

SPECIFICATION

Title of Invention

Apparatus for producing nanofiber and nozzle head used for the same

Technical Field

[0001]

The present invention relates to an apparatus for producing nanofibers and a nozzle head used for the same.

Background of the Invention

[0002]

A conventional apparatus for producing nonwoven fabrics is disclosed in Patent Document 1. This apparatus for producing nonwoven fabrics comprises, as shown in Fig. 40, an extruder 915 for extruding molten resin, a blower 916 and a heating unit 917 for heating an air from the blower 916. The apparatus for producing nonwoven fabrics comprises a melt blow unit 911 for filamentously spinning the molten resin from the extruder 915, and for spraying hot blast provided from the heating unit 917 to the filamentous molten resin.

[0003]

This melt blow unit 911 is provided a resin passage 912 for flowing the molten resin, and hot blast passages 913a and 913b. These hot blast passages 913a and 913b are provided on each side of the resin passage 912 with inclination toward the resin passage 912. The hot blast from the hot blast passages 913a and 913b is sprayed to the molten resin spun from the resin passage 912 thereby.

Description of Prior Art

Patent Literature

[0004]

Patent Literature 1: JP2010-185153A

Summary of Invention

Problems to be solved by the Invention

[0005]

In the above-mentioned apparatus for producing nonwoven fabrics, however, the hot blast passages 913a and 913b of the hot blast passage 913 is formed with inclination toward a lower surface 911a. When the hot blast passages 913a and 913b are formed by a drill, the drill is obliquely contacted the lower surface 911a. Therefore, a top of the drill may slip on the lower surface 911a, and it is difficult to form the hot blast passages 913a and 913b precisely. In

order to ensure the precision, it has been necessary to use electrochemical machining having a high cost.

[0006]

The present invention was made in consideration of the above problems, and an object of the present invention is to provide an apparatus for producing nanofibers and a nozzle head use for the same which can manufacture by drilling and efficiently carry molten resin on a gas flow.

Means for Solving the Problems

[0007]

According to the present invention, there is provided an apparatus for producing nanofibers comprising a raw material discharge surface on which a raw material flow passage for discharging a liquid raw material is arranged, and a gas discharge surface which is arranged with an angle α ($0 < \alpha \leq 90^\circ$) toward said raw material discharge surface and on which a gas flow passage for ejecting gas is arranged, wherein said raw material flow passage is orthogonal to said raw material discharge surface, said gas flow passage is orthogonal to said gas discharge surface, and said raw material flow passage and said gas flow passage are arranged so that said liquid raw material discharged from said raw material flow passage meets gas ejected from said gas flow passage.

[0008]

According to the present invention, there is provided an apparatus for producing nanofibers comprising a raw material discharge surface on which a raw material flow passage for discharging a liquid raw material is arranged, a gas discharge surface which is arranged downwardly from said raw material discharge surface and on which a gas flow passage for ejecting gas is arranged, a connecting surface which is connected with said raw material discharge surface and said gas discharge surface, and is arranged with an angle β ($0 \leq \beta < 90^\circ$) toward said raw material discharge surface, wherein said raw material flow passage is orthogonal to said raw material discharge surface, said gas flow passage is orthogonal to said gas discharge surface, an opening of said gas flow passage contacts with said connecting surface, and said raw material flow passage and said gas flow passage are arranged so that said liquid raw material discharged from said raw material flow passage reaches to the opening of said gas flow passage along said connecting surface.

[0009]

According to the present invention, there is provided a nozzle head used for an apparatus for producing nanofibers comprising: a raw material discharge surface on which a raw material flow passage for discharging a liquid raw

material is arranged, and a gas discharge surface which is arranged with an angle α ($0 < \alpha \leq 90^\circ$) toward said raw material discharge surface and on which a gas flow passage for ejecting gas is arranged, wherein said raw material flow passage is orthogonal to said raw material discharge surface, said gas flow passage is orthogonal to said gas discharge surface, and said raw material flow passage and said gas flow passage are arranged so that said liquid raw material discharged from said raw material flow passage meets gas ejected from said gas flow passage.

[0010]

According to the present invention, there is provided a nozzle head used for an apparatus for producing nanofibers comprising: a raw material discharge surface on which a raw material flow passage for discharging a liquid raw material is arranged, a gas discharge surface which is arranged downwardly from said raw material discharge surface, and on which a gas flow passage for ejecting gas is arranged, a connecting surface which is connected with said raw material discharge surface and said gas discharge surface, and is arranged with an angle β ($0 \leq \beta < 90^\circ$) toward said raw material discharge surface, wherein said raw material flow passage is orthogonal to said raw material discharge surface, said gas flow passage is orthogonal to said gas discharge surface, an opening of said gas flow passage contacts with said connecting surface, and said raw material flow passage and said gas flow passage are arranged so that said liquid raw material discharged from said raw material flow passage reaches to the opening of said gas flow passage along said connecting surface.

Effect of the Invention

[0011]

According to the present invention, a raw material flow passage is formed so as to be orthogonal to a raw material discharge surface, and a gas flow passage is formed so as to be orthogonal to a gas discharge surface. Therefore, the raw material flow passage is formed on the raw material discharge surface by drilling and the gas flow passage is formed on the gas discharge surface. It becomes possible to join directly or indirectly with an angle the liquid raw material discharged from the raw material flow passage to a gas flow ejected from the gas flow passage through a connecting surface connected to the raw material discharge surface and the gas discharge surface. It can be achieved to manufacture precisely by drilling and to carry efficiently the liquid raw material on the gas flow.

BRIEF DESCRIPTION OF DRAWINGS

[0012]

Fig. 1 shows an entire structure of an apparatus for producing nanofibers

according to a first embodiment of the present invention.

Fig. 2 is a perspective view showing a nozzle head of the apparatus for producing nanofibers of Fig. 1.

Fig. 3 is an explanatory diagram showing the nozzle head of Fig. 2.

Fig. 4 is an explanatory diagram showing a structure of a variation 1 of the nozzle head of Fig .2.

Fig. 5 is an explanatory diagram showing a structure of a variation 2 of the nozzle head of Fig .2.

Fig. 6 is an explanatory diagram showing a structure of a variation 3 of the nozzle head of Fig .2.

Fig. 7 is an explanatory diagram showing a structure of a variation 4 of the nozzle head of Fig .2.

Fig. 8 is an explanatory diagram showing a structure of a variation 5 of the nozzle head of Fig .2.

Fig. 9 is an explanatory diagram showing a structure of a variation 6 of the nozzle head of Fig .2.

Fig. 10 is an explanatory diagram showing a structure of a variation 7 of the nozzle head of Fig .2.

Fig. 11 is a perspective view showing a structure of a variation 8 of the nozzle head of Fig .2.

Fig. 12 is an explanatory diagram showing a structure of the variation 8 of the nozzle head of Fig .2.

Fig. 13 is a perspective view showing a variation 9 of the nozzle head of Fig .2.

Fig. 14 is an explanatory diagram showing a structure of the variation 9 of the nozzle head of Fig .2.

Fig. 15 is a perspective view showing a variation 10 of the nozzle head of Fig .2.

Fig. 16 is an explanatory diagram showing a structure of the variation 10 of the nozzle head of Fig .2.

Fig. 17 is a perspective view showing a variation 11 of the nozzle head of Fig .2.

Fig. 18 is an explanatory diagram showing a structure of the variation 11 of the nozzle head of Fig .2.

Fig. 19 is a perspective view showing a variation 12 of the nozzle head of Fig .2.

Fig. 20 is an explanatory diagram showing a structure of the variation 12 of the nozzle head of Fig. 2.

Fig. 21 is an explanatory diagram showing a structure of the variation 12 of the nozzle head of Fig. 2.

Fig. 22 is a perspective view showing a variation 13 of the nozzle head of Fig. 2.

Fig. 23 is an explanatory diagram showing a structure of the variation 13 of

the nozzle head of Fig. 2.

Fig. 24 is an explanatory diagram showing a structure of the variation 13 of the nozzle head of Fig. 2.

Fig. 25 is a perspective view showing a variation 14 of the nozzle head of Fig. 2.

Fig. 26 is a perspective view showing a variation 15 of the nozzle head of Fig. 2.

Fig. 27 is an explanatory diagram showing the nozzle head of the apparatus for producing nanofibers according to a second embodiment of the present invention.

Fig. 28 is a perspective view showing the apparatus for producing nanofibers according to a third embodiment of the present invention.

Fig. 29 is a cross sectional view showing the apparatus for producing nanofibers of Fig. 28.

Fig. 30 is an explanatory diagram showing the nozzle head of the apparatus for producing nanofibers of Fig. 28.

Fig. 31 is an explanatory diagram showing a structure of the variation 1 of the nozzle head of Fig. 30.

Fig. 32 is an explanatory diagram showing a structure of the variation 2 of the nozzle head of Fig. 30.

Fig. 33 is an explanatory diagram showing a structure of the variation 3 of the nozzle head of Fig. 30.

Fig. 34 is an explanatory diagram showing a structure of the variation 4 of the nozzle head of Fig. 30.

Fig. 35 is an explanatory diagram showing a structure of the variation 5 of the nozzle head of Fig. 30.

Fig. 36 is an explanatory diagram showing a structure of the variation 6 of the nozzle head of Fig. 30.

Fig. 37 is an explanatory diagram showing a structure of the variation 7 of the nozzle head of Fig. 30.

Fig. 38 is an explanatory diagram showing a structure of the variation 8 of the nozzle head of Fig. 30.

Fig. 39 is an explanatory diagram illustrating a basic concept of the present invention.

Fig. 40 is an explanatory diagram showing a structure of a conventional apparatus for producing nonwoven fabrics.

Detailed Description of Preferred embodiments

[0013]

The preferred embodiment of the present invention will be described hereinafter. The present invention is 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.

[0014]

According to the present invention, nanofibers are formed by supplying a liquid raw material to gas ejected under relatively high pressure. In the description, a term "gas" without specifying composition means gases consisting of any composition and a molecular structure. Additionally, in the description, a term "raw material" means all of materials applicable for forming the nanofibers. In the embodiments hereinafter, an explanation will be made for an example using synthetic resin as the "raw material", but not limited to, various kinds of composition material will be usable.

[0015]

A term "liquid raw material" in the description does not limit property of the material to liquid. The "liquid raw material", for example, includes "solvent" which is prepared by dissolving in advance a solid raw material or a liquid raw material as a solute in a predetermined solvent so that a predetermined concentration is obtained. Additionally, "liquid raw material" also includes "molten raw material" which the solid raw material is molten. In short, the "liquid raw material" of the present invention needs property having viscosity enough to supply (eject, discharge) "raw material" from supply holes (ejection holes, discharge holes), and the "raw material" having such liquid property is described as "liquid raw material" in the present invention.

[0016]

A basic concept of the present invention is, as shown in (I) Fig. 39(a) is to comprise a raw material discharge surface 22, a gas discharge surface 23, a raw material flow passage 24 for discharging the liquid raw material which is formed so as to be orthogonal to the raw material discharge surface 22, and a gas flow passage 26 for discharging the gas which is formed so as to be orthogonal to the gas discharge surface 23. The raw material discharge surface 22 and the gas discharge surface 23 are arranged with an angle α ($0 < \alpha \leq 90^\circ$), and an axis line P of the raw material flow passage 25 and an axis line Q of the gas flow passage 26 are intersected with the angle α .

[0017]

Additionally, as shown in (II) Fig. 39 (b), a basic concept of the present invention is to comprise the raw material discharge surface 22, the gas discharge surface 23, the raw material flow passage 25 which is formed so as to be orthogonal to the raw material discharge surface

22 and from which the liquid raw material is discharged, the gas flow passage 26 which is formed so as to be orthogonal to the gas discharge surface 23 and from which the gas is discharged, and a connecting surface 24 connected with the raw material discharge surface 22 and the gas discharge surface 23. The gas discharge surface 23 and the connecting surface 24 are arranged with an angle β ($0 \leq \beta < 90^\circ$), and a surface direction R of the connecting surface 24 and the axis line Q of the gas flow passage 26 are intersected with the angle α ($\alpha = 90^\circ - \beta$).

[0018]

Accordingly, the liquid raw material discharged from the raw material flow passage 25 is directly as shown in Fig. 39(a), or indirectly as shown in Fig. 39(b) meets the gas flow discharged from the gas flow passage 26 with the angle α through the connecting surface 24 connected with the raw material discharge surface 22 and the gas discharge surface 23.

[0019]

In Fig. 39(a), positional relationship of each component is as follows. If the gas discharge surface 23 which the gas flow passage 26 is formed is considered as a reference position, "distance a" represents a distance to the raw material flow passage 25, and "distance b" represents a distance to an meeting point of the liquid raw material from the raw material flow passage 25. "Distance c" represents an opening diameter of the gas flow passage 26, and "distance d" represents a distance orthogonal to the axis line Q between the raw material flow passage 25 and the gas flow passage 26. The same can be said about Fig. 39(b) (provided that $a = 0$).

[0020]

Herein, the axis line P of the raw material flow passage 25 has an angle α against the axis line Q of the gas flow passage 26. The raw material supply tangent angle α is obtained from the following Equation

$$\tan \alpha = d/(b-a)$$

wherein $0 \leq \alpha < 90^\circ$

[0021]

The raw material supply tangent angle α should be determined by the distance "a", the distance "b", and the distance "d", and moreover, should be determined by relation among the opening diameter "c" of the high-pressure gas, pressure and temperature of the ejected gas the gas flow passage 26.

[0022]

Regarding an arrangement condition of the raw material flow passage 25 and the gas flow passage 26, it is also capable of forming

nanofibers having an ununiformed diameter or fiber length by changing the number of passages, an arrangement interval, an arrangement distance (distance "a" from the gas ejection hole), an arrangement angle (angle α), and a diameter of the flow passage. According to types of the produced nanofibers, the arrangement condition of the raw material flow passage 25 and the gas flow passage 26 may be appropriately selected and changed.

[0023]

(First Embodiment)

Hereinafter, an apparatus for producing nanofibers according to a first embodiment of the present invention will be described referring to Figs. 1 to 26.

[0024]

Fig. 1 is a diagram showing an entire structure of the apparatus for producing nanofibers according to the first embodiment of the present invention. (a) is a side view, and (b) is a plan view. Fig. 2 is a perspective view showing a nozzle head of the apparatus for producing nanofibers of Fig. 1. Fig. 3 is an explanatory diagram showing the nozzle head of the first embodiment. (a) is a front view, (b) is a cross sectional view taken along the line A-A', and (c) is a cross sectional view taken along the line B-B'. Figs. 4 to 26 show explanatory diagrams of structures of variations 1 to 15 of the nozzle head showing a basic structure in Fig. 2 and in each figure, show a perspective view (including an exploded perspective view), or a front view and a cross sectional view as show in Figs. 2 and 3. Hereinafter, terms representing "front, back, left, right, up and down" may be used, which show a relative positional relationship of each component, not an absolute relationship unless otherwise explicitly. In each figure, a component having same function has a same reference number and the detailed explanation will be omitted.

[0025]

The apparatus for producing nanofibers 1 of the first embodiment uses a solvent which is prepared by dissolving in advance a solid raw material or a liquid raw material as a solute in a predetermined solvent so that a predetermined concentration is obtained.

[0026]

As shown in Fig. 1, the apparatus for producing nanofibers 1 comprises a rectangular flat-shaped base 10, a solvent storage 11 which is disposed on the base 10 and has function for extruding the solvent with the predetermined pressure, a hose 12 for supplying the solvent from the solvent storage 12 to a

nozzle head 20 described later, a gas ejection unit 13 which is disposed on the base 10 and ejects high-pressure gas and the nozzle head 20 connected to a top of the gas ejection unit 13. When temperature control is provided to the solvent in accordance with manufacturing conditions, a temperature control function (not illustrated), such as a heater may be provided in each of the solvent storage 11, the hose 12 and the nozzle head 20. In the present embodiments, the solvent storage 11, the hose 12 and the nozzle head 20 which are made of metal are used, however, they may be made of resin, glass and other materials in accordance with types of the solvent and condition of nanofiber products.

[0027]

As shown in Figs. 2 and 3, the nozzle head 20 has an approximately rectangular shape, and comprises a front surface 21 facing in a front side (left side of Fig. 1), a raw material discharge surface 22, and a gas discharge surface 23 which are connected in order in a downward direction. The front surface 21 and the gas discharge surface 23 are arranged in parallel each other, and the gas discharge surface 23 is arranged backwardly with a distance t away from the front surface 21. The raw material discharge surface 22 and the gas discharge surface 23 are arranged with an angle of α ($0 < \alpha \leq 90^\circ$), and the raw material discharge surface 22 faces an oblique downward direction. The nozzle head 20 is provided with a back surface 27 which is parallel with the front surface 21 and faces backwardly.

[0028]

The nozzle head 20 comprises the raw material flow passage 25 orthogonal to the raw material discharge surface 22, and the gas flow passage 26 orthogonal to the gas discharge surface 23. The raw material flow passage 25 is communicated with a raw material supply passage 28 orthogonal to the back surface 27 in the nozzle head 20. The gas flow passage 26 is provided so as to linearly penetrate the gas discharge surface 23 and the back surface 27.

[0029]

In the present embodiments, the raw material flow passage 25 has a cylindrical space (every cross sectional orthogonal to the axis line has the same circular shape), and the gas flow passage 26 also has the cylindrical space. The raw material discharge surface 22 has a width (a length in up and down direction of Fig. 3) larger than a diameter of the raw material flow passage 25 (about twice of the diameter), and the raw material flow passage 25 is arranged at a center area in a width direction. The gas flow passage 26 is arranged with an interval from the raw material discharge surface 22. An axis line P of the raw

material flow passage 25 and an axis line Q of the gas flow passage 26 are provided so as to be on a plane and the axis line P and the axis line Q are intersected at a point in front of the nozzle head 20 with an angle α .

[0030]

An opening on the back surface 27 of the raw material supply passage 28 is connected with a hose 12, and a solvent provided from a solvent storage 11 is passed through the hose 12, the raw material supply passage 28 and the raw material flow passage 25, and discharged from the opening of the raw material flow passage 25 on the raw material discharge surface 22.

[0031]

The opening on the back surface 27 of the gas flow passage 26 is connected with the gas ejection unit 13, and high-pressure gas supplied from the gas ejection unit 13 is passed through the gas flow passage 26 and discharged from the opening of the gas flow passage 26 on the gas discharge surface 23.

[0032]

The such structure is only an example, and if there are provided the raw material flow passage 25 and the gas flow passage 26 orthogonal to the raw material discharge surface 22 and the gas discharge surface 23 which are arranged with an angle α ($0 < \alpha \leq 90^\circ$), respectively, the structure may be optional within a purpose of the present invention. In the present embodiment, the nozzle head 20 is directly connected with the hose 12 and the gas ejection unit 13. For example, however, a manifold block connected with the hose 12 and the gas ejection unit 13 may be provided on a side of the back surface 27 of the nozzle head 20. In such structure, the nozzle head 20 may be detachable to the manifold block, and the raw material and gas may be supplied to the nozzle head 20 from the hose 12 and the gas ejection unit 13 through the manifold block.

[0033]

A description will be made of operation of the apparatus for producing nanofibers 1 and the nozzle head 20 according the present embodiments. The apparatus for producing nanofibers 1 is supplied with the solvent from the solvent storage 11 and discharges from the opening of the raw material flow passage 25 on the raw material discharge surface 22. The apparatus for producing nanofibers 1 is supplied with the high-pressure gas from the gas ejection unit 13 and ejects the same from the opening of the gas flow passage 26 on the

gas discharge surface 23. The solvent discharged from the raw material flow passage 25 meets the gas flow ejected from the gas flow passage 26 with the angle α and is carried out in the front direction while being elongated, so that the nanofibers are manufactured.

[0034]

According to the apparatus for producing nanofibers 1 and the nozzle head 20 of the above-mentioned embodiment, the raw material flow passage 25 is arranged so as to be orthogonal to the raw material discharge surface 22, and the gas flow passage 26 is arranged so as to be orthogonal to the gas discharge surface 23. Thereby, by drilling, the raw material flow passage 25 can be formed on the raw material discharge surface 22, and the gas flow passage 26 can be formed on the gas discharge surface 23. The solvent discharged from the raw material flow passage 25 directly meets the gas flow ejected from the gas flow passage 26 with the angle α .

It can be achieved to manufacture precisely by drilling and to carry efficiently the solvent on the gas flow.

[0035]

The apparatus for producing nanofibers 1 of the present embodiment is capable of establishing the structure without using a complicated device, such as a heating cylinder, a motor, a screw and so on because the solvent which is prepared by dissolving the raw material in the solvent. Therefore, size of the apparatus becomes small and mounting space is saved. The structure of the apparatus becomes compact, so that it may be achieved to realize a portable the apparatus for producing nanofiber. The portable-type apparatus for producing nanofibers is configured to spray nanofibers toward a place where the nanofibers should be adhered and the nanofibers are formed. Use of the nanofibers may be expanded by using such portable-type apparatus.

[0036]

(Variation 1 of the first embodiment)

Fig. 4 shows a variation 1 of the nozzle head 20 of the above-mentioned apparatus for producing nanofibers 1 (hereinafter referred to as a basic structure of the nozzle head 20). The nozzle head 20A of the variation 1 is configured so that a width of the raw material discharge surface 22 (a length in an up and down direction of Fig. 4) becomes same as a diameter of the raw material flow passage 25. Other structure of the nozzle head 20A of the variation 1 is the same as a basic structure of the nozzle head 20.

[0037]

Variation 2 of the first embodiment

Fig. 5 shows a variation 2 of the nozzle head 20 of the above-mentioned apparatus for producing nanofibers 1. The nozzle head 20B of the variation 2 is configured so that a width of the raw material discharge surface 22 (a length in an up and down direction of Fig. 5) is larger than the diameter of the raw material flow passage 25 (about three times of the diameter), and a part of the gas flow passage 26 is arranged so as to contact with the raw material discharge surface 22. Other structure of the nozzle head 20B of the variation 2 is the same as the basic structure of the nozzle head 20.

[0038]

Variation 3 of the first embodiment

Fig. 6 shows a variation 3 of the nozzle head 20 of the above-mentioned apparatus for producing nanofibers 1. The nozzle head 20C of the variation 3 is configured so that a width of the raw material discharge surface 22 (a length in an up and down direction of Fig. 6) becomes same as the diameter of the raw material flow passage 25, and a part of the gas flow passage 26 is arranged so as to contact with the raw material discharge surface 22. Thereby, the raw material flow passage 25 and the gas flow passage 26 are contact with each other. Other structure of the nozzle head 20C of the variation 3 is the same as the basic structure of the nozzle head 20.

[0039]

Variation 4 of the first embodiment

Fig. 7 shows a variation 4 of the nozzle head 20 of the above-mentioned apparatus for producing nanofibers 1. The nozzle head 20D of the variation 4 is configured so that the raw material flow passage 25 has a space in a square column shape which a cross section is rectangular. Other structure of the nozzle head 20D of the variation 4 is the same as the basic structure of the nozzle head 20.

[0040]

Variation 5 of the first embodiment

Fig. 8 shows a variation 5 of the nozzle head 20 of the above-mentioned apparatus for producing nanofibers 1. The nozzle head 20E of the variation 5 is configured so that the gas flow passage 26 has a space in a square column shape which a cross section is rectangular. Other structure of the nozzle head 20E of the variation 5 is the same as the basic structure of the nozzle head 20.

[0041]

Variation 6 of the first embodiment

Fig. 9 shows a variation 6 of the nozzle head 20 of the above-mentioned apparatus for producing nanofibers 1. The nozzle head 20F of the variation 6 is configured so that the raw material flow passage 25 has a space in a square column shape which a cross section is rectangular and the gas flow passage 26 also has a space in a square column shape which a cross section is rectangular. Other structure of the nozzle head 20F of the variation 6 is the same as the basic structure of the nozzle head 20.

[0042]

(Variation 7 of the first embodiment)

Fig. 10 shows a variation 7 of the nozzle head 20 of the above-mentioned apparatus for producing nanofibers 1. The nozzle head 20G of the variation 7 is configured so that a shape is rectangular parallelepiped, the front surface 21 is not provided at a front side of the nozzle head 20, and the gas discharge surface 23 facing the front side (a front side of a paper of Fig. 10(a), left side of (b) and (c)) is provided at the entire front side. The gas flow passage 26 is arranged so as to be orthogonal to the gas discharge surface 23, and the raw material discharge surface 22 arranged at the angle α toward the gas discharge surface 23 in the gas flow passage 26. The gas flow passage 26 has a space of column by cutting away a part of a cylinder taken along a chord. The nozzle head 20G of the variation 7 is configured so that a width of the raw material discharge surface 22 (a length in an up and down direction of Fig. 10(a)) becomes same as the diameter of the raw material flow passage 25. Other structure of the nozzle head 20G of the variation 7 is the same as the basic structure of the nozzle head 20.

[0043]

(Variation 8 of the first embodiment)

Figs. 11 and 12 show a variation 8 of the nozzle head 20 of the above-mentioned apparatus for producing nanofibers 1. In a nozzle head 20H of the variation 8, there are shown as a separate body a portion of the front surface 21, the raw material discharge surface 22 (a first portion 20a), and another portion of the gas discharge surface 23 (a second portion 20b). These two portions may be connected detachably with a connection means, such as a belt and a screw not illustrated.

[0044]

The first portion 20a of the nozzle head 20H of the variation 8 is a rectangular parallelepiped which a one side is chamfered, the front surface 21 and the raw material discharge surface 22 (corresponding to the chamfered portion) are connected in order in the downward direction, and the raw material flow passage 25 is provided orthogonally to the raw material discharge surface 22. The second portion 20b is a rectangular parallelepiped, the gas discharge surface 23 is provided at the entire front surface, and the gas flow passage 26 is provided orthogonally to the gas discharge surface 23. When the first portion 20a and the second portion 20b are connected, the raw material discharge surface 22 and the gas discharge surface 23 are arranged with the angle α . The nozzle head 20H of the variation 8 has a structure which the first portion 20a and the second portion 20b are detachable, and has the same structure of the basic structure of the nozzle head 20 when these portions are not connected.

[0045]

(Variation 9 of the first embodiment)

Figs. 13 and 14 show a variation 9 of the nozzle head 20 of the above-mentioned apparatus for producing nanofibers 1. In a nozzle head 20I of the variation 9, the second portion 20b has the same structure as that of the nozzle head 20H of the variation 8, the raw material discharge surface 22 and the gas discharge surface 23 are made an angled' when the first portion 20a and the second portion 20b are connected so as to have a different angle from the nozzle head 20H of the variation 8 ($\alpha' \neq \alpha$, $0 < \alpha' \leq 90^\circ$). As the variations 8 and 9, an intersecting angle of the axis line P of the raw material flow passage 25 and the axis line Q of the gas flow passage 26 can be easily changed by varying combination of the first portion 20a and the second portion 20b if a plurality of the first portion 20a and the second portion 20b are prepared which have different connection angles of the raw material discharge surface 22 and the gas discharge surface 23. Furthermore, an intersecting angle of the axis line P and the axis line Q can be easily changed if the first portion 20a is shifted toward the second portion 20b in the front and back direction. In this case, a spacer to which the raw material or the gas flow passage are provided may be disposed at a back side of the first portion 20a or the second portion 20b.

[0046]

(Variation 10 of the first embodiment)

Figs. 15 and 16 show a variation 9 of the nozzle head 20 of the above-mentioned apparatus for producing nanofibers 1. A nozzle head 20J of the variation 9 has the first portion 20a and the second portion 20b as a separate body in a similar manner as the nozzle head 20H of the

variation 8. These two portions may be connected detachably with a connection means, such as a belt and a screw not illustrated.

[0047]

The first portion 20a of the nozzle head 20J of the variation 10 is configured so that a shape is rectangular parallelepiped, the front surface 21 is provided at the entire front surface thereof for facing the front side (a front side of a paper of Fig. 16(a), left side of (b) and (c)), the raw material discharge surface 22 is provided at the bottom surface facing downwardly, and the raw material flow passage 25 are arranged so as to be orthogonal to the raw material discharge surface 22. The second portion 20b has a similar structure as the nozzle head 20H of the variation 8 and has a rectangular parallelepiped shape. The gas discharge surface 23 is provided at the front surface and has the gas flow passage 26 orthogonal to the gas discharge surface 23. In the nozzle head 20J of the variation 10, the raw material discharge surface 22 and the gas discharge surface 23 are arranged orthogonally ($\alpha=90^\circ$) when the first portion 20a and the second portion 20b are connected.

[0048]

(Variation 11 of the first embodiment)

Figs. 17 and 18 show a variation 11 of the nozzle head 20 of the above-mentioned apparatus for producing nanofibers 1. Fig. 17(a) is an exploded perspective view showing the nozzle head 20K of the variation 11, and (b) is a perspective view showing an unprocessed component K before cutting away the first portions 20a of the nozzle head 20A. The nozzle head 20K of the variation 11 comprises a raw material discharge pipe 29 which projects from the raw material discharge surface 22 and the raw material flow passage 25 is arranged inside thereof. Other structure of the nozzle head 20K of the variation 11 is the same as the nozzle head 20H of the variation 8. Additionally, in a similar manner as the discharge pipe 29, another discharge pipe (not illustrated) may be arranged which projects from the gas discharge surface 23 and the gas flow passage 26 is arranged inside thereof.

[0049]

(Variation 12 of the first embodiment)

Figs. 19 and 20 show a variation 12 of the nozzle head 20 of the above-mentioned apparatus for producing nanofibers 1. A nozzle head 20L of the variation 12 is provided with a concave groove 31 having a rectangular cross section on a top surface of the second portion 20b instead of the gas flow passage 26 having the cylindrical space of the nozzle head 20H of the variation 8. The nozzle head 20L of the

variation 12 has the gas flow passage 26 having the space in a square column shape which a cross section is rectangular by means of one surface of the first portion 20a contacting with the second portion 20b and the concave groove 31 of the second portion 20b when the first portion 20a and the second portion 20b are connected. Other structure of the nozzle head 20L of the variation 12 is the same as the nozzle head 20H of the variation 8. As shown in Fig. 21, the first portion 20a and the second portion 20b may be shifted in the front and back direction so that the front surface 21 and the gas discharge surface 23 are included on the same plane.

[0050]

(Variation 13 of the first embodiment)

Figs. 22 and 23 show a variation 13 of the nozzle head 20 of the above-mentioned apparatus for producing nanofibers 1. A nozzle head 20M of the variation 13 is provided with a concave groove 31 having a rectangular cross section on a top surface of the second portion 20b instead of the gas flow passage 26 having the cylindrical space of the nozzle head 20J of the variation 10. The nozzle head 20M of the variation 13 has the gas flow passage 26 having the space in a square column shape which a cross section is rectangular formed by one surface of the first portion 20a contacting with the second portion 20b and the concave groove 31 of the second portion 20b when the first portion 20a and the second portion 20b are connected. Other structure of the nozzle head 20M of the variation 13 is the same as the nozzle head 20J of the variation 10. As shown in Fig. 24, the first portion 20a and the second portion 20b may be shifted in the front and back direction so that the front surface 21 and the gas discharge surface 23 are included on the same plane.

[0051]

(Variation 14 of the first embodiment)

Figs. 25 shows a variation 14 of the nozzle head 20 of the above-mentioned apparatus for producing nanofibers 1. A nozzle head 20S of the variation 14 comprises two the raw material flow passages 25, 25, and the gas flow passage 26 arranged between these two the raw material flow passages 25, 25. In other words, the nozzle head 20S of the variation 14 comprises a set of flow passages including two the raw material flow passages 25, 25 and the gas flow passage 26. The nozzle head 20S of the variation 14 comprises two the raw material discharge surfaces 22, 22 to which the gas discharge surface 23 is inserted. The raw material discharge surfaces 22, 22 and the gas discharge surface 23 are arranged with the angle α ($0 < \alpha \leq 90^\circ$). The

nozzle head 20S of the variation 14 comprises two the raw material flow passages 25, 25 orthogonal to the raw material discharge surfaces 22, 22, respectively, and the gas flow passage 26 orthogonal to the gas discharge surface 23. The nozzle head 20S of the variation 14, in a similar manner of the apparatus for producing nanofibers 1, the axis line P, P (not illustrated) of the raw material flow passages 25, 25 and the axis line Q of the gas flow passage 26 are intersected at a point in front of the nozzle head 20S with an angle α . Thereby, the solvent discharged from the two raw material flow passages 25, 25 meets the gas flow ejected from the gas flow passage 26 with the angle α and is carried out in the front direction while being elongated. In the present structure, different kinds of raw materials may be discharged from these two raw material flow passages 25, 25, respectively. Therefore, two different kinds of fibers can be manufactured and mixed with these two different kinds of raw materials by using the same gas.

[0052]

(Variation 15 of the first embodiment)

Figs. 26 shows a variation 15 of the nozzle head 20 of the above-mentioned apparatus for producing nanofibers 1. A nozzle head 20T of the variation 15 comprises two the raw material flow passages 25, 25, and two the gas flow passages 26, 26. In other words, the nozzle head 20S of the variation 14 comprises a set of flow passages including two the raw material flow passages 25, 25 and the gas flow passage 26. The nozzle head 20S of the variation 14 comprises a plurality of (two) sets of flow passages each including one raw material flow passage 25 and one gas flow passage 26. The nozzle head 20T of the variation 15 comprises two first portions 20a, 20a and the second portions 20b inserted into the two first portions 20a, 20a. The first portions 20a, 20a has the same structure as the first portion 20a of the above-mentioned variation 8. The second portion 20b has a rectangular parallelepiped shape and is provided the concave grooves 31, 31 on the top surface and a lower surface. The nozzle head 20T of the variation 15 has the gas flow passages 26, 26 having the space in a square column shape which a cross section is rectangular formed by one surfaces of the first portions 20a, 20a contacting with the second portion 20b and the concave grooves 31, 31 of the second portion 20b when the first portions 20a, 20a and the second portion 20b are connected. The relationship between the raw material flow passage 25 and the gas flow passage 26 of the nozzle head 20T of the variation 15 is the same the relationship between the raw material flow passage 25 and the gas flow passage 26 of the nozzle head 20L of the variation 12. In the present structure, different kinds of raw materials may

be discharged from these two raw material flow passages 25, 25, and different kinds of gas may be ejected from the gas flow passages 26, 26. Therefore, two different kinds of fibers can be manufactured at the same time and mixed by using these two different liquid raw materials and two different gases.

[0053]

In Table 1, an outline of the basic structure and the structures of the variations 1 to 15 of the nozzle head 20 according to the Embodiment 1.

[0054]

[Table 1]

1st Embodiment	Shape of Raw material flow passage	Shape of gas flow passage	Difference of Variation from basic structure	Figure
Basic Structure	Cylindrical	Cylindrical	—	Fig. 2, 3
Variation 1	Cylindrical	Cylindrical	Width of raw material discharge surface is same as diameter of raw material flow passage	Fig. 4
Variation 2	Cylindrical	Cylindrical	Gas flow passage contacts with raw material discharge surface	Fig. 5
Variation 3	Cylindrical	Cylindrical	Raw material flow passage contacts with gas flow passage	Fig. 6
Variation 4	Square column shape	Cylindrical	Raw material flow passage is formed in square column shape	Fig. 7
Variation 5	Cylindrical	Square column shape	Gas flow passage is formed in square column shape	Fig. 8
Variation 6	Square column shape	Square column shape	Raw material flow passage and gas flow passage are formed in square column shape	Fig. 9
Variation 7	Cylindrical	Shape of cylinder taken along chord	Raw material flow passage is arranged in gas flow passage	Fig. 10
Variation 8	Cylindrical	Cylindrical	First portion and second portion are arranged which are detachable each other	Fig. 11, 12
Variation 9	Cylindrical	Cylindrical	There is arranged with an angle α' different from an angle α of Variation 8	Fig. 13, 14
Variation 10	Cylindrical	Cylindrical	There is arranged with an angle (90 degrees) different from an angle α of Variation 8	Fig. 15, 16
Variation 11	Cylindrical	Cylindrical	Raw material discharge pipe is added to structure of Variation 8	Fig. 17, 18
Variation 12	Cylindrical	Square column shape (concave groove)	Gas flow passage is concave groove in a similar structure of Variation 8	Fig. 19, 20, 21
Variation 13	Cylindrical	Square column shape (concave groove)	Gas flow passage is concave groove in a similar structure of Variation 10	Fig. 22, 23, 24
Variation 14	Cylindrical	Cylindrical	There are provided two raw material flow passages and one gas flow passage	Fig. 25
Variation 15	Cylindrical	Square column shape (concave groove)	There are provided two sets of flow passages consisting of one raw material flow passage and one gas flow passage	Fig. 26

[0055]

(Second Embodiment)

Hereinafter, an apparatus for producing nanofibers according to a second embodiment of the present invention will be described referring to Fig.

27.

The apparatus for producing nanofibers 2 of the second embodiment (not illustrated) comprises the nozzle head 20U instead of the nozzle head 20, however, other structure is the same as of the apparatus for producing nanofibers 1 of the first embodiment in Fig. 1.

[0056]

Fig. 27 is an explanatory diagram showing the nozzle head of the apparatus for producing nanofibers 2 according to a second embodiment of the present invention. (a) is a front view, (b) is a cross sectional view taken along the line A-A', and (c) is a cross sectional view taken along the line B-B'.

[0057]

The nozzle head 20U of the apparatus for producing nanofibers 2 of the second embodiment comprises the raw material discharge surface 22 facing the front side (front side of a paper of Fig. 27(a), left side of (b) and (c)), a connecting surface 24, and the gas discharge surface 23, which are connected in order in a downward direction as an absolute positional relationship. The raw material discharge surface 22 and the gas discharge surface 23 are arranged in parallel each other, and the gas discharge surface 23 is arranged forwardly with a distance t away from the front surface 21. The nozzle head 20U is provided with a back surface (not illustrated) which is parallel with the front surface 21 and faces backwardly (back side of a paper of Fig. 27(a), right side of (b) and (c)).

[0058]

The nozzle head 20U comprises the raw material flow passage 25 orthogonal to the raw material discharge surface 22, and the gas flow passage 26 orthogonal to the gas discharge surface 23. The raw material flow passage 25 is configured to linearly penetrate the raw material discharge surface 22 and a back surface. The gas flow passage 26 is also configured to linearly penetrate the gas discharge surface 23 and the back surface 27. The axis line P of the raw material flow passage 25 and the axis line Q of the gas flow passage 26 are provided so as to be on a plane.

[0059]

The connecting surface 24 and the gas discharge surface 23 are arranged with an angle β ($0 \leq \beta < 90^\circ$), and the connecting surface 24 faces an oblique upward direction. In other words, a surface direction R of the connecting surface 24 and the axis line Q of the gas flow passage 26 has an angle α ($\alpha = 90 - \beta$). The nozzle head 20U is configured to intersect the surface direction R and the axis line Q at a point in front of the nozzle

head 20U with an angle α from a side direction (a front side to a back side of Fig. 27(b), (c)). The "side direction" is a direction parallel to the connecting surface 24 and the gas discharge surface 23.

[0060]

According to the present embodiment, the raw material flow passage 25 and the gas flow passage 26 have cylindrical spaces (cross sections orthogonal to the axis lines are entirely same), respectively.

Alternatively, the raw material flow passage 25 and the gas flow passage 26 may have the spaces in a square column shape. One part of the raw material flow passage 25 contacts with the connecting surface 24, and also one part of the gas flow passage 26 contacts with the connecting surface 24. The connecting surface 24 is provided with a raw material flow groove 24a linearly connecting the raw material flow passage 25 and the gas flow passage 26.

[0061]

A description will be made of operation of the apparatus for producing nanofibers 1 and the nozzle head 20U according the present embodiments. The apparatus for producing nanofibers is supplied with the solvent from the solvent storage 11 and discharges from the opening of the raw material flow passage 25 on the raw material discharge surface 22. The apparatus for producing nanofibers is supplied with the high-pressure gas from the gas ejection unit 13 and ejects the same from the opening of the gas flow passage 26 on the gas discharge surface 23. The solvent discharged from the raw material flow passage 25 reaches at the opening of the gas flow passage 26 through the raw material flow groove 24a, meets the gas flow ejected from the gas flow passage 26 with the angle α , and is carried out in the front direction while being elongated, so that the nanofibers are manufactured.

[0062]

According to the apparatus for producing nanofibers 2 and the nozzle head 20U of the above-mentioned embodiment, the raw material flow passage 25 is arranged so as to be orthogonal to the raw material discharge surface 22, and the gas flow passage 26 is arranged so as to be orthogonal to the gas discharge surface 23. Thereby, by drilling, the raw material flow passage 25 can be formed on the raw material discharge surface 22, and the gas flow passage 26 can be formed on the gas discharge surface 23. The solvent discharged from the raw material flow passage 25 directly meets the gas flow ejected from the gas flow passage 26 through the raw material flow groove 24a with the

angle α . It can be achieved to manufacture precisely by drilling and to carry efficiently the solvent on the gas flow.

[0063]

(Third Embodiment)

Hereinafter, an apparatus for producing nanofibers according to a third embodiment of the present invention will be described referring to Figs. 28 to 38.

The apparatus for producing nanofibers 3 has a structure by using molten raw material prepared by melting a solid raw material.

[0064]

Figs. 28 and 29 are a perspective view and a cross sectional view showing the apparatus for producing nanofibers according to a third embodiment of the present invention. Fig. 30 is an explanatory diagram showing the nozzle head of the apparatus for producing nanofibers of Fig. 28, (a) is a front view, and (b) is a cross sectional view taken along the line A-A'. Figs. 31 to 38 are explanatory diagrams showing structures of the variations 1 to 8 of the nozzle head having the basic structure of Fig. 30, and a front view and a cross sectional view are illustrated in each figure in the same manner of Fig. 30. Hereinafter, terms representing "front, back, left, right, up and down" may be used, which show a relative positional relationship of each component, not an absolute relationship unless otherwise explicitly. In each figure, a component having same function has a same reference number and the detailed explanation will be omitted.

[0065]

The apparatus for producing nanofibers 3 according to the present embodiment comprises a hopper 62 for feeding a pellet-shaped resin (a granular synthetic resin having a fine particle) to be a material for the nanofibers into the apparatus for producing nanofibers 3, a heating cylinder 63 for heating and melting the resin supplied from the hopper 62, a heater 64 as a heating unit for heating the heating cylinder 63 from outside, a screw 65 which is rotatably stored in the heating cylinder 63 and functions as an extruding unit for moving the molten resin to the end of the heating cylinder 63 by rotating, a motor 66 as a driving unit for rotating the screw 65 through a connecting unit 69 (not shown in detail), and a cylindrical nozzle head 70 which is provided at the end of the heating cylinder 63. The nozzle head 70 is connected with a gas ejection unit (not illustrated) through a supply pipe 68. In the present embodiment, each structure such as the heating cylinder 63 and the nozzle head 70 is mainly made of metal, however, other materials may be applicable such as resin and glass in accordance with conditions of modes, such as kinds of resin as materials of the nanofibers or nanofiber

products.

[0066]

As shown in Fig. 30, in the nozzle head 70, there are connected in order in the downward direction a front surface 71, facing the front side (front side of a paper of Fig. 30(a), left side of (b) and (c)), a raw material discharge surface 72, and a gas discharge surface 73. The front surface 71 and the gas discharge surface 23 are arranged in parallel each other, and the gas discharge surface 23 is arranged backwardly (right side of Fig. 30(b)) with a distance t away from the front surface 71. The raw material discharge surface 72 and the gas discharge surface 73 are arranged with an angle α ($0 < \alpha \leq 90^\circ$), and the raw material discharge surface 72 faces an oblique downward direction. The nozzle head 70 is also provided with the back surface (not illustrated) which is parallel with the front surface 71 and faces backwardly.

[0067]

The nozzle head 70 comprises a plurality of raw material flow passages 75 orthogonal to the raw material discharge surface 72, and the gas flow passage 76 orthogonal to the gas discharge surface 73. In the present embodiment, the number of the raw material flow passage 75 and the gas flow passage 76 is same (seven), and the raw material flow passage 75 and the gas flow passage 76 arranged in up and down direction correspond each other. In other words, there are a plurality (seven) of flow passage sets of one the raw material flow passage 75 and one gas flow passage 76. These sets are arranged in one direction so that the raw material flow passage 75 and the gas flow passage 76 become are arranged in two line in parallel.

[0068]

In the present embodiments, the raw material flow passage 75 has a cylindrical space, and the gas flow passage 76 also has the cylindrical space. The raw material discharge surface 72 has a width (a length in up and down direction of Fig. 30(a)) larger than a diameter of the raw material flow passage 75 (about twice of the diameter), and the raw material flow passage 75 is arranged at a center area in a width direction. The gas flow passage 76 is arranged with an interval from the raw material discharge surface 72. An axis line P of the raw material flow passage 75 and an axis line Q of the gas flow passage 76 are provided so as to be on a plane and the axis line P and the axis line Q are intersected at a point in front of the nozzle head 70 with an angle α .

[0069]

A plurality of the raw material flow passages 75 communicates with the heating cylinder 63, and the molten resin raw material supplied from the heating cylinder 63 flows through a plurality of the raw material flow passages 75 and is discharged from the opening of the plurality of raw material flow passages 75 on the raw material discharge surface 72.

[0070]

A plurality of the gas flow passage 76 communicates with a gas supply pipe 68 in the nozzle head 70, and high-pressure gas supplied from the gas ejection unit flows through the gas supply pipe 68 and a plurality of gas flow passages 76 and is ejected from the opening of the plurality of the gas flow passages 76 on the gas discharge surface 73.

[0071]

The such structure is only an example, and if there are provided the raw material flow passage 75 and the gas flow passage 76 orthogonal to the raw material discharge surface 72 and the gas discharge surface 73 which are arranged with an angle α ($0 < \alpha \leq 90^\circ$), respectively, the structure may be optional within a purpose of the present invention.

[0072]

A description will be made of operation of the apparatus for producing nanofibers 3 and the nozzle head 70 according to the present embodiments. In the apparatus for producing nanofibers 3, the pellet-shaped raw material (resin) fed into the hopper 62 is supplied and melted in the heating cylinder 63 heated by the heater 64 and delivered to a front side of the heating cylinder 63 by the screw 65 rotated by the motor 66. The molten raw material (molten resin) arrived at the top of the heating cylinder 63 is discharged from the plurality of raw material flow passages 75 through the inside of the nozzle head 70. The high-pressure gas is ejected from the plurality of the gas flow passage 76 arranged in the nozzle head 70. The molten raw material discharged from the raw material flow passage 75 meets the gas flow ejected from the gas flow passage 76 with the angle α , and is carried out in the front direction while being elongated, so that the nanofibers are manufactured.

[0073]

According to the apparatus for producing nanofibers 3 and the nozzle head 70 of the above-mentioned embodiment, the raw material flow passage 75 is arranged so as to be orthogonal to the raw material discharge surface 72, and the gas flow passage 76 is arranged so as to

be orthogonal to the gas discharge surface 73. Thereby, by drilling, the plurality of the raw material flow passage 75 can be formed on the raw material discharge surface 72, and the plurality of the gas flow passage 26 can be formed on the gas discharge surface 23. The molten raw material discharged from the raw material flow passage 75 directly meets the gas flow ejected from the gas flow passage 76 with the angle α . It can be achieved to manufacture precisely by drilling and to carry efficiently the solvent on the gas flow. Since the apparatus comprises a plurality of the raw material flow passages 75 and the gas flow passages 76, a large amount of nanofibers are manufactured efficiently in short time.

[0074]

(Variation 1 of the third embodiment)

Fig. 31 shows a variation 1 of the nozzle head 70 of the above-mentioned apparatus for producing nanofibers 3 (hereinafter referred to as a basic structure of the nozzle head 70). The nozzle head 70A of the variation 1 comprises the plurality of the gas flow passage 76 configured to have a space in a square column shape which a cross section is rectangular. As other structures, the nozzle head 70A of the variation 1 is the same as the basic structure of the nozzle head 70.

[0075]

(Variation 2 of the third embodiment)

Fig. 32 shows a variation 2 of the nozzle head 70 of the above-mentioned apparatus for producing nanofibers 3. The nozzle head 70B of the variation 2 comprises a slit-like shape gas flow passage 76 extending in a side direction (a left and right side of Fig. 32(a), a front and back side of a paper in (b)), and the gas flow passage 76 has a space in a square column shape which a cross section is rectangular. As other structures, the nozzle head 70B of the variation 2 is the same as the basic structure of the nozzle head 70. The nozzle head 70B of the variation 2 comprises a set of flow passage of the slit-like shaped gas flow passage 76 extending in one direction and the plurality of the raw material flow passages arranged in one direction. The nozzle head 70B of the variation 2 is configured to intersect the axis line P of the raw material flow passage 75 and the axis line Q of the gas flow passage 76 at a point in front of the nozzle head with an angle α from a side direction. The "side direction" is a direction parallel to the raw material discharge surface 72 and the gas discharge surface 73.

[0076]

(Variation 3 of the third embodiment)

Fig. 33 shows a variation 3 of the nozzle head 70 of the above-mentioned apparatus for producing nanofibers 3. The nozzle head 70C of the variation 3 comprises m raw material flow passages 75 and n gas flow passages 76 ($m \neq n$). The nozzle head 70C of the Variation 3 comprises six the raw material flow passages 75 and the gas flow passages 76, which are arranged so that a position of the side direction (the left and right direction of Fig. 33(a), the front to back side of a paper in (b)) of each raw material flow passage 75 becomes an intermediate position of the gas flow passage 76 adjacent thereto. As other structures, the nozzle head 70C of the variation 3 is the same as the basic structure of the nozzle head 70. The nozzle head 70C of the variation 3 comprises a set of the flow passage of m the raw material flow passages 75 and n the gas flow passages 76. The nozzle head 70C of the variation 3 is configured to intersect the axis line P of the raw material flow passage 75 and the axis line Q of the gas flow passage 76 at a point in front of the nozzle head 70 with an angle α from a side direction.

[0077]

(Variation 4 of the third embodiment)

Fig. 34 shows a variation 4 of the nozzle head 70 of the above-mentioned apparatus for producing nanofibers 3. In the nozzle head 70D of the variation 4, there are shown as a separate body a portion of the front surface 71, one portion having the raw material discharge surface 72 (a first portion 70a), and another portion having the gas discharge surface 73 (a second portion 70b). These portions may be connected detachably with a connection means, such as a belt and a screw not illustrated.

[0078]

The first portion 70a of the nozzle head 70D of the variation 4 is prepared by cutting the cylinder taken along a radius, and one side corresponding to the radius is chamfered. The front surface 71 and the raw material discharge surface 72 (chamfered portion) are connected in order in a downward direction, and the plurality of raw material flow passages 75 orthogonal to the plurality of the raw material discharge surface 72 is provided. The second portion 70b is prepared by cutting the cylinder taken along a radius and becomes the cylinder as a whole by connecting the first portion 70a. The gas discharge surface 73 is provided at the entire front surface and the gas flow passage 76 orthogonal to the gas discharge surface 73 is provided. In a nozzle head 70D of the variation 4, the raw material discharge surface 72 and the gas discharge surface 73 are arranged with the angle α when the first portion 70a and the second portion 70b are connected. The nozzle head 70D of the variation 4 comprises these

two portions may be connected detachably, and has the same structure as the nozzle head 70 of the basic structure other than connecting each other.

[0079]

(Variation 5 of the third embodiment)

Fig. 35 shows a variation 5 of the nozzle head 70 of the above-mentioned apparatus for producing nanofibers 3. The nozzle head 70E of the variation 5 comprises an annular front surface 71 of a cylindrical body facing the front side (the front side of the paper of Fig. 35(a), left side of (b)), the annular raw material discharge surface 72, and the circular gas discharge surface 73 which are connected in order from the periphery to the center and arranged concentrically. The front surface 71 and the gas discharge surface 73 are arranged in parallel each other, and the gas discharge surface 73 is arranged backwardly (Fig. 30(b)) with a distance t away from the front surface 21. The raw material discharge surface 72 and the gas discharge surface 73 are arranged with an angle α ($0 < \alpha \leq 90^\circ$), and the raw material discharge surface 72 is tapered and faces inwardly. The nozzle head 70E of the variation 5 is also provided with the back surface (not illustrated) which is parallel with the front surface 71 and faces backwardly.

[0080]

The nozzle head 70E of the variation 5 comprises a plurality of the raw material flow passage 75 which are orthogonal to the raw material discharge surface 72 and arranged at an equal interval in a circumferential direction, and the gas flow passage 76 orthogonal to a center of the gas discharge surface 73. The nozzle head 70E of the variation 5 comprises the plurality of (eight) raw material flow passages 75 are arranged around the gas flow passage 76. The nozzle head 70E of the variation 5 has a set of flow passage of the gas flow passage 76 and the plurality of the raw material flow passages 75 arranged round the gas flow passage 76.

[0081]

In the nozzle head 70E of the variation 5, the raw material flow passage 75 has a cylindrical space and the gas flow passage 76 also has a cylindrical space. The raw material discharge surface 72 has a width (a length in a radius direction) same as that of a diameter of the raw material flow passage 75. The gas flow passage 76 is arranged with an interval from the raw material discharge surface 72. The axis line P of the raw material flow passage 75 and an axis line Q of the gas flow passage 76 are intersected at a point in front of the nozzle head 70B with an angle α .

[0082]

(Variation 6 of the third embodiment)

Fig. 36 shows a variation 6 of the nozzle head 70 of the above-mentioned apparatus for producing nanofibers 3. The nozzle head 70F of the variation 6 comprises a plurality of raw material discharge pipes 79 which projects from the raw material discharge surface 72 and the plurality of the raw material flow passages 75 are arranged inside thereof. Other structure of the nozzle head 70F of the variation 6 is the same as the nozzle head 70E of the variation 5.

[0083]

(Variation 7 of the third embodiment)

Fig. 37 shows a variation 7 of the nozzle head 70 of the above-mentioned apparatus for producing nanofibers 3. The nozzle head 70G of the variation 7 comprises an annular front surface 71 of a cylindrical body facing the front side (the front side of the paper of Fig. 37(a), left side of (b)), the annular raw material discharge surface 72, and the circular gas discharge surface 73 which are connected in order from the periphery to the center and arranged concentrically. The front surface 71 and the gas discharge surface 73 are arranged in parallel each other, and the gas discharge surface 73 is arranged backwardly (Fig. 30(b)) with a distance t away from the front surface 21. The raw material discharge surface 72 and the gas discharge surface 73 are arranged with an angle α ($0 < \alpha \leq 90^\circ$), and the raw material discharge surface 72 is tapered and faces inwardly. The nozzle head 70G of the variation 7 is also provided with the back surface (not illustrated) which is parallel with the front surface 71 and faces backwardly.

[0084]

The nozzle head 70G of the variation 7 comprises a plurality of the raw material flow passage 75 which are orthogonal to the raw material discharge surface 72 and arranged at an equal interval in a circumferential direction, and the plurality of the gas flow passages 76 which are orthogonal to the gas discharge surface 73 and arranged at an equal interval in a circumferential direction. The nozzle head 70G of the variation 7 comprises the plurality of (eight) raw material flow passages 75 and the gas flow passages 76, respectively. The nozzle head 70G of the variation 7 has eight sets of flow passage of one raw material flow passages 75 and one gas flow passage 76 corresponding thereto. A plurality of flow passage sets are arranged annularly so that the raw material flow passage 75 and the gas flow passage 76 are arranged on the circumference of two circles which become concentric.

[0085]

In the nozzle head 70G of the variation 7, the raw material flow passage 75 has a cylindrical space and the gas flow passage 76 also has a cylindrical space. The raw material discharge surface 72 has a width (a length in a radius direction) larger (about two times) than the raw material flow passage 75. The plurality of the gas flow passages 76 are arranged with contacting with the raw material discharge surface 72, respectively. The axis line P of the raw material flow passage 75 and an axis line Q of the gas flow passage 76 are intersected at a point in front of the nozzle head 70G with an angle α .

[0086]

(Variation 8 of the third embodiment)

Fig. 38 shows a variation 8 of the nozzle head 70 of the above-mentioned apparatus for producing nanofibers 3. In the nozzle head 70H of the variation 8, the plurality of the gas flow passages 76 are configured to have a space in a square column shape which a cross section is rectangular, and are arranged with an interval from the raw material discharge surface 72. As other structures, the nozzle head 70H of the variation 8 is the same as that of the nozzle head 70G of the variation 7.

[0087]

In table 2, an outline of the basic structure and the structures of the variations 1 to 8 of the nozzle head 70 according to the Embodiment 3.

[0088]

[Table 2]

3rd Embodiment	Shape of Raw material flow passage	Shape of gas flow passage	Difference of Variation from basic structure	Figure
Basic Structure	Cylindrical (7)	Cylindrical (7)	A plurality of raw material flow passage and a plurality of gas flow passage are arranged on two line in parallel	Fig. 30
Variation 1	Cylindrical (7)	Square column shape (7)	Gas flow passage is formed in square column shape	Fig. 31
Variation 2	Cylindrical (7)	Slit-type shape (1)	Gas flow passage is formed in slit-type shape	Fig. 32
Variation 3	Cylindrical (6)	Cylindrical (7)	Raw material flow passage and gas flow passage are arranged shifted in side direction	Fig. 33
Variation 4	Cylindrical (7)	Cylindrical (7)	First portion and second portion are arranged which are detachable each other	Fig. 34
Variation 5	Cylindrical (8)	Cylindrical (1)	A plurality of raw material flow passages are arranged in a circumferential direction so as to surround one gas flow passage	Fig. 35
Variation 6	Cylindrical (8)	Cylindrical (1)	Raw material discharge pipe is added to structure of Variation 5	Fig. 36
Variation 7	Cylindrical (8)	Cylindrical (8)	A plurality of raw material flow passages and a plurality of gas flow passages are arranged in a circumferential direction	Fig. 37
Variation 8	Cylindrical (8)	Square column shape (8)	Gas flow passage is formed in square column shape in a structure of variation 7	Fig. 38

(1)(6)(7)(8): number of flow passage

[0089]

Though description is 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.

[0090]

For example, in the above embodiment, the horizontal apparatus for producing nanofibers is disclosed which the molten resin and the gas ejection hole are provided in a horizontal direction, however it is not limited to, and there is no problem to arrange the vertical apparatus and the nozzle head in the downward direction. Rather, such vertical apparatus is capable of efficiently preventing influence by the gravity.

[0091]

In each embodiment and variation, positions of the raw material flow passage and the gas flow passage may be replaced each other. Specifically, in the nozzle head 20 of the embodiment 1, the position of the raw material discharge surface 22 may be replaced with the position of the gas discharge surface 23, the raw material discharge surface 22 and the front surface 21 are arranged in parallel, the gas

discharge surface 23 is arranged with an angle α toward the raw material discharge surface 22. The raw material discharge surface 22 and the gas discharge surface 23 may be provided with the raw material flow passage 25 and the gas flow passage 26, respectively. The structure is not limited to any arrangement shown in figures of each embodiment. For example, the figures of each embodiment may be upside down and the raw material flow passage (the raw material discharge surface) and the gas flow passage (the gas discharge surface) may be replaced. Additionally, by rotating by 90° degrees, the raw material flow passage (the raw material discharge surface) and the gas flow passage (the gas discharge surface) may be arranged in horizontal direction.

[0092]

The extruding means is described as the screw, an intermittent extrusion with a piston by supplying solution sequentially such as a die casting may be applicable.

[0093]

The apparatus for producing nanofibers and the nozzle head according to the present invention preferably comprise a raw material temperature control function (not illustrated) in accordance with conditions of the liquid raw material and production of the nanofibers.

[0093]

The apparatus for producing nanofibers and the nozzle head according to the present invention preferably comprises a gas temperature control function (not illustrated) for controlling a temperature of the gas at the gas exit.

Claims

Claim 1:

An apparatus for producing nanofibers comprising

a raw material discharge surface on which a raw material flow passage for discharging a liquid raw material is arranged, and

a gas discharge surface which is arranged with an angle α ($0 < \alpha \leq 90^\circ$) toward said raw material discharge surface and on which a gas flow passage for ejecting gas is arranged, wherein said raw material flow passage is orthogonal to said raw material discharge surface, said gas flow passage is orthogonal to said gas discharge surface, and said raw material flow passage and said gas flow passage are arranged so that said liquid raw material discharged from said raw material flow passage meets gas ejected from said gas flow passage.

Claim 2:

An apparatus for producing nanofibers claimed in claim 1 comprising one or more flow passage set of said one raw material flow passage and said one gas flow passage.

Claim 3:

An apparatus for producing nanofibers claimed in claim 2 wherein a plurality of flow passage sets are provided and these flow passage sets are arranged in one direction so that said raw material flow passage and said gas flow passage are arranged on two linear lines parallel each other.

Claim 4:

An apparatus for producing nanofibers claimed in claim 2 wherein a plurality of flow passage sets are provided and the plurality of flow passage sets are arranged annularly so that said raw material flow passage and said gas flow passage are arranged on the circumference of two circles which become concentric.

Claim 5:

An apparatus for producing nanofibers claimed in any one of claims 1 to 4 wherein an axis line of said raw material flow passage and an axis line of said gas flow passage are provided on a plane.

Claim 6:

An apparatus for producing nanofibers claimed in Claim 1 comprising one or more flow passage sets of a plurality of said raw material flow passage and said gas flow passage.

Claim 7:

An apparatus for producing nanofibers claimed in Claim 6 wherein said flow

passage set comprises said gas flow passage having a slit-like shape and extending in one direction, and said plurality of raw material flow passages arranged in said one direction.

Claim 8:

An apparatus for producing nanofibers claimed in Claim 6 wherein said flow passage set comprises said gas flow passage and a plurality of said raw material flow passage arranged around said gas flow passage.

Claim 9:

An apparatus for producing nanofibers claimed in any one of claims 1 to 8 wherein a discharge pipe projecting from said raw material discharge surface is provided and said raw material flow passage is arranged inside thereof.

Claim 10:

An apparatus for producing nanofibers claimed in any one of claims 1 to 9 wherein a discharge pipe projecting from said gas discharge surface is provided and said gas flow passage is arranged inside thereof.

Claim 11:

An apparatus for producing nanofibers claimed in any one of claims 1 to 10 comprising a first portion having said raw material discharge surface, and a second portion having said gas discharge surface, wherein said first portion and said second portion are connected detachably.

Claim 12:

An apparatus for producing nanofibers comprising

- a raw material discharge surface on which a raw material flow passage for discharging a liquid raw material is arranged,

- a gas discharge surface which is arranged downwardly from said raw material discharge surface and on which a gas flow passage for ejecting gas is arranged,

- a connecting surface which is connected with said raw material discharge surface and said gas discharge surface, and is arranged with an angle β ($0 \leq \beta < 90^\circ$) toward said raw material discharge surface,

- wherein said raw material flow passage is orthogonal to said raw material discharge surface, said gas flow passage is orthogonal to said gas discharge surface, an opening of said gas flow passage contacts with said connecting surface, and said raw material flow passage and said gas flow passage are arranged so that said liquid raw material discharged from said raw material flow passage reaches to the opening of said gas flow passage along said connecting surface.

Claim 13:

A nozzle head used for an apparatus for producing nanofibers comprising:

- a raw material discharge surface on which a raw material flow passage for discharging a liquid raw material is arranged, and

- a gas discharge surface which is arranged with an angle α ($0 < \alpha \leq 90^\circ$) toward said raw material discharge surface and on which a gas flow passage for ejecting gas is arranged, wherein said raw material flow passage is orthogonal to said raw material discharge surface, said gas flow passage is orthogonal to said gas discharge surface, and said raw material flow passage and said gas flow passage are arranged so that said liquid raw material discharged from said raw material flow passage meets gas ejected from said gas flow passage.

Claim 14:

A nozzle head used for an apparatus for producing nanofibers comprising:

- a raw material discharge surface on which a raw material flow passage for discharging a liquid raw material is arranged,

- a gas discharge surface which is arranged downwardly from said raw material discharge surface, and on which a gas flow passage for ejecting gas is arranged,

- a connecting surface which is connected with said raw material discharge surface and said gas discharge surface, and is arranged with an angle β ($0 \leq \beta < 90^\circ$) toward said raw material discharge surface,

- wherein said raw material flow passage is orthogonal to said raw material discharge surface, said gas flow passage is orthogonal to said gas discharge surface, an opening of said gas flow passage contacts with said connecting surface, and said raw material flow passage and said gas flow passage are arranged so that said liquid raw material discharged from said raw material flow passage reaches to the opening of said gas flow passage along said connecting surface.