concept of the present invention is, as shown in Fig. 11, that the discharge unit 73a for discharging the liquid raw material is provided at the supply angle θ to a central line 91 of the high-pressure gas flow 90, and the liquid raw material is discharged/supplied from a plurality of the discharge units 73a toward the central line 91 of the high-pressure gas flow 90. The liquid raw material discharged/supplied from the plurality of discharge units 73a is preferably provided to be intersected on the central line 91.

[0024] In Fig. 11, arrangement condition of each component is as mentioned above, and positional relationship is as follows. On the basis of a position of the gas ejection hole (an opening nozzle) of the high-pressure gas ejection unit 71, "distance a" represents a distance from the gas ejection hole to the discharge unit 73a, "distance b" represents a distance from the gas ejection hole to a point that the raw materials discharged from the discharge unit 73a are intersected, "distance c" represents an opening diameter of the gas ejection hole, and "distance d" represents a distance between the gas ejection holes.

[0025] Herein, the discharge unit 73a for discharging the liquid raw material is provided at the supply angle θ

to the central line 91 of the high-pressure gas flow 90. The raw material supply tangent angle θ is obtained from the following Equation (1)

$$\tan \theta = d/(b-a) \quad (1).$$

The raw material supply tangent angle θ is adjustable within a scope of $0^\circ < \theta < 90^\circ$. As an example, when the "distance a" is equal to 30mm, the "distance c" is equal to 2mm, the "distance d" is equal to 7mm, and pressure of the ejected high-pressure gas is equal to about 0.15MPa, θ is preferably equal to 20° plus/minus 10° .

[0026] The raw material supply tangent angle θ should be determined by the "distance a", the "distance b", and the "distance d" between the gas ejection holes, and moreover, should be determined by relationship among the opening diameter "distance c" of the high-pressure gas ejection hole, pressure and temperature of the ejected high-pressure gas.

[0027] According to the apparatus and method for producing the nanofiber of the embodiment 1 of the present invention, a pellet-shaped raw material (resin) fed into a hopper is supplied and melted in a heating cylinder heated by a heater, and sent to a front part of the heating cylinder by a screw rotated by a motor. The heating cylinder is provided with a head portion, and the high-pressure gas is ejected from the gas ejection hole provided at a center of the head portion. The liquid molten raw material (molten resin) sent to an end of the heating cylinder is supplied (discharged) from the supply unit (the discharge unit) of the liquid molten raw material (molten resin) having a plurality of superfine tubes provided in a downstream side of the gas ejection unit, through inside of the head portion. A plurality of superfine tubes of the discharge units of the liquid molten raw material are provided equally around the gas ejection hole provided at a center. Thereby, the molten resin discharged from the discharge units of the liquid molten raw material is elongated and the fiber having the nanometer-order fiber can be obtained.

[0028] According to the apparatus and method for producing the nanofiber of the embodiment 2 of the present invention, configuration is made to eject the high-pressure gas from the gas ejection hole provided at a center thereof, and the liquid dissolved raw material is discharged from a plurality of superfine tubes of the discharge units of the liquid dissolved raw material provided in a downstream side of the discharge units of the liquid dissolved raw material.

Embodiment 1

[0029] Hereinafter, entire structure of a nanofiber producing apparatus according to the embodiment 1 of the present invention will be described in detail referring to Figs. 1 to 3.

[0030] A nanofiber producing apparatus 1 as shown in

Fig. 1 according to the embodiment 1 of the present invention comprises a hopper 2, a heating cylinder 3, a heater 4 as a heating unit, a screw 5 as an extruding unit, a motor 6 as a driving unit, and a cylindrical head portion 7. The hopper 2 feeds a resin (a granular synthetic resin having a fine particle) to be a material for the nanofiber into the nanofiber producing apparatus 1. The heating cylinder 3 heats and melts the resin supplied from the hopper 2. The heater heats the heating cylinder from outside. The screw 5 is rotatably stored in the heating cylinder 3 and functions to move the molten resin to the end of the heating cylinder 3 by rotating. The motor 6 rotates the screw 5 through a connecting unit 61 (not shown in detail), and the head portion 7 is provided at the end of the heating cylinder 3. A nanofiber producing apparatus 1 further comprises a gas ejection hole 71 (an opening nozzle) for ejecting a gaseous hot air from the center area, and a resin discharge unit inside thereof for discharging the molten resin described below from the periphery of the gas ejection hole 71 (an opening nozzle). The high-pressure gas is supplied to the head portion 7 through a pipe 81 connected to a gas piping unit 8 as a gas supplying pipe for ejecting the gas from the center area. The gas piping unit 8 is provided with a heating unit such as a heater or the like (not shown), and configuration is made to eject a hot air from the gas ejection unit 71 (the opening nozzle). The head portion 7 and the heating cylinder 3 are connected via a seal portion 9 of a sheet member having a shape of O-ring and a doughnut-shape, and the molten resin is not leaked to outside of the apparatus thereby.

[0031] A plurality of heaters 4 provided at an outer circumference of the heating cylinder 3 is capable of controlling temperature separately or collectively by a control unit (not shown). According to the present embodiment, four heaters 4 are provided as shown in Fig. 1, but not limited thereto, modification is applicable to the number of installation, size of each heater, and condition of arrangement in conformity to material and property of the resin to be used, and conditions of a diameter and length of the heating cylinder 3.

[0032] Fig. 2 is a plan view and Fig. 3 is a front view of a nanofiber producing apparatus 1 according to the present embodiment. Figs. 4 to 6 are explanatory diagrams showing structure of the head portion 7.

[0033] The head portion 7 of the present embodiment, as shown in Fig. 3, is connected to the pipe 81 into which the high-pressure gas is fed from the outer circumference of the heating cylinder 3 through the gas piping unit 8. The high-pressure gas from the pipe 81 is introduced to inside of the head portion 7 and ejected from the gas ejection hole (the opening nozzle: Fig. 3) provided at the center area. A plurality of resin discharge units 73 are provided equally around the gas ejection holes 71. According to the present embodiment, the resin discharge unit 73 comprises a resin discharge needle 73a and a resin discharge needle fitting unit 73b having a structure for fitting the resin discharge needle 73a to the head por-

tion 7.

[0034] The head portion 7 shown in Fig. 3 comprises a heating cylinder cover unit 77 for covering the end portion of the heating cylinder 3 and a resin discharge unit holding ring 78 as a means for holding the resin discharge unit 73. The resin discharge unit holding ring 78 is fixed to the heating cylinder cover unit 77 without fixing means such as a bolt (without reference number).

[0035] According to this resin discharge unit holding ring 78, if a plurality of the resin discharge units 73 are provided around the gas ejection hole 71 (the opening nozzle), there is achieved greatly increasing productivity of the nanofiber having a uniform diameter and fiber length by arranging a plurality of resin discharge unit 73 at an equal interval, an equal distance ("distance a" from the gas ejection hole), or an equal angle (discharge angle θ).

[0036] Referring to Fig. 11, description will be made of positional relationship of the gas ejection hole 71 (the opening nozzle) and the resin discharge unit 73 provided around thereof. The gas flow 90 is ejected from the gas ejection hole 71 provided at a center area of the head portion 7. There is provided a plurality of the resin discharge units 73 provided around the gas flow 90, and the resin is ejected from resin discharge holes of the resin discharge needles 73a with a discharge angle θ to the gas flow 90. The resin discharge holes of the resin discharge needles 73a are provided forward (in downstream side along with the gas flow 90 from the ejection holes 71) with "distance a" from the ejection hole 71. Each resin discharge hole of a plurality of resin discharge needles 73a is provided for discharging the resin forward with "distance b" from the ejection holes 71 (in the downstream side along with the gas flow 90 from the ejection holes 71) so as to intersect resins.

[0037] Regarding an arrangement condition of a plurality of resin discharge units 73, it is also capable of forming a nanofiber having an ununiformed diameter or fiber length by changing the number of the resin discharge units 73, an arrangement interval, an arrangement distance ("distance a" from the gas ejection hole), and an arrangement angle θ . According to use of the produced nanofiber, the arrangement condition of the resin discharge unit 73 such as the arrangement interval or the like may be appropriately selected and changed.

[0038] Fig. 4 is a cross-sectional view of the head portion 7 of Fig. 3, taken along the line A-A. Fig. 5 (a), (b) and (c) are cross-sectional views of main part of the head portion 7 of Fig. 4, taken along the lines B-B, C-C and D-D, respectively. Fig. 6 is an explanatory diagram showing a flow passage A of the high-pressure gas and a flow passage B of the molten resin. As shown in Figs. 4 to 6, six resin flow passages 75 (an arrow B in the drawings) are provided in at equal interval corresponding to the resin discharge unit 73 in the head portion 7. The resin discharge unit 73 is connected to the heating cylinder 3 through the resin flow passage 75. The molten resin pressed by rotation of the screw 5 flows into the resin

flow passage 75 shown in the cross-sectional view, taken along the lines D-D of Fig. 5(c), and through the resin flow passage 75 shown in the cross-sectional view taken along the lines C-C, the molten resin flows in the resin discharge needle fitting unit 73b shown in the cross-sectional view, taken along the lines B-B and is discharged from the resin discharge needle 73a. In this case, as shown in Fig. 4, the gas flow passage 72 (an arrow A in the drawings) is provided at a center of the head portion 7 so as not to interfere the resin flow passage 75 (an arrow B in the drawings). Additionally, as shown in a cross-sectional view, taken along the lines C-C of Fig. 5(b), the gas flow passage 72 is provided by changing a direction from outside to inside of the head portion 7 through the any adjacent resin flow passage 75. The gas piping unit 8 is connected to the gas flow passage 72 through the pipe 81. The high-pressure and high-temperature gas fed from the gas piping unit 8 through such provided gas flow passage 72 and ejected from the gas ejection hole 71 (the opening nozzle). The resin flow passage 75 and the gas flow passage 72 are provided in the head portion 7 so as not to interfere each other. The numeral reference 79 in Fig. 5 (b) represents a screw portion 79 for fitting the pipe (the gas flow passage) 81 on the heating cylinder cover unit 77.

[0039] In order to adjust the arrangement condition of the resin discharge unit 73 to the gas flow passage 72, a holding adjusting unit 74 for the resin discharge unit 73 is provided. A diameter of the resin discharge hole of the resin discharge needle 73a in the resin discharge unit 73 is very small and the resin discharge needle 73a is susceptible to the effects of stress such as vibrations of an apparatus and pressure of the resin, and therefore, the arrangement condition of the previously mentioned resin discharge unit 73 may be changed and detachment may be occurred from the head portion 7. It becomes necessary to avoid stress on the resin discharge needle 73a if an angle of the resin discharge needle 73a is adjusted and changed, and to make a structure not to detach the resin discharge needle 73a from the head portion 7.

[0040] Fig. 7(a) is an explanatory diagram showing a support structure of the holding adjusting unit 74 for fixing the resin discharge unit 73 to the resin discharge unit holding ring 78, and for making a fitting angle adjustable. The resin discharge unit 73 comprises the resin discharge needle 73a and the resin discharge needle fitting unit 73b, and the resin discharge needle fitting unit 73b is fixed on the resin discharge unit holding ring 78 of the head portion 7 by screwing (not shown), engaging and using a fixing means such as a pin or the like. The resin discharge needle 73a is provided with the holding adjusting unit 74. This holding adjusting unit 74 comprises a resin discharge needle gripping unit 74a for gripping the resin discharge needle 73a from the periphery and a adjusting unit 74b having an adjusting pestle 74c which is retractable and provided penetrating from outside to inside of the head portion 7. By operating the adjusting unit 74b, the adjusting pestle 74c is advanced and retracted,

and the resin discharge needle gripping unit 74a is moved in a diameter direction of the head portion 7. Thereby, the resin discharge needle 73a can be fixed at a desired position and angle. By using such resin discharge hole support unit 74, the resin discharge unit 73 is adjusted so that the discharging molten resin is discharged at a desired discharge angle to the ejection gas flow from the gas ejection hole 71, and is surely fixable at the angle.

[0041] This structure is useful as the adjusting unit of the discharge angle of the molten resin against the ejection has flow, and the resin discharge needle 73a has a shape of very thin pipe. When the nanofiber producing apparatus 1 is operated, big vibration of the pipe may be occurred on the top thereof by driving the motor 6 and the screw 5, and the holding adjusting unit 74 can suppress the vibration effectively. In Fig. 2 of the present embodiment, six resin discharge units 73 are provided, and the six holding adjusting unit 74 are also provided, but not limited thereto, the number of thereof may be appropriately selected in accordance with condition of the resin for use, an amount of production, property of products.

[0042] Fig. 7(b) shows another example of an angle adjusting function of the resin discharge unit 73. In this embodiment, the holding adjusting unit 74 comprises a resin discharge needle gripping unit 74d for gripping the resin discharge needle 73a from the periphery, and an adjusting unit (not shown) having an adjusting pestle 74e which is retractable and provided penetrating from outside to inside of the head portion 7. By operating the adjusting unit, the adjusting pestle 74e is advanced and retracted, and the resin discharge needle gripping unit 74d is moved in a diameter direction of the head portion 7. Thereby, the resin discharge needle 73a can be fixed at a desired position and angle. The resin discharge needle fitting unit 73c is made spherical and cylindrical, a sliding surface 76 on which the resin discharge needle fitting unit 73c can rotate or be rotatable is provided on the resin discharge unit holding ring 78 of the head portion 7, and the resin discharge needle fitting unit 73c is provided. Thereby, an angle of the resin discharge needle 73a can be easily adjusted and it becomes capable of adjusting the angle of the resin discharge unit 73 without concern for dropout of the resin discharge needle 73a.

[0043] Regarding the gas ejection hole 71 and the resin discharge unit 73, as shown in the drawings, the gas ejection hole 71 is provided in a downstream side from the resin discharge unit 73. According to this structure, the molten resin is gradually elongated along with a distribution of ejected gas flow ejected from the gas ejection hole 71, and a fiber having nanometer-order is obtained. By using the heating unit not shown in the drawings, gas is ejected from the gas piping unit 8 as a hot air. Accordingly, the resin discharged from the resin discharge unit 73 has a nanofiber larger in length and smaller in fiber diameter in comparison with the case the normal temperature gas is ejected.

[0044] Description will be made of a series of operation

of the nanofiber producing apparatus 1 having the above structure. the raw material (the resin) fed into the hopper 2 is melted in the heating cylinder 3 by heating by the heater 4, and sent to a front part of the heating cylinder 3 by a screw rotated by the motor 6. The molten resin arrived at the end of the heating cylinder 3 is discharged from the raw material discharge holes of six resin discharge needles 73 through six resin flow passages 75 provided in the inside of the head portion 7. The discharged molten resin is carried along with an air current generated by the high-pressure and high-temperature gas supplied from the gas piping unit 8 and ejected from the gas ejection hole 71. The nanofiber is formed by elongating the molten resin by the difference in velocity between rapid air current of the high-temperature gas and slow air retained therearound.

Embodiment 2

[0045] According to the embodiment 1 of the present invention, detailed description of the nanofiber producing apparatus was made in which the granular synthetic resin having a fine particle is melted and used as a raw material. As mentioned before, the liquid raw material of the nanofiber is not limited thereto, and a dissolved raw material may be used, which is prepared by dissolving the solid or liquid raw material in the predetermined solvent in advance so as to obtain the predetermined concentration. This is also called as the liquid raw material. Figs. 8 to 10 show the nanofiber producing apparatus for forming the nanofiber from the dissolved raw material. Same reference numerals are used to the structure same as that in the embodiment 1.

[0046] According to the embodiment 2 of the present invention, a solvent storage unit 5A is used having function for extruding the dissolved raw material with the predetermined pressure instead of using the hopper 2, the screw 5 and the motor 6 of the embodiment 1. The gravity caused by difference in height may be applied as the predetermined pressure. The head portion 7A is connected to a solvent supplying hose 3A and the gas piping unit 8. The unit for ejecting gas (illustration omitted) may be provided in the gas piping unit 8 or be introduced from the high-pressure gas supply unit (not shown) to the gas piping unit 8. As shown in Fig. 9, the head portion 7A is provided with a gas flow passage 72A and a gas ejection hole 71A as a flow passage of the gas supplied from the gas piping unit 8. In a similar manner, the head portion 7A is provided with a resin flow passage 75A as the flow passage of the dissolved raw material, and the resin flow passage 75A is connected to the resin discharge unit 73. In a similar manner in the embodiment 1, the resin discharge unit 73 comprises the resin discharge needles 73a as a discharge hole of the dissolved raw material and the resin discharge needle fitting unit not shown in Figs. 8 to 10. The head portion 7A is provided with the resin discharge unit holding ring 78A. By providing the holding adjusting unit 74 comprising the resin discharge

needle gripping unit 74a and the adjusting unit 74b having the adjusting pestle 74c which is retractable and provided penetrating from outside to inside of the head portion 7A, the discharge angle of the resin discharge needle 73a can be adjustable at all by the holding adjusting unit 74 as same in the embodiment 1.

[0047] The nanofiber producing apparatus according to the embodiment 2 is, as shown in Fig. 10, provided with two resin discharge units 73. The number of resin discharge unit 73 is not limited to two, and three or more resin discharge units 73 can be equally provided around the gas ejection holes 71A. In this case, the resin discharge unit 73 is preferably equally provided. The embodiment in the drawings shows a horizontal ejection type, however, those skilled in the art can easily consider variations for ejecting vertically (from upward to downward, or from downward to upward) in a vertical direction from the gas ejection hole 71A to the gas flow passage 72A.

[0048] In comparison with the structure of the embodiment 1, according to the present embodiment, the dissolved raw material is used which the raw material is dissolved in the solvent, and the nanofiber producing apparatus can be composed without using a complicated component, such as the heating cylinder, the motor, the screw and so on. Thereby, the apparatus becomes small in size and space can be saved. Additionally, since the apparatus becomes small in size, a portable nanofiber producing apparatus can be obtained. In such a portable apparatus, the nanofiber can be formed by spraying the nanofiber to an area where the nanofiber should be attached, and use of a fiber can be expanded.

[0049] Though description was made of the embodiments of the present invention in detail, the present invention is not limited to the prescribed embodiments, and various modifications may be possible within a scope of the present invention. For example, in the above embodiment, the horizontal nanofiber producing apparatus is described which the molten resin and the gas ejection hole are provided in a horizontal direction, however it is not limited thereto, there is no problem to arrange the vertical apparatus and method for producing the nanofiber in the downward. If we adopt the vertical apparatus and method, an effect of gravity can be effectively prevented. The extruding unit is explained as the screw 5, however as a die cast method, there is no problem if the solvent is supplied in order and intermittent extrusion is made by using a piston, although countermeasures should be taken against interruption of produced nanofiber. Furthermore, the gas ejection hole 71 may be nozzle shape by forming in a taper shape so as to increase the pressure thereof. Two examples are raised and described about the structure of adjusting the angles of the resin discharge needle 73a, however, there can be applied the structure capable of adjusting the angles of the bellows-type resin discharge unit and so on.

1 nanofiber producing apparatus

2 hopper
 3 heating cylinder
 4 heater
 5 screw
 6 motor
 7 head portion
 71 gas ejection unit
 72 gas flow passage
 73 resin discharge unit
 73a resin discharge needle
 73b, 73c resin discharge needle fitting unit
 74 holding adjusting unit
 74a resin discharge needle gripping unit
 74b adjusting unit
 74c adjusting pestle
 75 resin flow passage
 76 sliding surface
 77 heating cylinder cover unit
 78 resin discharge unit holding ring
 8 gas piping unit
 81 pipe
 90 high-pressure gas flow
 91 central line

Claims

1. An apparatus for producing a nanofiber comprising a liquid raw material discharge unit for discharging a liquid raw material to a high-pressure gas flow ejected from a high-pressure gas ejection unit, wherein a plurality of said liquid raw material discharge units are provided around a center of the high-pressure gas flow ejected from said high-pressure gas ejection unit.
2. An apparatus for producing the nanofiber according to claim 1, wherein said liquid raw material discharge unit comprises an extruding unit for melting and extruding a raw material.
3. An apparatus for producing the nanofiber according to claim 1, wherein said liquid raw material discharge unit comprises a unit for supplying dissolved raw material.
4. An apparatus for producing the nanofiber according to any one of claims 1 to 3, wherein said high-pressure gas ejection unit is provided with a gas supply unit for supplying a high-pressure and a high-temperature gas, and said high-pressure gas ejection unit ejects said high-temperature gas in a high pressure.
5. An apparatus for producing the nanofiber according to any one of claims 1 to 4, comprising an angle adjustment unit capable of adjusting an installation

angle of said liquid raw material discharge unit to the high-pressure gas flow ejected from said high-pressure gas ejection unit.

- 5 6. An apparatus for producing the nanofiber according to any one of claims 1 to 5, wherein at least two or more said liquid raw material discharge unit are symmetrically provided to said high-pressure gas ejection unit.
- 10 7. An apparatus for producing the nanofiber according to any one of claims 1 to 6, wherein said liquid raw material discharge units are is equally provided around the high-pressure gas flow ejected from said high-pressure gas ejection unit.
- 15 8. An apparatus for producing the nanofiber according to any one of claims 1 to 7, wherein the high-pressure gas flow ejected from said high-pressure gas ejection unit is provided in a vertical direction to an installation surface of the nanofiber producing apparatus.
- 20 9. A method for producing a nanofiber by discharging a liquid raw material from a liquid raw material discharge unit to a high-pressure gas flow ejected from a high-pressure gas ejection means, wherein a discharge angle of the liquid raw material discharged from said liquid raw material discharge unit to said high-pressure gas flow is adjusted, when a plurality of said liquid raw material discharge units discharge the liquid raw material to the high-pressure gas flow as a center ejected from said high-pressure gas ejection unit.
- 25 10. A method for producing a nanofiber using a nanofiber producing apparatus comprising a heating cylinder to which a raw material is fed, a heating unit for heating the heating cylinder, and an extruding unit for extruding the raw material in said heating cylinder, wherein, an end portion of said heating cylinder is provided with a gas ejection hole for ejecting a high-pressure gas, a plurality of raw material discharge units for discharging the raw material in melting state in said heating cylinder are provided around said gas ejection hole, and a fiber having nanometer-order diameter is obtained by heating said heating cylinder by said heating unit, by melting the raw material supplied in said heating cylinder or being maintained in a melting state, by extruding the raw material from said extruding unit and discharging from said raw material discharge unit, by generating an air current by the gas ejected from said gas ejection hole, and by carrying and elongating said discharged raw material along with the air current of the ejected gas from the periphery.
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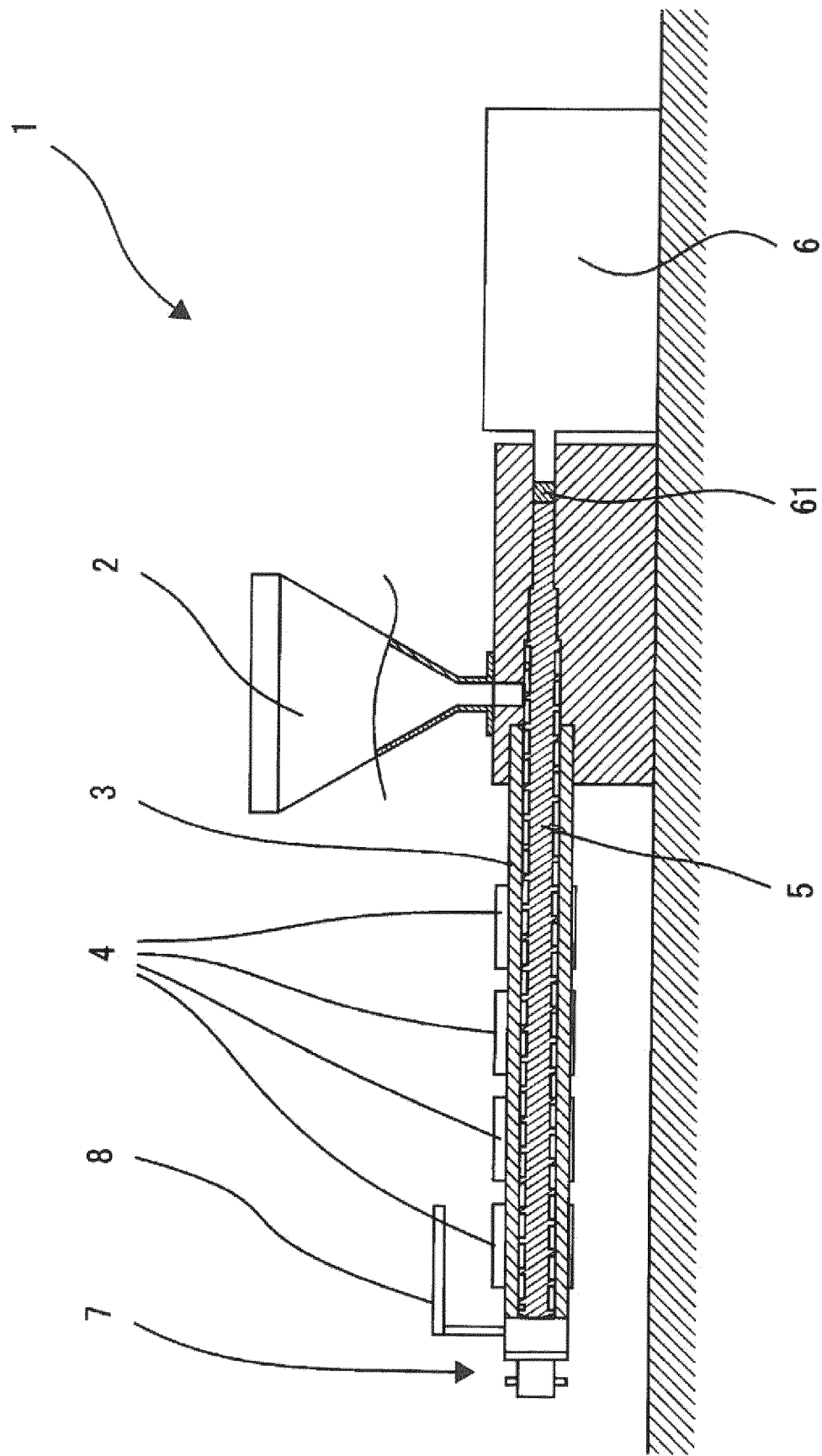


Fig.1

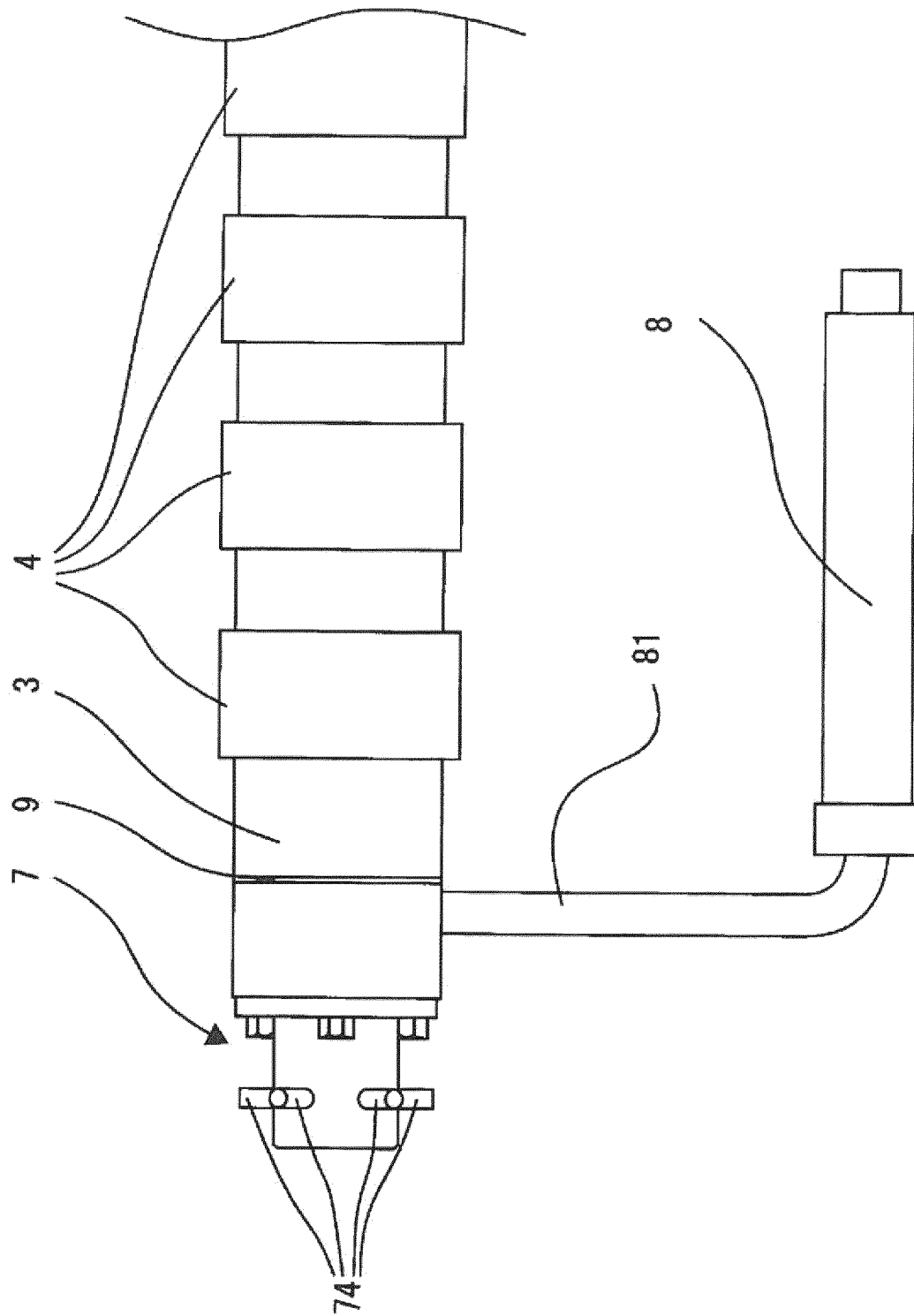


Fig. 2

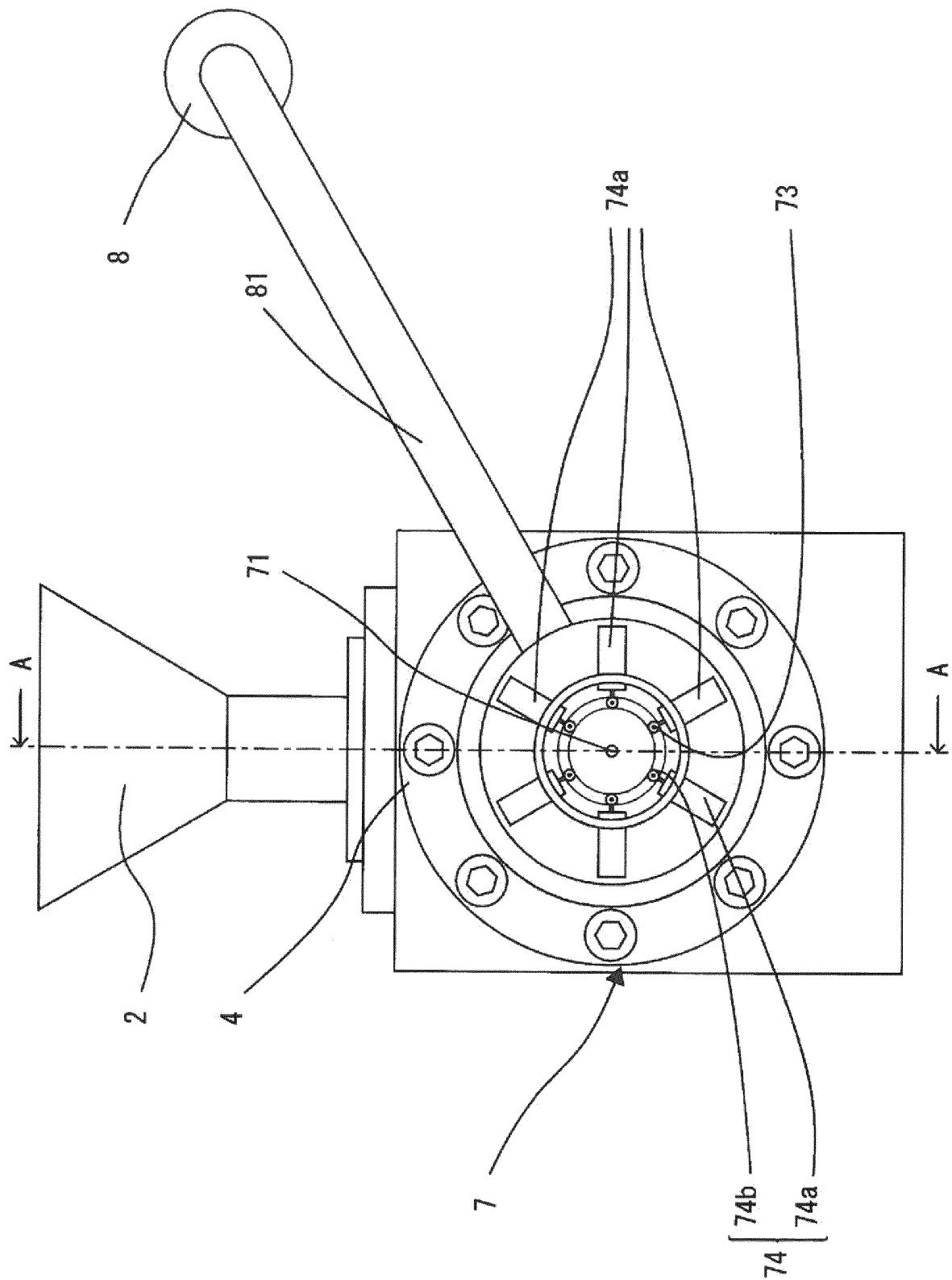


Fig. 3

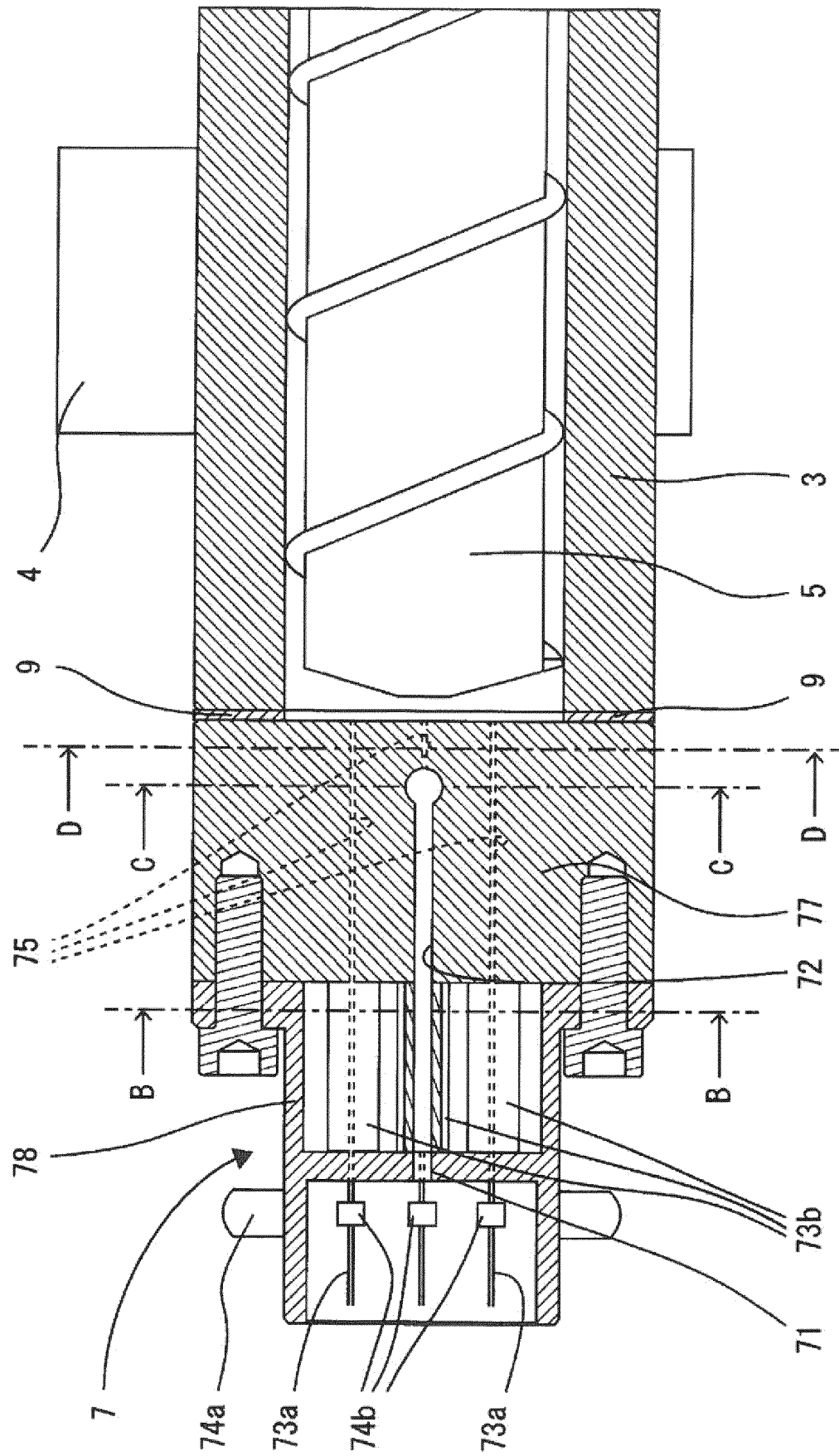


Fig. 4

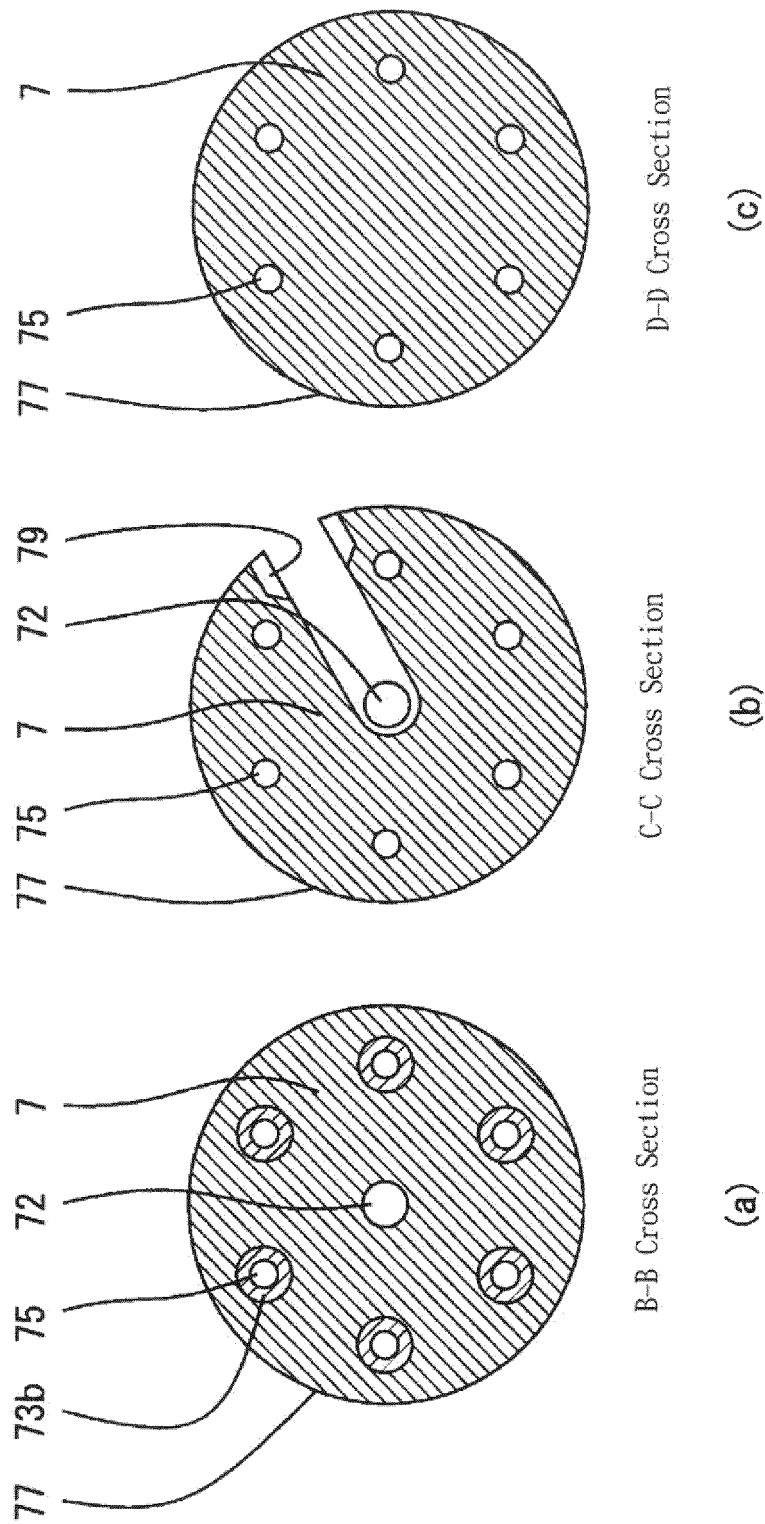


Fig. 5

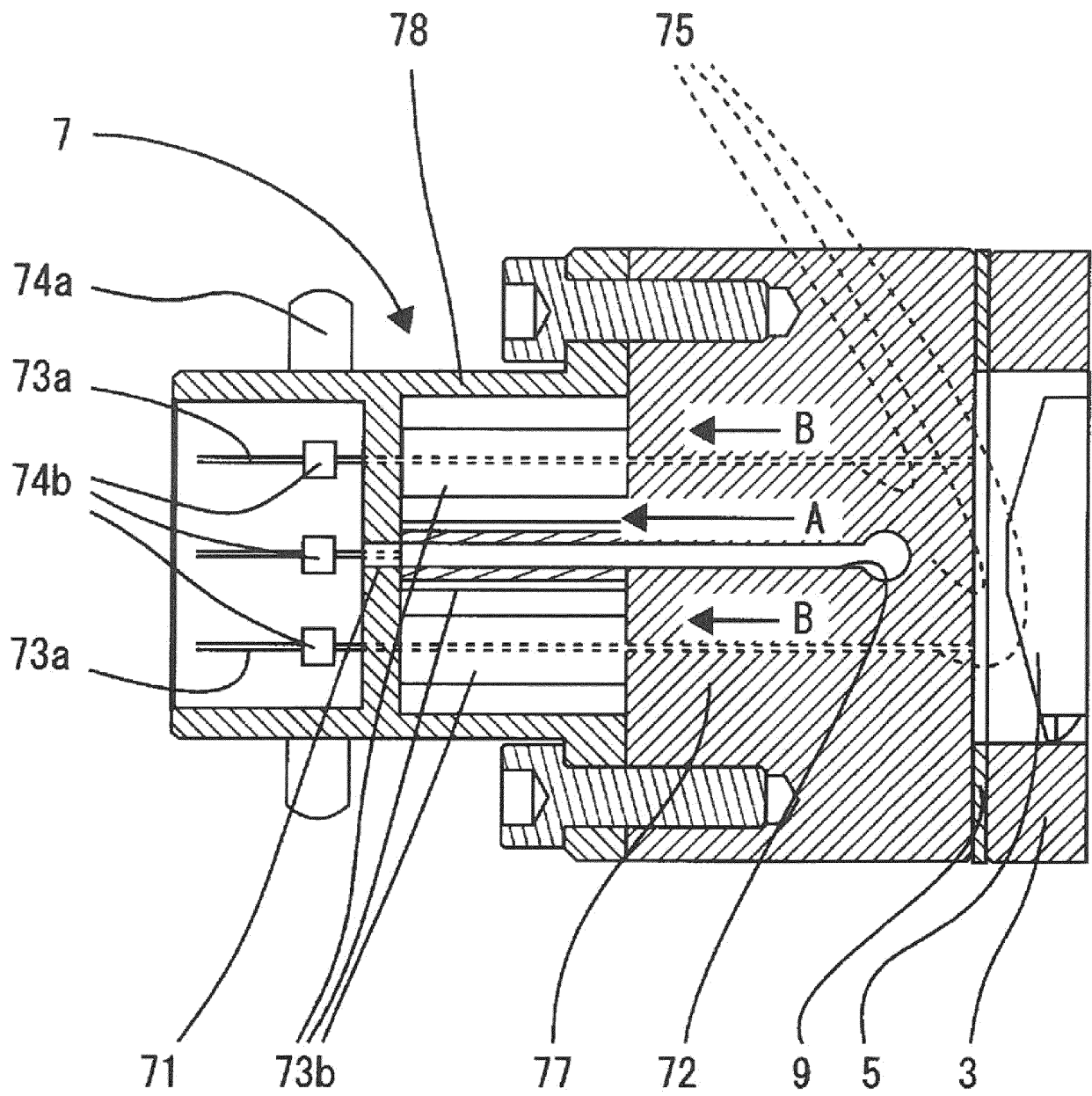
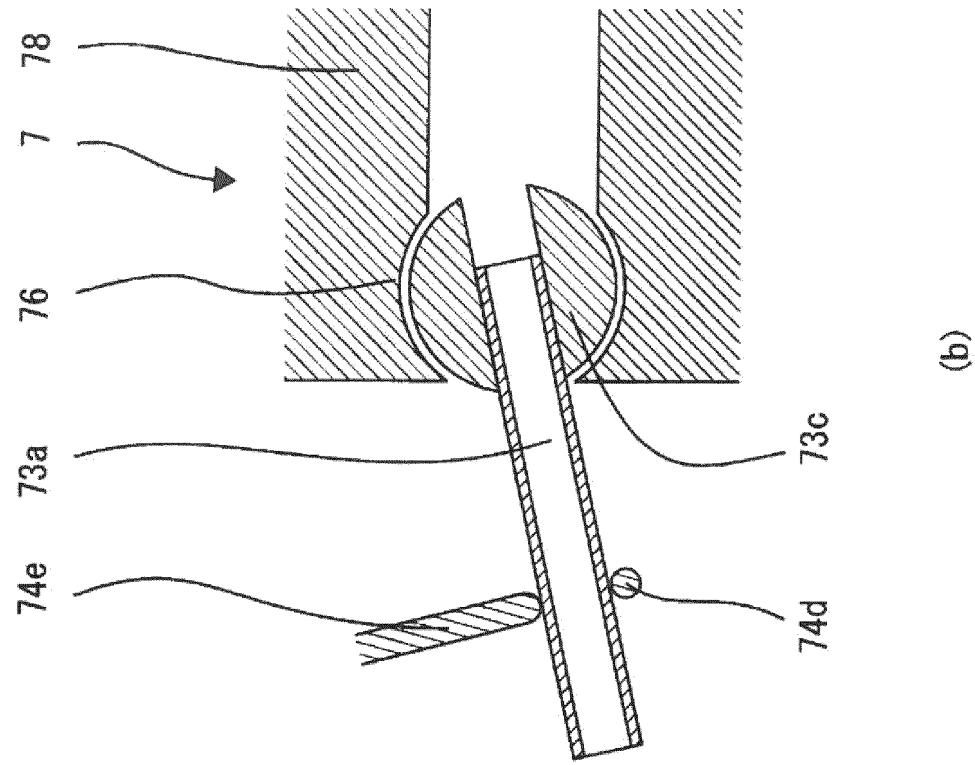
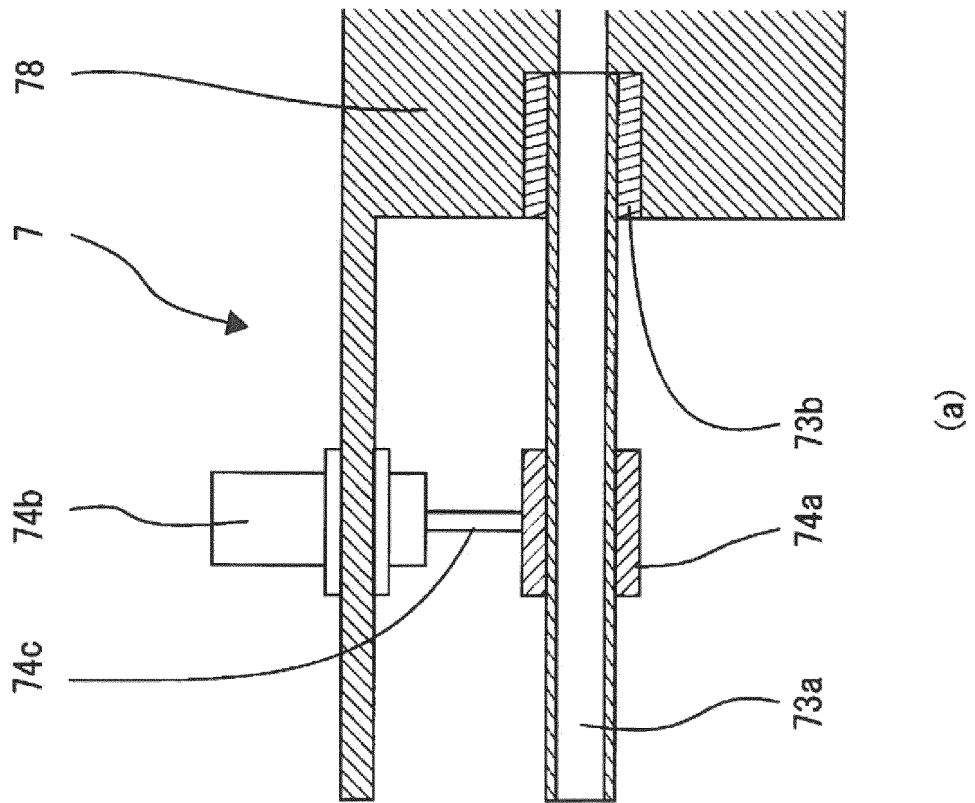


Fig. 6



(b)



(a)

Fig. 7

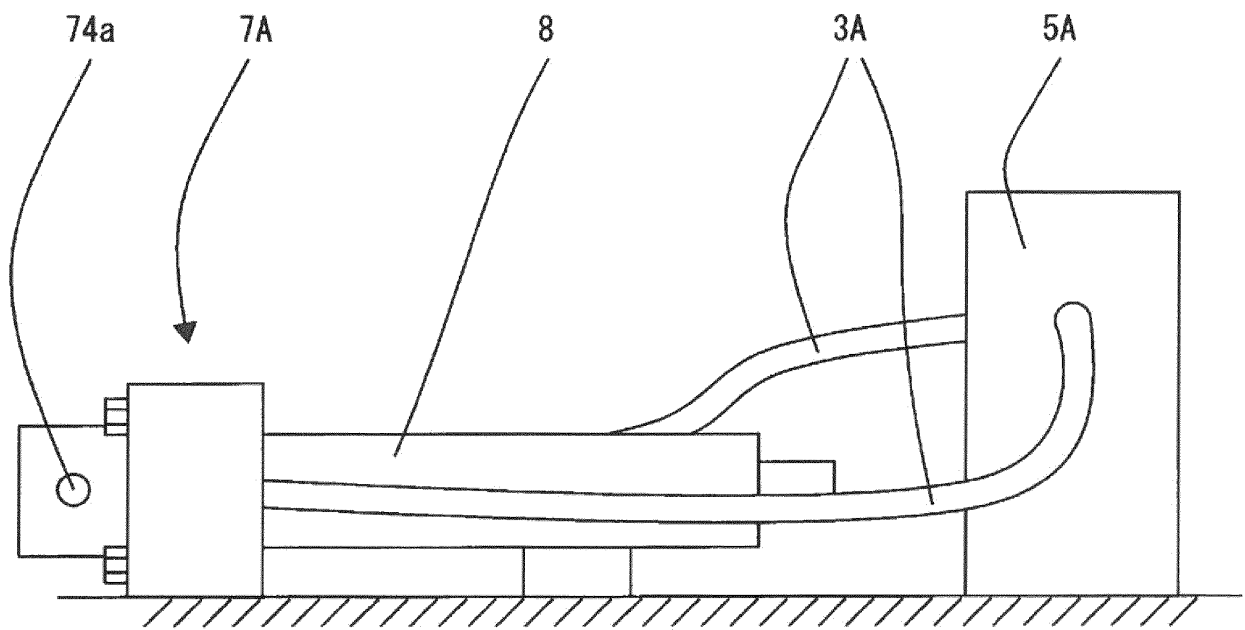


Fig. 8

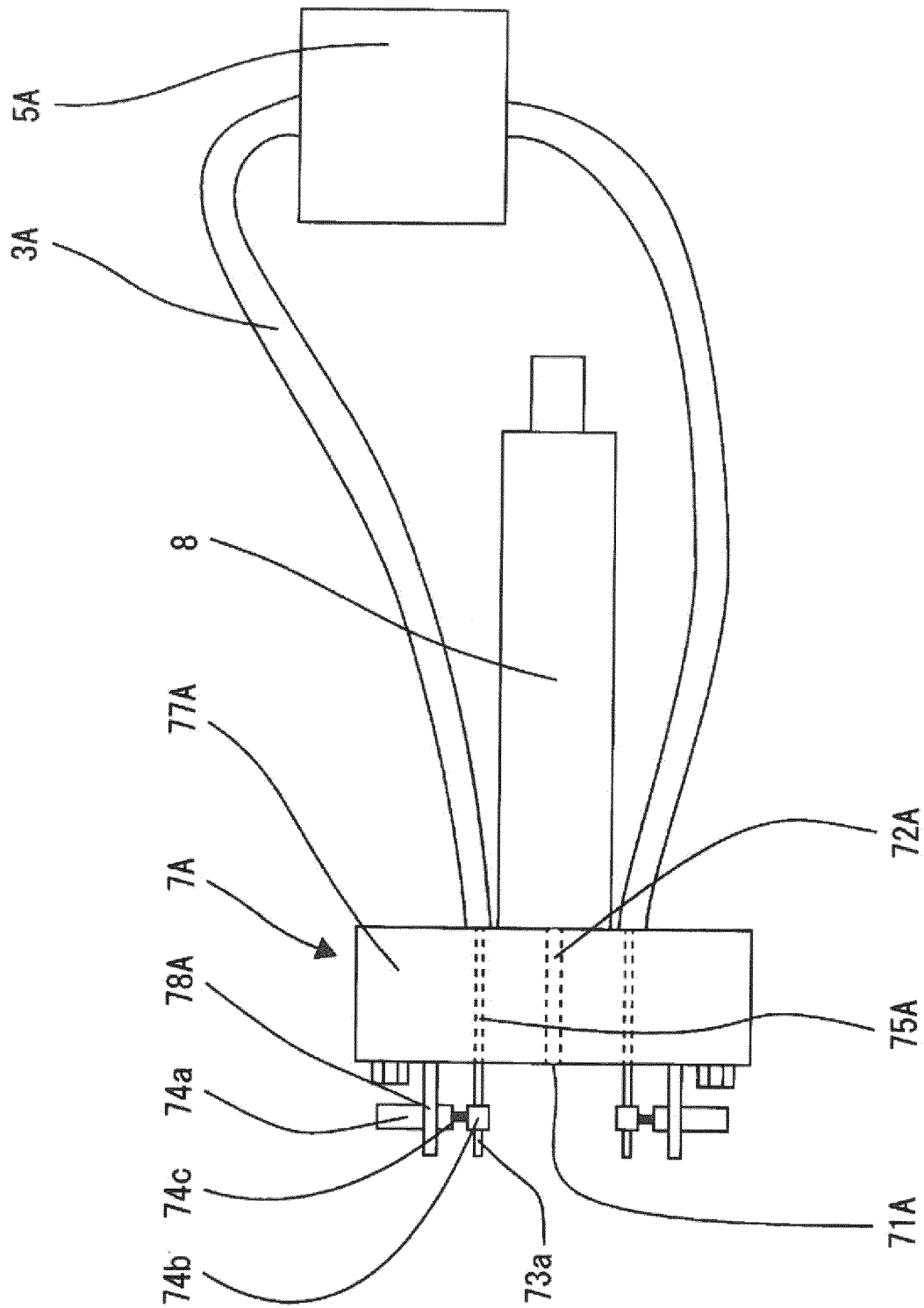


Fig. 9

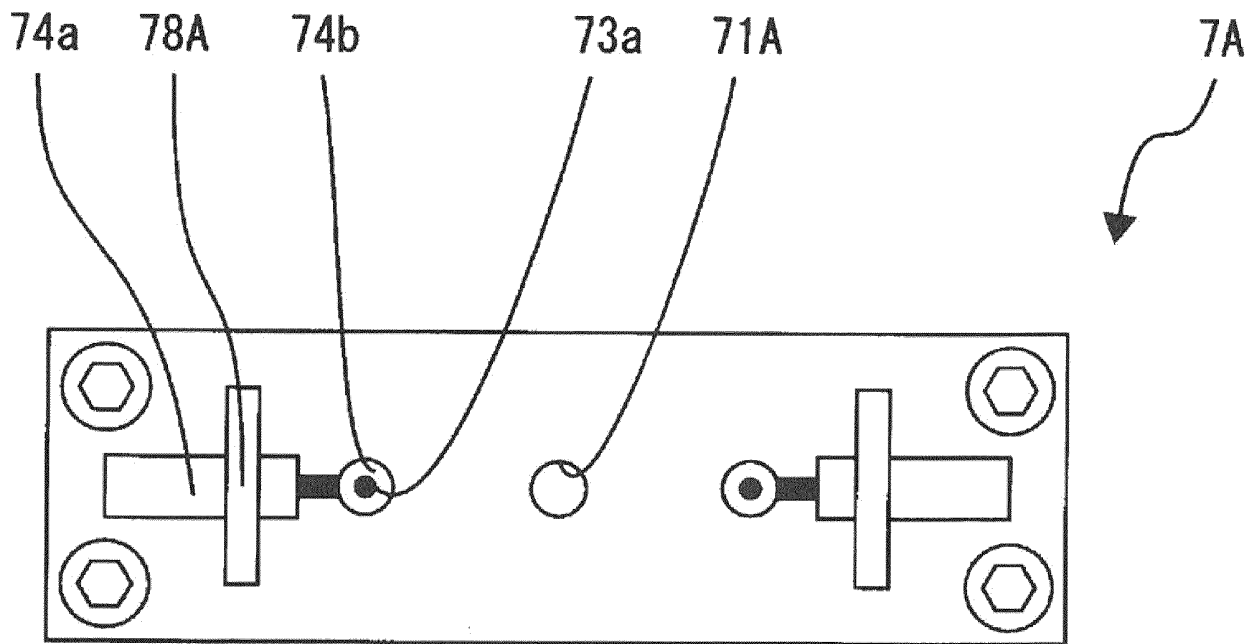


Fig. 10

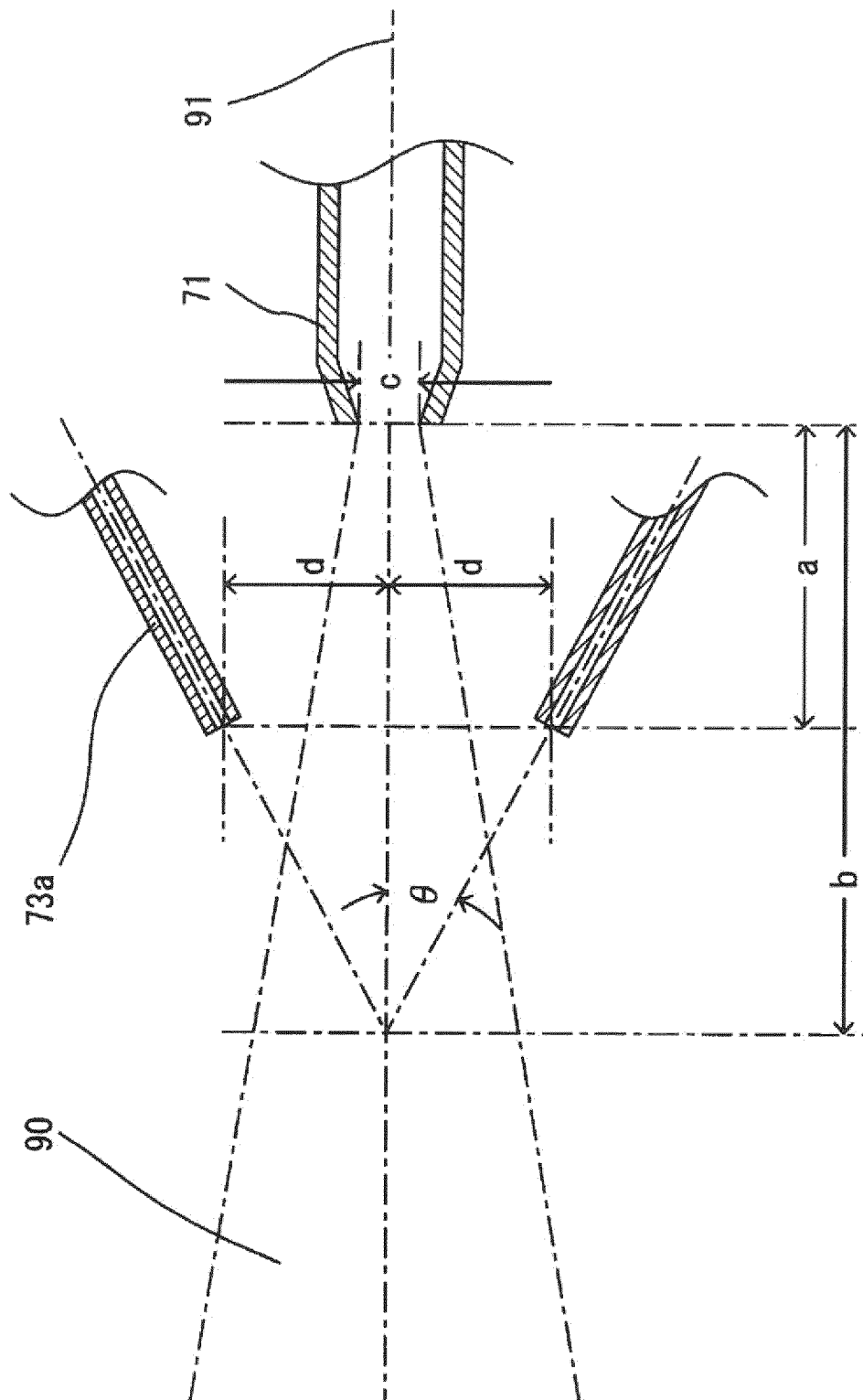


Fig. 11

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/059462

A. CLASSIFICATION OF SUBJECT MATTER

D01D5/08(2006.01)i, D04H3/16(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

D01D1/00-13/02, D04H1/00-18/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2016

Kokai Jitsuyo Shinan Koho 1971-2016 Toroku Jitsuyo Shinan Koho 1994-2016

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

JSTPlus/JST7580/JSTChina(JDreamIII), Japio-GPG/FX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 61-113809 A (Kimberly-Clark Corp.), 31 May 1986 (31.05.1986), claims; each figure; page 6; page 10, lower left column & EP 173333 A2 claims; each figure; pages 5 to 7, 17 & DE 3582908 D & KR 10-1992-0008961 B	1-10
X	JP 2012-112077 A (Japan Vilene Co., Ltd.), 14 June 2012 (14.06.2012), claims; each figure; 0042, 0053, 0142, 0145 to 0146 (Family: none)	1-4, 6-8, 10

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

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document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"

document member of the same patent family

Date of the actual completion of the international search

19 August 2016 (19.08.16)

Date of mailing of the international search report

30 August 2016 (30.08.16)

Name and mailing address of the ISA/

Japan Patent Office

3-4-3, Kasumigaseki, Chiyoda-ku,

Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/059462

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, X	WO 2015/145880 A1 (Mitsuhiro TAKAHASHI), 01 October 2015 (01.10.2015), 0037 to 0043, 0102 to 0103; fig. 2, 12 (Family: none)	1-10
P, X	WO 2016/013051 A1 (Zepto Co., Ltd.), 28 January 2016 (28.01.2016), claims; 0043 to 0044; each figure (Family: none)	1-4, 6-8, 10
A	JP 2013-503979 A (3M Innovative Properties Co.), 04 February 2013 (04.02.2013), & WO 2011/028661 A2 & CN 102482799 A & KR 10-2012-0076348 A	1-10
A	JP 2005-515316 A (The University of Akron), 26 May 2005 (26.05.2005), & WO 2003/062510 A1 & DE 60328581 D & CN 1643190 A	1-10

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REFERENCES CITED IN THE DESCRIPTION

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- JP 2010185153 A [0005]