

**FINE BUBBLE GENERATION DEVICE AND METHOD FOR
MANUFACTURING FINE BUBBLE GENERATION DEVICE**

5 Technical Field

[0001]

The present invention relates to a fine bubble generating device for generating fine bubbles in liquid and a method for manufacturing the fine bubble generating device.

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Background Art

[0002]

Fine bubbles having a bubble diameter of less than 50 μm are referred to as so-called "microbubbles" or "nanobubbles", and have characteristics different from those of bubbles having a large diameter, such as bubbles (having a bubble

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diameter of 1 mm or more) contained in general carbonated water. Examples of the characteristics of fine bubbles may be as follows. Fine bubbles allow a large amount of gas to be dissolved into a liquid, thus increasing the concentration of a dissolved gas, such as dissolved oxygen. The surfaces of bubbles are negatively charged. The fine bubbles allow the large amount of gas, such as air or oxygen, to be dissolved. The fine bubbles have various physiological effects. Therefore, a technique of this kind related to fine bubbles has been used in various fields.

[0003]

For example, in the field of agriculture, in soil-based agriculture or hydroponics, spraying water containing air formed into fine bubbles to medium allows oxygen to be preferably supplied to roots which are liable to have a shortage of oxygen. Forming air into fine bubbles increases the amount of gas dissolved, and bubbles having a smaller bubble diameter are less likely to burst, thus being stably held in water. As a result, water with a high concentration of

dissolved oxygen can be supplied to plants and hence, the plants grow quickly whereby high quality crops can be obtained. Further, it is also reported that increasing the concentration of dissolved oxygen in water causes an effect of suppressing anaerobic bacteria and an effect of controlling insect pests.

5 [0004]

Further, in the field of beauty and health, it is known that when water containing air formed into fine bubbles is used for washing hair or skin, such as scalp, fine bubbles selectively adsorb to oil or dirt adhering to hair and the like and hence, high washing effect can be obtained. At this point of operation, fine

10 bubbles having a smaller bubble diameter are allowed to enter clearances between hair roots or hair tissues more easily. Accordingly, it is considered that fine bubbles having a smaller bubble diameter have a higher washing effect. Further, effects are also recognized, such as an effect that blood flow increases due to sensory nerve stimulation caused by fine bubbles, so that blood circulation is

15 promoted.

[0005]

As a device generating such fine bubbles, Patent Literature 1 discloses a device for generating fine bubbles inside a tubular body. The fine bubble generating device described in Patent Document 1 is a groundbreaking device

5 capable of generating fine bubbles allowing a liquid to have a high concentration of fine bubbles, and having a small bubble diameter of several tens of micrometers or less.

Citation List

10 Patent Literature

[0006]

Patent Literature 1: International Patent Publication No. WO 2019/212028

Summary of Invention

15 Technical Problem

[0007]

The conventional fine bubble generating device described in Patent Literature 1 (cf. Figure 19) generates fine bubbles by mixing a liquid L continuously supplied from a liquid supply source with a gas G supplied from a gas supply unit, and discharges a gas-liquid mixture M in which the fine bubbles and the liquid are mixed. In order to introduce the pressurized gas G into the liquid L that is continuously supplied in this manner, a tubular body 130, which serves as a liquid flow passage 70, needs to be able to withstand high atmospheric pressure around a through hole 56 through which the gas G flows, as well as high water pressure inside the tubular body 130.

[0008]

To address these requirements, a tubular body 130 disclosed in Patent Literature 1 is integrally formed so that an axis of the flow passage 70 is straight, and is fixed in close contact with a casing 110 by tightening a portion around the

through hole 56 with a nut 120. However, such a structure needs many components, making a manufacturing process complicated.

[0009]

The present invention is made from such a point of view, and an object of
5 the present invention is to provide a fine bubble generating device and a method
for manufacturing the fine bubble generating device capable of increasing product
strength while keeping manufacturing costs low.

Solution to Problem

10 [0010]

As a result of diligent research, the inventor has succeeded in reducing
manufacturing costs by combining tubular bodies respectively formed as
independent components. In Patent Literature 1, pressure resistance is ensured
by integrally forming the tubular body. However, it has been found that, in
15 accordance with a configuration of a tubular body (internal component) and a

casing (confluence pipe) of the present invention, sufficient pressure resistance can be ensured even when the tubular body is a divided body.

[0011]

According to the present invention, a fine bubble generating device is

5 provided including a bubble generator configured to generate fine bubbles by mixing a liquid continuously supplied from a liquid supply source and a gas supplied from a gas supply unit, and to discharge a gas-liquid mixture obtained by mixing the fine bubbles and the liquid with each other. The bubble generator includes: a confluence pipe formed as an independent component and having a

10 liquid introduction portion configured to supply liquid to an inside, a gas introduction portion configured to supply gas to the inside, and an outlet portion configured to generate fine bubbles and exhaust a gas-liquid mixture containing the fine bubbles; and a tubular internal component assembled and housed inside the confluence pipe, and having therein a flow passage that allows the liquid

15 supplied from the liquid introduction portion to flow to the outlet portion. The

internal component includes a downstream inner pipe formed as an independent component and disposed on a downstream side in a direction of the flow of the liquid, and an upstream inner pipe formed as an independent component and disposed on an upstream side. The upstream inner pipe includes a through-hole
5 bored and formed for introducing the gas supplied from the gas introduction portion into the flow passage. The downstream inner pipe is coupled to the upstream inner pipe inside the confluence pipe. The flow passage allows communication between the upstream inner pipe and the downstream inner pipe substantially along the same axis from the liquid introduction portion to the outlet
10 portion.

[0012]

According to the present invention, the gas is mixed to the liquid flowing through the flow passage in the bubble generator, and the gas-liquid mixture containing the fine bubbles having a bubble diameter of a nano order level can be
15 efficiently discharged. This bubble generator is configured so that a casing

formed of the confluence pipe as an independent component, inside which internal components are disposed. The internal components are assembled so that the upstream inner pipe and the downstream inner pipe, which are formed as independent components, are housed and coupled to inside the confluence pipe.

- 5 Assembly operation of introducing long tubular members into the inside of another tubular member is extremely complicated, but assembling can be facilitated as internal component is divided into a plurality of components. Moreover, pressure resistance is ensured by coupling the upstream inner pipe and the downstream inner pipe to each other inside the confluence pipe.
- 10 Furthermore, since the bubble generator is formed so that the internal components are housed inside the confluence pipe, the product strength is improved, and connection to the piping is also easier. Therefore, the fine bubble generating device not only has low manufacturing costs, but also enables reduction in maintenance costs.

Preferably, the downstream inner pipe includes a downstream coupling portion coupled to the upstream inner pipe, a downstream end portion connected inside the outlet portion, and a downstream reduced diameter portion having an inner diameter reduced from the downstream coupling portion towards the downstream end portion. The upstream inner pipe includes an upstream reduced diameter portion having an inner diameter reduced towards the downstream side, an enlarged diameter portion having an inner diameter enlarged from the upstream reduced diameter portion towards the downstream side, and an upstream coupling portion coupled to the downstream coupling portion. The through hole is disposed in the enlarged diameter portion.

[0014]

In accordance with such a configuration, in the flow passage through which the liquid continuously supplied from the liquid supply source flows inside the bubble generator, the diameter is reduced in the upstream inner pipe, then is enlarged, reduced again in the downstream inner pipe, and then is enlarged at the

outlet portion. The portion of the flow passage having a small diameter is in a reduced pressure state due to the Venturi effect, resulting in a large pressure difference with the gas pressurized than the atmospheric pressure, and thereby a large amount of gas is suctioned into the flow passage through the through hole.

- 5 In the present invention, a flow velocity of the gas introduced into the flow passage is increased, and the gas, which is forcefully introduced into the flow passage from the through hole, generates a strong swirling flow (in the gas-liquid mixing portion) between the enlarged diameter portion and the downstream reduced diameter portion. Therefore, a large amount of gas is introduced into
- 10 the flow path, and the gas and liquid are certainly mixed with each other within this flow passage, so that the gas-liquid mixture containing a large number of bubbles can be obtained. Moreover, since the flow velocity of the gas introduced into the flow passage through the through hole is high, the flow velocity of the liquid (gas-liquid mixture) flowing through the flow passage is
- 15 accelerated. Moreover, in the present invention, the gas-liquid mixture, which

has passed through the portion having a smaller inner diameter and the gas-liquid mixing portion, subsequently passes through the portion having a smaller inner diameter downstream. At this time, the portion having a smaller inner diameter downstream is in a reduced pressure state due to the Venturi effect, causing the bubbles in the gas-liquid mixture to expand, but since the outlet portion has a larger inner diameter, the flow velocity is decreased and the pressure is increased. Therefore, at the outlet portion, the expanded bubbles shrink and collapse, making it possible to obtain fine bubbles having a smaller bubble diameter.

[0015]

Preferably, the minimum inner diameter of the downstream inner pipe is smaller than the minimum inner diameter of the upstream inner pipe, and the outlet portion has at least a portion larger than the minimum inner diameter of the downstream inner pipe. This makes it possible to further reduce the bubble diameter, and to obtain a gas-liquid mixture containing fine bubbles having a bubble diameter of a nano-order level. Note that, in this specification, fine

bubbles having a bubble diameter of a nano-order level refer to fine bubbles having a bubble diameter of less than 1 μm .

[0016]

Preferably, the downstream end portion is fitted and coupled to the outlet
5 portion. This configuration makes it possible to strongly couple between the outlet portion and the downstream inner pipe, thereby increasing the pressure resistance of the bubble generator. Moreover, by fitted coupling, the internal components can be positioned, and assembling of the components becomes easy.

[0017]

10 Preferably, a central axis of the flow passage in the downstream reduced diameter portion is coaxially disposed with a central axis of the flow passage in the upstream reduced diameter portion. As a result, the flow velocity of the gas-liquid mixture flowing through the flow passage is maintained with being high, and, therefore, the gas-liquid mixture discharged through the outlet portion can
15 also have suitable hydraulic pressure.

[0018]

Preferably, the downstream coupling portion is coupled to the upstream coupling portion so that its inner surface is substantially flush with an inner surface of the upstream coupling portion. High pressure is generated in the liquid flowing through the flow passage at the downstream coupling portion and the upstream coupling portion, but the inner surfaces of these portions are flush with each other, thereby improving the pressure resistance of the fine bubble generating device.

[0019]

Preferably, an end surface of the downstream coupling portion and an end surface of the upstream coupling portion are coupled to each other, the end surfaces being substantially perpendicular to the central axis of the flow passage in the upstream reduced diameter portion. This configuration simplifies the assembly of internal components and also provides superior pressure resistance.

[0020]

Preferably, the through hole is inclined with respect to the central axis of the flow passage in the upstream reduced diameter portion and passes through a pipe wall of the enlarged diameter portion. With this configuration, the gas is introduced more forcefully into the gas-liquid mixing portion through the through
5 hole, generating a strong swirling flow in the gas-liquid mixing portion, and thereby a gas-liquid mixture containing a large number of bubbles can be obtained. Therefore, according to the present invention, the gas-liquid mixture discharged can contain fine bubbles at a higher concentration.

[0021]

10 Preferably, a plurality of the through holes are disposed equidistantly along a circumferential direction of the enlarged diameter portion. As a result, since the pressurized gas is introduced more forcefully into the gas-liquid mixing portion, and a strong swirling flow is generated, the pressurized gas and liquid are surely mixed in the flow path, and thereby a gas-liquid mixture containing a large
15 number of bubbles can be obtained.

[0022]

Preferably, a gap is formed between outer surfaces of the upstream reduced diameter portion and the enlarged diameter portion and an inner surface of the confluence pipe, and each through hole extends from the gap to the flow passage.

- 5 This configuration makes it possible to realize more efficient introduction of the pressurized gas into the gas-liquid mixing portion.

[0023]

Preferably, screw threads to be threadedly engaged with other pipes are respectively formed in the liquid introduction portion, the gas introduction portion,

- 10 and the outlet portion. This configuration makes it possible to realize more efficient and secure connection of the piping with respect to the bubble generator, while further improving the pressure resistance of the bubble generator.

[0024]

- Furthermore, according to the present invention, a method for
15 manufacturing a fine bubble generating device is provided, the fine bubble

generating device configured to generate fine bubbles by mixing a liquid continuously supplied from a liquid supply source and a gas supplied from a gas supply unit, and to discharge a gas-liquid mixture obtained by mixing the fine bubbles and the liquid with each other. The manufacturing method includes:

- 5 forming a confluence pipe, as an independent component, having a liquid introduction portion configured to supply liquid to an inside, a gas introduction portion configured to supply gas to the inside, and an outlet portion configured to generate fine bubbles and exhaust a gas-liquid mixture containing the fine bubbles; forming a downstream inner pipe disposed on a downstream side in a
- 10 direction where the liquid flows, as an independent component; forming an upstream inner pipe disposed on an upstream side in a direction of the flow of the liquid and having a through hole bored and formed for introducing gas supplied from the gas introduction portion, as an independent component; and assembling and housing the downstream inner pipe and the upstream inner pipe
- 15 communicating with the downstream inner pipe inside the formed confluence

pipe so that the formed upstream inner pipe and the formed downstream inner pipe are coaxially disposed and form a flow passage for the liquid supplied from the liquid introduction portion to flow to the outlet portion.

[0025]

5 According to the present invention, the gas is mixed to the liquid flowing through the flow passage in the bubble generator, and the gas-liquid mixture containing the fine bubbles having a bubble diameter of a nano order level can be efficiently discharged. This bubble generator is configured so that a casing formed of the confluence pipe as an independent component, inside which internal
10 components are disposed. The internal components are assembled so that the upstream inner pipe and the downstream inner pipe, which are formed as independent components, are housed and coupled to inside the confluence pipe. Assembly operation of introducing long tubular members into the inside of another tubular member is extremely complicated, but assembling can be
15 facilitated as internal component is divided into a plurality of components.

Moreover, pressure resistance is ensured by coupling the upstream inner pipe and the downstream inner pipe to each other inside the confluence pipe.

Furthermore, since the bubble generator is formed so that the internal components are housed inside the confluence pipe, the product strength is improved, and

5 connection to the piping is also easier. Therefore, the fine bubble generating device not only has low manufacturing costs, but also enables reduction in maintenance costs.

[0026]

Preferably, the forming of the downstream inner pipe includes forming the downstream inner pipe including a downstream coupling portion coupled to the upstream inner pipe, a downstream end portion connected inside the outlet portion, and a downstream reduced diameter portion having an inner diameter reduced from the downstream coupling portion towards the downstream end portion.

The forming of the upstream inner pipe includes forming the upstream inner pipe including an upstream reduced diameter portion having an inner diameter reduced

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towards the downstream side, an enlarged diameter portion having an inner diameter enlarged from the upstream reduced diameter portion towards the downstream side, and an upstream coupling portion coupled to the downstream coupling portion, and disposing the through hole in the enlarged diameter portion.

5 [0027]

Preferably, the forming of the downstream inner pipe or the forming of the upstream inner pipe includes forming the minimum inner diameter of the downstream inner pipe to be smaller than the minimum inner diameter of the upstream inner pipe. The forming of the confluence pipe includes forming the outlet portion so as to have at least a portion larger than the minimum inner diameter of the downstream inner pipe.

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[0028]

Preferably, the assembling includes fitting and coupling the downstream end portion of the downstream inner pipe to the outlet portion of the confluence pipe.

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[0029]

Preferably, the assembling includes coaxially disposing a central axis of the flow passage in the downstream reduced diameter portion of the downstream inner pipe with a central axis of the flow passage in the upstream reduced diameter portion of the upstream inner pipe.

[0030]

Preferably, the assembling includes coupling the upstream coupling portion so that an inner surface of the downstream coupling portion of the downstream inner pipe is substantially flush with an inner surface of the upstream coupling portion of the upstream inner pipe.

[0031]

Preferably, the assembling includes coupling an end surface of the downstream coupling portion of the downstream inner pipe to an end surface of the upstream coupling portion of the upstream inner pipe, the end surfaces being

substantially perpendicular to the central axis of the flow passage in the upstream reduced diameter portion of the upstream inner pipe.

[0032]

Preferably, the forming of the upstream inner pipe includes forming the upstream inner pipe so that the through hole is inclined with respect to the central axis of the flow passage in the upstream reduced diameter portion and passes through a pipe wall of the enlarged diameter portion.

[0033]

Preferably, the forming of the upstream inner pipe includes forming a plurality of the through holes disposed equidistantly along a circumferential direction of the enlarged diameter portion.

[0034]

Preferably, the assembling includes forming a gap between outer surfaces of the upstream reduced diameter portion and the enlarged diameter portion of the

upstream inner pipe and an inner surface of the confluence pipe so that the plurality of through holes extend from the gap to the flow passage.

[0035]

Preferably, the forming of the confluence pipe includes respectively

5 forming screw threads to be threadedly engaged with other pipes in the liquid introduction portion, the gas introduction portion, and the outlet portion.

Advantageous Effects of Invention

[0036]

10 According to the present invention, it is possible to provide a fine bubble generating device and a manufacturing method of the fine bubble generating device having the following excellent effects. In other words, in the fine bubble generating device, the bubble generator houses the upstream inner pipe formed as an independent component and the downstream inner pipe formed as an

15 independent component inside the confluence pipe formed as an independent

component, and the upstream inner pipe and the downstream inner pipe are assembled to be coupled to each other inside the confluence pipe, making assembly easy and providing excellent pressure resistance. Moreover, it can effectively discharge a gas-liquid mixture containing fine bubbles having nano-
5 order-level diameters.

Brief Description of Drawings

[0037]

[Figure 1] Figure 1 is a diagram showing a configuration of a fine bubble
10 generating device according to one embodiment of the present invention.

[Figure 2] Figure 2 is a schematic perspective view showing a bubble generator forming the fine bubble generating device shown in Figure 1.

[Figure 3] Figure 3 is an exploded perspective view of the bubble generator shown in Figure 2.

[Figure 4] Figure 4 is a schematic perspective view showing a portion of a confluence pipe shown in Figure 3.

[Figure 5] Figure 5 is a front view showing a configuration of the confluence pipe shown in Figure 4.

5 [Figure 6] Figure 6 is a cross sectional view taken in the line VI-VI shown in Figure 4.

[Figure 7] Figure 7 is a cross sectional view taken in the line VII-VII shown in Figure 4.

[Figure 8] Figure 8 is a schematic perspective view showing a portion of a downstream inner pipe shown in Figure 3.

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[Figure 9] Figure 9 is a front view showing a configuration of the downstream inner pipe shown in Figure 8.

[Figure 10] Figure 10 is a bottom view showing the configuration of the downstream inner pipe shown in Figure 8.

[Figure 11] Figure 11 is a schematic perspective view showing a portion of an upstream inner pipe shown in Figure 3.

[Figure 12] Figure 12 is a front view showing a configuration of the upstream inner pipe shown in Figure 11.

5 [Figure 13] Figure 13 is a bottom view showing the configuration of the upstream inner pipe shown in Figure 11.

[Figure 14] Figure 14 is a front view showing a configuration of the bubble generator shown in Figure 2.

[Figure 15] Figure 15 is a bottom view showing the configuration of the bubble
10 generator shown in the Figure 2.

[Figure 16] Figure 16 is a cross sectional view taken in the line XVI-XVI shown in Figure 2.

[Figure 17] Figure 17 is a cross sectional view taken in the line XVII-XVII shown in Figure 2.

[Figure 18] Figure 18 is a partially enlarged cross-sectional view showing an operation of the fine bubble generating device shown in Figure 1.

[Figure 19] Figure 19 is a schematic partially enlarged cross-sectional view showing a conventional fine bubble generating device.

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Description of Embodiments

[0038]

Embodiments of the present invention will be described in detail below with reference to the drawings. Although the descriptions will be provided with reference to the drawings as necessary, the content illustrated herein is merely a schematic and illustrative representation for the purpose of understanding the present invention, and the appearance and dimensional ratios may differ from the actual product. Moreover, although the embodiments will be described in detail below, the present invention is not limited to these embodiments.

15 [0039]

(Overall Configuration of Fine Bubble Generating Device)

First, an overall configuration of the fine bubble generating device according to the present embodiment will be described. Figure 1 is a diagram showing a usage state of a fine bubble generating device 1 according to one
5 embodiment of the present invention, used in beauty parlors, and the like. As shown in Figure 1, the fine bubble generating device 1 includes a bubble generator 2 configured to generate fine bubbles and exhaust a gas-liquid mixture M containing the fine bubbles. The bubble generator 2 mixes a liquid L and a gas G to generate fine bubbles therein. As shown in Figure 1, the bubble generator
10 2 is connected to a faucet 7 of public water supplies, which is an example of the liquid supply source, through a pipe 4, and is configured to continuously supply the liquid L. Moreover, the bubble generator 2 is connected to a compressor 8, which is an example of the gas supply unit, through a pipe 5, and is configured to supply the pressurized gas G. Moreover, the bubble generator 2 is connected to
15 a releasing tool such as a shower head 3 through the pipe 6, and is capable of

continually releasing the gas-liquid mixture M containing fine bubbles from the shower head 3.

[0040]

Figure 18 is a partially enlarged cross-sectional view showing an operation
5 of the fine bubble generating device 1 of the present embodiment. As shown in
Figure 18, the bubble generator 2 is assembled so that a downstream inner pipe
30 and an upstream inner pipe 50, both formed as independent components, are
housed inside a cylindrical confluence pipe 10, which is formed as an independent
component, to form a flow passage 70 through which the liquid L or gas G flows.
10 One end of the confluence pipe 10 on the upstream side includes a liquid
introduction portion 20, and a liquid supply port 21 connected to the faucet
through the pipe 4 is provided. On the other hand, one end of the confluence
pipe 10 on the downstream side includes an outlet portion 26, and a discharge port
27 discharging the gas-liquid mixture M generated inside the bubble generator 2
15 is provided. Moreover, a main body portion 12 connecting the liquid

introduction portion 20 and the outlet portion 26 to each other includes a gas introduction portion 14 including a gas supply port 15, and the gas L is supplied to inside the confluence pipe 10 from the gas supply port 15 connected to the compressor 8 through the pipe 5.

5 [0041]

As shown in Figure 18, internal space of the internal components (the downstream inner pipe 30 and the upstream inner pipe 50) forms the flow passage 70. The flow passage 70 is communicated, from the upstream side of the upstream inner pipe 50 to the downstream side of the downstream inner pipe 30, with the axis Cz, as a central axis, along the Z-axis direction. In other words, the flow passage 70 is configured so that the center of the cross-section perpendicular to the Z-axis forms approximately a straight line. Therefore, it is possible to suppress a back flow and a reduction in flow velocity of the liquid L or the gas-liquid mixture M which flows in the flow passage 70 in a flow direction F, making it possible to maintain a smooth flow of the liquid L or the like in the

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flow passage 70. The flow passage 70 includes a first flow passage portion 71 which increases a flow velocity and the second flow passage portion 72 (gas-liquid mixing portion) which is positioned downstream thereof and mixes the liquid G and the gas G. Note that "downstream" used herein refers to a region
5 beyond the direction in which the liquid L and the gas-liquid mixture M flow, and in the case of the bubble generator 2, it refers to a side where the discharge port 27 in the Z-axis direction is located. In contrast, "upstream" used herein refers to a source from which the liquid L and the gas-liquid mixture M flow, and in the case of the bubble generator 2, it refers to a side where the liquid supply port 21
10 in the Z-axis direction is located.

[0042]

As shown in Figure 18, the downstream side of the first flow passage portion 71 is narrowed in diameter and connected to the second flow passage portion 72. Therefore, the liquid L flowing through the first flow passage
15 portion 71 is continually supplied to the second flow passage portion while

increasing its flow velocity. Moreover, the second flow passage portion 72 expands in diameter from a portion having a minimum diameter of $\phi 7$ in the first flow passage portion 71 towards the downstream. A through hole 56 is provided near the downstream side of the portion having a minimum inner diameter of $\phi 7$ in the first flow passage portion 71 and is connected to the second flow passage portion 72 from the outside of the upstream inner pipe 50. The gas G supplied from the gas introduction portion 14 passes through the through hole 56 and is supplied to the second flow passage portion 72 from the outside of the upstream inner pipe 50. Due to the Venturi effect, the liquid L is in a reduced pressure state in the vicinity of the portion having a minimum inner diameter of $\phi 7$. As a result, the gas G is forcefully introduced from the through hole 56 into the second flow passage portion 72, and subsequently generates a strong swirling flow in the first gas-liquid mixing portion 24. Therefore, in the second flow passage portion 72, the gas G and the liquid L are surely mixed, and the gas-liquid mixture M containing a large number of bubbles is obtained.

[0043]

The second flow passage portion 72 further narrows in diameter in the downstream side towards the downstream, and the gas-liquid mixture M is in the reduced pressure state due to the Venturi effect. The most downstream side of the second flow passage portion 72 has a minimum inner diameter of $\phi 5$ and is connected to a generating portion 29. Note that the minimum diameter of $\phi 5$ in the second flow passage portion 72 is not particularly limited, but it is preferably smaller than the minimum diameter of $\phi 7$ in the first flow passage portion 71. This configuration makes it possible to forcefully supply the gas-liquid mixture M to the generating portion 29. Moreover, an inner diameter of $\phi 2$ of the generating portion 29 is increased more sharply than the minimum diameter of $\phi 5$ in the second flow passage portion 72. As a result, a pressure difference between the second flow passage portion 72 and the generating portion 29 is increased, thereby promoting shrinking and collapse of the bubbles in the gas-liquid mixture M in the generating portion 29, and generating fine bubbles.

[0044]

(Overall Configuration of Bubble Generator)

Next, a configuration of the bubble generator 2 will be described in detail.

Figure 2 is a schematic perspective view showing the configuration of the bubble

5 generator 2. As shown in Figure 2, the bubble generator 2 includes a liquid

introduction portion 20 for supplying liquid to the inside and an outlet portion 26

for exhausting the gas-liquid mixture to the outside. Moreover, the bubble

generator 2 includes the main body portion 12 extending along the Z-axis

direction and connecting the liquid introduction portion 20 and the introduction

10 portion 20 to each other. The bubble generator 2 includes the liquid supply port

21 in the liquid introduction portion 20 and the discharge port 27 in the outlet

portion 26, and has a cylindrical structure in which these components are

communicated with the axis Cz along the Z-axis direction as the central axis.

Moreover, the bubble generator 2 includes the gas introduction portion 14 for

15 supplying the gas to the inside. The gas introduction portion 14 includes the gas

supply port 15 connected to the inside thereof, on a first surface 11b1 of an outer surface 11b of the main body portion 12, with the axis Cy along the Y-axis as the central axis. In the drawing, the X, Y, and Z-axes are perpendicular to each other.

[0045]

5 Figure 3 is an exploded perspective view showing the configuration of the bubble generator 2. As shown in Figure 3, the bubble generator 2 includes the confluence pipe 10 having the cylindrical main body 12, and the downstream inner pipe 30 and the upstream inner pipe 50 housed inside the main body 12 with the axis Cz as the central axis. The downstream end portion 35 of the

10 downstream inner pipe 30 is fitted and coupled to the outlet portion 26 inside the main body 12. Moreover, upstream inner pipe 50 is disposed on the upstream side of the downstream inner pipe 30 inside the main body portion 12, and a coupled end surface 58 of the upstream coupling portion 57 is coupled to a coupled end surface 33 of the downstream coupling portion 32 of the downstream

15 inner pipe 30. In the present embodiment, the confluence pipe 10 functions as a

casing which completely houses the downstream inner pipe 30 and the upstream inner pipe 50 therein.

[0046]

The materials of the confluence pipe 10, the downstream inner pipe 30, and the upstream inner pipe 50 are not particularly limited, but materials that are resistant to corrosion due to tap water are preferable. Moreover, it is preferable that the confluence pipe 10, the downstream inner pipe 30, and the upstream inner pipe 50 are made of a material having sufficient strength so as to not break even when pressurized gas is introduced into the liquid flowing inside the above pipes.

For example, the confluence pipe 10, the downstream inner pipe 30, and the upstream inner pipe 50 can be made of materials such as rigid polyvinyl chloride resin (PVC), aluminum, or steel use stainless (SUS), but stainless steel is particularly preferred. It is preferable that the confluence pipe 10, the downstream inner pipe 30, and the upstream inner pipe 50 are integrally molded.

[0047]

Figure 4 is a perspective view showing a configuration of the confluence pipe 10. The confluence pipe 10 includes the liquid introduction portion 20 having the liquid supply port 21 and the outlet portion 26 having the discharge port 27. Moreover, the confluence pipe 10 includes the main body portion 12 connecting the liquid introduction portion 20 and the introduction portion 20 to each other. The confluence pipe 10 has a cylindrical structure in which the components from the liquid supply port 21 to the discharge port 27 are communicated with one another and an inner surface 11a are formed. In the main body portion 12, the gas supply port 15 of the gas introduction portion 14 for supplying the gas to the inside passes through the pipe wall 10b (cf. Figure 7).

[0048]

As shown in Figure 4, the confluence pipe 10 includes the outer surface 11b of the main body portion 12 and the liquid introduction portion 20 having a first surface 11b1, a second surface 11b2, a third surface 11b3, a fourth surface 11b4, a fifth surface 11b5, and a sixth surface 11b6, and generally has an outer

shape that is a long, substantially regular hexagonal prism from the first end surface 11b1 to the second end surface 11b2 in the Z-axis direction (cf. Figure 7). Therefore, the confluence pipe 10 can be easily held with a spanner, a hexagon wrench, or the like.

5 [0049]

As shown in Figure 4, a screw thread 22 is formed on an inner peripheral surface of the liquid introduction portion 20 so as to be threadedly engaged with the pipe 4 shown in Figure 1. Moreover, the confluence pipe 10 includes the outlet portion 26 having a screw thread 28 on an outer peripheral surface thereof and protrudes from the second end surface 11b2 of the formed regular hexagonal prism-shaped portion to a distal end surface 11c3 so as to be threadedly engaged with the pipe 6 shown in Figure 1. A screw thread 16 is formed on an inner peripheral surface of the gas introduction portion 12 so as to be threadedly engaged with the pipe 5 shown in Figure 1. Therefore, it is configured to facilitate the connection work with the pipes 4, 5, 6, and the like shown in Figure

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1. In this embodiment, the end portions in the Z-axis direction are chamfered to facilitate gripping with a hexagon wrench (cf. Figure 5).

[0050]

The confluence pipe 10 has a depth D0 in the Y-axis direction (cf. Figure 7), a width W0 in the X-axis direction (cf. Figure 5), and a length H0 in the Z-axis direction (cf. Figure 5). The depth D0, the width W0, and the length H0 are not particularly limited. For example, the depth D0 may be 20 mm to 50 mm, and is preferably 22 mm to 30 mm from the viewpoint of reducing manufacturing costs, making the product more compact, and increasing product strength. The depth D0 is preferably compatible with existing wrench sizes. The width W0 is preferably compatible with the depth D0 so that the outer shape is a regular hexagon in plan view, and may be 23 mm to 58 mm. The length H0 may be 40 mm to 170 mm, and the length H0 is preferably 45 mm to 65 mm from the viewpoint of reducing manufacturing costs, making the product more compact, and increasing product strength. Moreover, when the pressure of the liquid or

the pressure of the pressurized gas supplied to the inside is high, the depth D0, the width W0, and the length H0 may be further increased in accordance with the pressure thereof.

[0051]

5 The length H1 of the liquid introduction portion 20 from the first end surface 11b1 to the stopper surface 11a0, as shown in Figures 5 and 6, is not particularly limited and may be 7 mm to 25 mm. The length H1 is preferably 8 mm to 12 mm from the viewpoint of reducing manufacturing costs, making the product more compact, and increasing product strength. Moreover, the length

10 H2 of the main body portion 12 from the stopper surface 11a0 to the second end surface 11b2 is not particularly limited and may be 20 mm to 120 mm. The length H2 is preferably 30 mm to 40 mm from the viewpoint of reducing manufacturing costs, making the product more compact, and increasing product strength.

15 [0052]

As shown in Figure 5, in this embodiment, the distal end surface 11c3 of the outlet portion 26 is disposed at a position where it protrudes from the second end surface 11c2 of the substantially hexagonal prism-shaped portion by the length H3 in the Z-axis direction. The protruding length H3 of the outlet portion 26 is not particularly limited and may be 7 mm to 25 mm. The length H3 is preferably 8 mm to 12 mm from the viewpoint of reducing manufacturing costs, making the product compact, increasing product strength, and generating satisfactory fine bubbles. Moreover, when the pressure of the liquid or the pressure of the pressurized gas supplied to the inside is high, the lengths H1, H2, and H3 may be made larger in accordance with the depth D0, the width W0, and the length H0.

[0053]

As shown in Figure 6, the confluence pipe 10 includes a main body portion inner surface 11a1 forming a cylindrical internal portion 10a extending along the Z-axis direction and an outlet portion inner surface 11a3 (cf. Figure 7). As

shown in Figures 6 and 7, in the present embodiment, the inner diameter $\phi 2$ of the outlet portion 26 is smaller than the inner diameter $\phi 1$ of the internal portion 10a in the main body portion 12, but the inner diameter $\phi 1$ and the inner diameter $\phi 2$ are not particularly limited. However, it is preferable that the inner diameter $\phi 1$ of the main body portion 12 is such that the internal components (the downstream inner pipe 30 and the upstream inner pipe 50) are housed inside the internal portion 10a of the confluence pipe 10, and that the downstream inner pipe 30 and the upstream inner pipe 50 are fitted thereto. For example, the inner diameter $\phi 1$ may be 10mm to 25mm, and it is preferable for inner diameter $\phi 1$ to be 15mm to 20mm. Moreover, it is preferable that the inner diameter $\phi 2$ of the outlet portion 26 has a size so that the downstream end portion 35 of the downstream inner pipe 30 is fitted thereto. For example, the inner diameter $\phi 2$ may be 8 mm to 20 mm, and it is preferable for the inner diameter $\phi 2$ to be 12 mm to 18 mm. Moreover, the wall thickness D1 of the pipe wall 10b of the confluence pipe 10 shown in Figure 7 is not particularly limited. For example, the wall thickness

D1 of the pipe wall 10b may be 2mm to 12mm. It is preferable that the wall thickness D1 of the pipe wall 10b is not less than 3mm from the viewpoint of reducing manufacturing costs, making the product more compact, and increasing product strength. Moreover, when the pressure of the liquid or the pressure of the pressurized gas supplied to the inside is high, the inner diameters $\phi 1$ and $\phi 2$ and the wall thickness D1 may be made larger in accordance with the depth D0, the width W0, and the length H0.

[0054]

As shown in Figure 6, the main body portion inner surface 11a1 is connected to the stopper surface 11a0 which is substantially perpendicular thereto. The main body portion inner surface 11a1 and the outlet portion inner surface 11a3 are connected by a positioning surface 11a2, which is perpendicular to each surface. The stopper surface 11a0 defines the downstream position into which the aforementioned pipe 4 can be inserted. The positioning surface 11a2 is in contact with the stepped surface 38 of the downstream inner pipe 30 (cf. Figure

9), which will be described later, enabling the positioning of the downstream inner pipe 30.

[0055]

As shown in Figure 8, the downstream inner pipe 30 includes a pipe wall 31 having an outer surface 31b extending schematically along the Z-axis and an inner surface 31a, and has a substantially circular tubular shape with the axis Cz as the central axis. Moreover, as shown in Figure 9, the downstream inner pipe 30 schematically includes the downstream end portion 35 positioned on the downstream side, the downstream coupling portion 32 positioned on the upstream side, and the downstream reduced diameter portion 34 positioned between the downstream end portion 35 and the downstream coupling portion 32.

[0056]

As shown in Figure 9, the first portion 31a1, which is the inner surface 31a of the downstream coupling portion 32, extends in the Z-axis direction by the length H4. Moreover, the third portion 31a3, which is the inner surface 31a at

the downstream end portion 35, extends in the Z-axis direction by the length H6.

The inner diameter $\phi 5$ at the downstream end portion 35 of the downstream inner pipe 30 is smaller than the inner diameter $\phi 6$ at the downstream coupling portion

32 of the downstream inner pipe 30. Moreover, the downstream reduced

5 diameter portion 34 has a length H5 in the Z-axis direction, and the second portion

31a2, which is the inner surface 31a of the downstream diameter reduced portion

34, is continuously connected in an arc from the first portion 31a to the third

portion 31a3. The inner diameter of the downstream inner pipe 30 at the

downstream reduced diameter portion 34 is decreased from the downstream

10 coupling portion 32 towards the downstream end portion 35.

[0057]

The thickness D2 of the pipe wall 31 at the downstream coupling portion

32 shown in Figure 9 is not particularly limited, but it is preferably not less than

2 mm from the viewpoint of promoting ease of assembly and increasing product

15 strength. The diameter $\phi 3$ of the downstream inner pipe 30 shown in Figures 9

and 10 is preferably designed to be the same diameter as or smaller than the inner diameter $\phi 1$ of the internal portion 10a of the confluence pipe 10 (cf. Figure 7), so that the downstream inner pipe 30 is fitted to the confluence pipe 10.

[0058]

5 As shown in Figure 9, the downstream inner pipe 30 includes a coupled end surface 33 of the downstream coupling portion 32 perpendicular to the Z-axis direction, and the tip portion 36 of the downstream end portion 35 protrudes so as to be positioned and connected inside the outlet portion 26 (cf. Figure 6). The tip portion 36 includes a tip outer surface 37 formed along the outlet portion inner

10 surface 11a3, and an end surface 39 perpendicular to the tip outer surface 37. The outer surface 31b and the tip outer surface 37 are connected by the stepped surface 38 perpendicular to each surface. The stepped surface 38 of the downstream end portion 35 is in contact with the positioning surface 11a2 of the confluence pipe 10. Moreover, it is preferable that a corner where the stepped

15 surface 38 and the outer surface 31b intersect is chamfered so that the downstream

inner pipe 30 can be easily inserted into the internal portion 10a of the confluence pipe 10 from the liquid supply port 21.

[0059]

In order for the tip portion 36 of the downstream end portion 35 shown in

5 Figures 9 and 10 to be fitted to the outlet portion 26, it is preferable that the diameter $\phi 4$ at the tip portion 36 is designed to be the same as or smaller than the inner diameter $\phi 2$ of the internal portion 10a of the outlet portion 26 (cf. Figure

4). A protruding length H12 of the tip portion 36 is not particularly limited, but it is preferable to be not less than 0.5 mm from the viewpoint of fitting and fixing

10 the tip portion 36 to the outlet portion 26. Moreover, it is preferable that the tip portion 36 of the downstream end portion 35 has a chamfered corner where the tip outer surface 37 and the end surface 39 intersect, so as to easily be fitted to the outlet portion 26.

[0060]

The inner diameter $\phi 6$ at the downstream coupling portion 32, the inner diameter $\phi 5$ at the downstream end portion 35 of the downstream inner pipe 30, and the radius of the arc traced by the second portion 31a2 of the inner surface 31a shown in Figure 9 are not particularly limited. The inner diameter $\phi 6$ is preferably 8 mm to 20 mm, and more preferably 10 mm to 15 mm, from the viewpoint of ease of manufacturing, making the product compact, and satisfactory mixing of the gas with the liquid. The inner diameter $\phi 5$ is preferably 3 mm to 15 mm, and more preferably 5 mm to 8 mm, from the viewpoint of ease of manufacturing, making the product compact, and satisfactory mixing of the gas with the liquid. The radius of the arc traced by the second portion 31a2 shown in Figure 9 may be 15 mm to 20 mm, and preferably 16 mm to 18 mm, from the viewpoint of ease of manufacturing, making the product compact, and satisfactory mixing of the gas with the liquid. Note that the second portion 31a2 of the inner surface 31a may be connected in a straight line from the first portion 31a to the third portion 31a3 without tracing an arc. Moreover, when the pressure of the

liquid and the pressure of the pressurized gas supplied to the inside are high, the radius of the arc traced by the inner diameters $\phi 6$, $\phi 5$ and the second portion 31a2 may be made larger in accordance with the depth D0, the width W0, and the length H0.

5 [0061]

The length H4 of the downstream coupling portion 32, the length H5 of the downstream reduced diameter portion 34, and the length H6 of the downstream end portion 35 shown in Figure 9 are not particularly limited. However, when the entire downstream inner pipe 30 becomes longer in the Z-axis direction, it becomes difficult to insert and assemble the downstream inner pipe 30 into the confluence pipe 10. Moreover, when the entire length of the downstream inner pipe 30 is short, the gas-liquid mixing portion (second flow passage portion 72) where the gas-liquid mixing is performed may not be sufficiently secured. Therefore, the lengths H4, H5, and H6 may be

10

15 appropriately designed from these viewpoints, and for example, the length H4

may be 1 mm to 15 mm, the length H5 may be 7 mm to 20 mm, and the length H6 may be 2 mm to 15 mm. In addition, it is preferable that the length H4 is 1 mm to 5 mm, the length H5 is 5 mm to 12 mm, and the length H6 is 2 mm to 5 mm. Moreover, when the pressure of the liquid or the pressure of the pressurized gas supplied to the inside is high, the lengths H4, H5, H6, H12, and D2 may be made larger in accordance with the depth D0, the width W0, and the length H0.

[0062]

As shown in Figure 11, the upstream inner pipe 50 has a substantially circular tubular shape with the axis Cz as the central axis. As shown in Figure 12, the upstream inner pipe 50 has a substantially constant thickness D3 from the outer surface 51b to the inner surface 51a of the pipe wall 51, and the inner diameter $\phi 7$ at the constricted portion 60 is smaller than the inner diameter $\phi 8$ at both ends in the Z-axis direction, and has a constricted outer shape that has the smallest inner diameter in the upstream inner pipe 50. The thickness D3 of the pipe wall 51 is not particularly limited, but it is preferably equal to the thickness

D2 of the pipe wall 31 at the downstream coupling portion 32 of the downstream inner pipe 30 (cf. Figure 9). Moreover, it is preferable that the diameter of the upstream inner pipe 50 at both ends in the Z-axis direction is equal to the diameter $\phi 3$ of the downstream inner pipe 30, and that it is designed to be the same diameter as or smaller than the inner diameter $\phi 1$ of the internal portion 10a of the confluence pipe 10 (cf. Figure 7) so as to be fitted to the confluence pipe 10. Moreover, the upstream inner pipe 50 schematically includes the upstream end portion 52, the upstream reduced diameter portion 54, the enlarged diameter portion 55, and the upstream coupling portion 57.

10 [0063]

As shown in Figure 12, the first portion 51a1, which is the inner surface 51a at the upstream end portion 52, extends along the Z-axis by the length H7. Moreover, the fourth portion 51a4, which is the inner surface 51a of the upstream coupling portion 57, extends in the Z-axis direction by the length H10. Moreover, the upstream reduced diameter portion 54 has the length H8 in the Z-

15

axis direction, and the second portion 51a2, which is the inner surface 51a of the upstream reduced diameter portion 54, is continuously connected from the first portion 51a1 toward the constricted portion 60 which has the minimum inner diameter of $\phi 7$. The inner diameter of the upstream inner pipe 50 at the upstream reduced diameter portion 54 is decreased from the upstream end portion 52 toward the constricted portion 60. Moreover, the enlarged diameter portion 55 has the length H9 in the Z-axis direction, and the third portion 51a3, which is the inner surface 51a of the enlarged diameter portion 55, is continuously connected from the constricted portion 60 toward the upstream coupling portion 57. The inner diameter of the upstream inner pipe 50 at the enlarged diameter portion 55 expands from the constricted portion 60 toward the upstream coupling portion 57.

[0064]

As shown in Figure 13, a plurality of through holes 56 are bored and formed on the upstream inner pipe 50. Through holes 56 are rotationally symmetrical about the axis Cz, rotated by 90° from each other and equidistantly

disposed in the enlarged diameter portion 55. As shown in Figure 12, the through hole 56 passes through the pipe wall 51 from the outer surface 51b of the enlarged diameter portion 55 toward the internal third portion 51a3, such that its central axis Cg is inclined at the angle $\theta 1$ with respect to the axis Cz. Moreover,

5 the through hole 56 is formed so that the center O1 on the outer surface 51b is disposed by H11 downstream in the Z-axis direction from the position C0 on the Z-axis of the constricted portion 60. For example, the length H11 may be not more than 5 mm. Moreover, the inner diameter $\phi 9$ of the through hole 56 is not particularly limited, but it is preferably smaller than the minimum inner diameter

10 $\phi 7$ of the upstream inner pipe 50, and may be, for example, 2 mm to 7 mm. The angle $\theta 1$ is not limited, but is preferably 20° to 50° .

[0065]

As shown in Figure 12, the upstream inner pipe 50 has the coupled end surface 58 of the upstream coupling portion 57 and the end surface 53 of the

15 upstream end portion 52 perpendicular to the Z-axis direction. The coupled end

surface 58 of the upstream coupling portion 57 is in contact with the coupled end surface 33 of the downstream coupling portion 32. The end surface 53 and the outer surface 51b of the upstream end portion 52 intersect approximately perpendicularly to each other. On the other hand, it is preferable that the corner
5 where the coupled end surface 58 and the outer surface 51b of the upstream coupling portion 57 intersect is chamfered so that the upstream inner pipe 50 can be easily inserted into the internal portion 10a from the liquid supply port 21 of the confluence pipe 10.

[0066]

10 The inner diameter $\phi 8$ at the upstream coupling portion 57 and the upstream end portion 52 of the upstream inner pipe 50 shown in Figure 12 is not particularly limited. The inner diameter $\phi 8$ at the upstream end portion 52 can be designed to be the same value as the inner diameter $\phi 6$ at the downstream coupling portion 32, and it is preferable equal to the inner diameter $\phi 6$ at the
15 downstream coupling portion 32 (cf. Figure 9). With this configuration, when

the upstream coupling portion 57 is connected to the downstream coupling portion 32 inside the confluence pipe 10, the fourth portion 51a4, which is the inner surface of the upstream coupling portion 57, and the first portion 31a1, which is the inner surface of the downstream coupling portion 32, are substantially flush with each other. The term "substantially flush with" used herein means a surface that is smooth enough not to reduce the flow velocity of the liquid flowing inside the internal components; minor irregularities are acceptable. The "substantially flush with" used herein includes cases where there is a step difference of not more than 0.5 mm between the fourth portion 51a4, which is the inner surface of the upstream coupling portion 57, and the first portion 31a1, which is the inner surface of the downstream coupling portion 32.

[0067]

The inner diameter $\phi 7$ at the constricted portion 60 shown in Figure 12 is preferably larger than the inner diameter $\phi 5$ at the downstream end portion 35 of the downstream inner pipe 30 (cf. Figure 9). The inner diameter $\phi 7$ is preferably

5 mm to 20 mm, and more preferably 6 mm to 10 mm, from the viewpoint of ease of manufacturing, making the product compact, and satisfactory mixing of the gas with the liquid.

[0068]

5 The length H7 of the upstream end portion 52, the length H8 of the upstream reduced diameter portion 54, the length H9 of the enlarged diameter portion 55, and the length H10 of the upstream end portion 37 shown in Figure 12 are not particularly limited. However, when the entire upstream inner pipe 50 becomes longer in the Z-axis direction, it becomes difficult to insert and
10 assemble the upstream inner pipe 50 into the confluence pipe 10. Moreover, when the upstream inner pipe 50 becomes longer than the outer diameter of the constricted portion 60, the strength around the constricted portion 60 is reduced.

From these viewpoints, the lengths H7, H8, H9, H10 may be designed as appropriate. For example, the length H7 may be 1 mm to 15 mm, the length H8
15 may be 4 mm to 20 mm, the length H9 may be 4 mm to 20 mm, and the length

H10 may be 1 mm to 15 mm. Preferably, the length H7 is 1 mm to 5 mm, the length H8 is 7 mm to 12 mm, the length H9 is 7 mm to 12 mm, and the length H10 is 1 mm to 5 mm. Moreover, when the pressure of the liquid or the pressure of the pressurized gas supplied to the inside is high, the lengths H7, H8, H9, H10, H11, and D3 may be made larger in accordance with the depth D0, the width W0, and the length H0.

[0069]

Figure 14 is a front view showing the configuration of the bubble generator 2 in which the confluence pipe 10 and internal components (the downstream inner pipe 30 and the upstream inner pipe 50) are assembled. As shown in Figure 14, the minimum inner diameter $\phi 0$ in the liquid introduction portion 20 is larger than the diameter $\phi 3$ of the internal components. Therefore, it is configured so that internal components can be inserted through the liquid supply port 21 of the liquid introduction portion 20. When assembling the bubble generator 2, first, the downstream inner pipe 30 is inserted from the liquid supply port 21, and then the

upstream inner pipe 50 is inserted, and thereby the bubble generator 2 can be assembled in which the downstream inner pipe 30 and the upstream inner pipe 50 are housed inside the confluence pipe 10.

[0070]

5 Figure 17 is a cross-sectional view showing the configuration of the bubble generator 2 in which the confluence pipe 10 and internal components (the downstream inner pipe 30 and the upstream inner pipe 50) are assembled. A screw thread is formed at each of the liquid introduction portion 20, the gas introduction portion 14 and the outlet portion 26, and therefore the fine bubble
10 generating device 1 can be assembled merely by connecting the liquid introduction portion 20 to the faucet 7 with the pipe 4, connecting the gas introduction portion 14 to the compressor 8 with the pipe 5, and connecting the outlet portion 26 to the shower head 7. Therefore, such a fine bubble generating device 1 not only has low manufacturing costs, but also enables reduction in
15 maintenance costs.

[0071]

As shown in Figure 17, the inner diameter $\phi 2$ at the outlet portion 26 is larger than the minimum inner diameter $\phi 5$ in the downstream inner pipe 30. Furthermore, the end surface 39 of the tip portion 36 is perpendicular to the axis Cz of the flow passage 70. In other words, the diameter $\phi 5$ on the downstream side of the flow passage 70 sharply widens to the diameter $\phi 2$ in the generating portion 29. Moreover, in the downstream inner pipe 30, a spot where the minimum inner diameter is $\phi 5$ is located at the tip portion 36 on the most downstream side, and the minimum inner diameter $\phi 5$ is smaller than the minimum inner diameter $\phi 7$ in the upstream inner pipe 50. Therefore, the gas-liquid mixture has the highest flow velocity and becomes in a reduced pressure state when it passes through the tip portion 36 of the downstream inner pipe 30 in the flow passage 70. Therefore, the gas-liquid mixture flowing continuously through the flow passage 70 is sharply pressurized at the generating portion 29 of the outlet portion 26, which causes the gas bubbles contained in the liquid to

collapse more effectively, resulting in a gas-liquid mixture having fine bubbles having a diameter of nano-order level (less than 1 μm).

[0072]

As shown in Figure 17, the internal components include the upstream
5 reduced diameter portion 54, and the first flow passage portion 71, which has a diameter of $\phi 8$ at the uppermost part of the flow passage 70, is reduced in diameter to the minimum diameter $\phi 7$. Moreover, the internal components include the enlarged diameter portion 55, and the second flow passage portion 72 of the flow passage 70 is enlarged to the diameter $\phi 6$. Therefore, in the flow passage 70
10 around the constricted portion 60, the liquid is accelerated and a reduced pressure is created, making it possible to efficiently introduce the gas into the second flow passage portion 72 of the liquid flow passage 70.

[0073]

As shown in Figure 14, the downstream inner pipe 30 and the upstream
15 inner pipe 50 are arranged side by side in the Z-axis direction with the same axis

Cz as the central axis inside the confluence pipe 10. As shown in Figure 15, the flow passage 70 within the internal component passes through to the discharge port 27 of the outlet portion 26, with the same axis Cz as the central axis. As a result, the flow velocity of the gas-liquid mixture flowing through the flow passage 70 is maintained high, and the gas-liquid mixture discharged through the outlet portion can also have suitable hydraulic pressure. Moreover, as shown in Figure 17, it is preferable that the confluence pipe 10 and the internal components are designed so that the constricted portion 60 of the upstream inner pipe 50 is disposed on the XY plane having the central axis Cy of the gas supply port 15. This configuration makes it possible to efficiently introduce the gas into the liquid flow passage.

[0074]

Figure 16 is a cross sectional view in the XY plane having the central axis Cy of the gas supply port 15. As shown in Figure 16, the gap 80 is formed between the outer surface 51b and the inner surface 11a1 of the main body portion

of the confluence pipe 10, so as to surround the outer surface 51b of the constricted portion 60 of the upstream inner pipe 50 from the circumferential direction. Moreover, all through holes 56 extend from the gap 80 to the flow passage 70. Therefore, the gas supplied from the gas supply port 15 into the

5 confluence pipe 10 is supplied to all the through holes 56 through the gap 80, and then supplied to the flow passage 70 through all the through holes 56. The through holes 56 are equidistantly disposed, and the central axis C_g of each through hole 56 is inclined with respect to the central axis C_z of the flow passage, passing through the pipe wall 51 of the enlarged diameter portion 55 (cf. Figure

10 12). With this configuration, the gas introduced into the flow passage 70 is introduced therein more forcefully through the through hole 56. Since the gas is supplied thereto in this manner from all the through holes 56, a strong swirling flow is generated in the second flow passage portion 72, resulting in a gas-liquid mixture containing a large number of bubbles. Therefore, in the present

embodiment, the gas-liquid mixture discharged can be made to contain fine bubbles at a higher concentration by the fine bubble generating device.

[0075]

Moreover, as shown in Figure 17, the downstream inner pipe 30 is disposed so that the stepped surface 38 is in contact with the positioning surface 11a2 of the confluence pipe 10. Moreover, the upstream inner pipe 50 is disposed so that the end surface 53 of the upstream end portion 52 and the stopper surface 11a0 of the confluence pipe 10 are flush with each other. With this configuration, the internal components (the upstream inner pipe 50 and the downstream inner pipe 30) are completely housed within the casing, which is the confluence pipe 10. Therefore, when the bubble generator 2 is connected to the pipes 4, 5, and 6, the internal components are no longer exposed to the outside of the confluence pipe 10, and the product strength of the bubble generator 2 is significantly improved (cf. Figure 18).

15 [0076]

Furthermore, as shown in Figure 17, since the end surface 53 of the upstream end portion 52 is substantially flush with the stopper surface 11a0 of the confluence pipe 10, liquid is less likely to enter between the confluence pipe 10 and the upstream end portion 52, thereby improving the strength of the product.

- 5 As shown in Figure 18, when the pipe 4 and the confluence pipe 10 are screwed to each other so that the end portion of the pipe 4 in contact with the end surface 53 and the stopper surface 11a0, the strong connection between the pipe 4 and the confluence pipe 10 through screwing will make the housing of internal components into the confluence pipe 10 more secure. Moreover, as shown in
- 10 Figure 17, the coupled end surface 58 of the upstream inner pipe 50 is coupled to the coupled end surface 33 of the downstream inner pipe 30 inside the confluence pipe 10 downstream of the gas supply port 15. By coupling the upstream inner pipe 50 to the downstream inner pipe 30 in this position, assembly is made easier and product strength can be ensured. Note that the coupling between the
- 15 upstream inner pipe 50 and the downstream inner pipe 30 does not need to involve

direct contact between the coupled end surfaces; it is sufficient that the coupling is made in such a way that no gap is created that would allow the gas-liquid mixture to leak from the flow passage. For example, airtightness may be improved by coupling them via adhesive or packing. Alternatively, the upstream inner pipe 50 and the downstream inner pipe 30 may be indirectly coupled to each other by disposing another tubular member therebetween.

[0077]

Figure 17 is a cross sectional view in the YZ plane having the central axis Cz of the flow passage 70. As shown in Figure 17, as for the downstream inner pipe 30, the tip portion 36 of the downstream end portion 35 is fitted and coupled to the outlet portion 26 of the confluence pipe 10. This configuration makes it possible to strongly couple between the outlet portion 26 and the downstream inner pipe 30, thereby increasing the pressure resistance of the bubble generator.

2. Moreover, by fitting and coupling, the internal components can be positioned, and assembling of the components becomes easy. Moreover, the tip outer

surface 37 of the tip portion 36 is in contact with the outlet portion inner surface 11a3. Moreover, the stepped surface 38 of the downstream inner pipe 30 is in contact with the positioning surface 11a2. Furthermore, the outer surface 31b of the downstream inner pipe 30 is in contact with the main body portion inner surface 11a1. Accordingly, the downstream inner pipe 30 is fitted to the confluence pipe 10 substantially without gaps except for the chamfered portion, thereby realizing a strong connection between the confluence pipe 10 and the downstream inner pipe 30, and improving the product strength.

[0078]

As shown in Figure 17, the coupled end surface 33 of the downstream coupling portion 32 and the coupled end surface 58 of the upstream coupling portion 57 are substantially perpendicular to the axis Cz of the flow passage 70. This configuration simplifies the assembly of internal components, allows for substantially gapless connection of the coupled end surfaces except for the chamfered portions, and provides excellent pressure resistance. Moreover, since

the downstream coupling portion 32 is coupled to the upstream coupling portion 57 so that the first portion 31a1 on the inner surface is substantially flush with the fourth portion 51a4 on the inner surface of the upstream coupling portion 57, the pressure resistance of the fine bubble generating device can be improved.

- 5 Moreover, the outer surface 51b of the upstream coupling portion 57 and the outer surface 51b of the upstream end portion 52 of the upstream inner pipe 50 are in contact with the inner surface 11a1 of the main body portion. Accordingly, the downstream inner pipe 50 is fitted to the confluence pipe 10 substantially without gaps except for the chamfered portion and the gap 80, thereby realizing a strong
- 10 connection between the confluence pipe 10 and the upstream inner pipe 50, and improving the product strength.

[0079]

- Note that, in the present embodiment, the confluence pipe 10 and the internal components (the downstream inner pipe 30 and the upstream inner pipe
- 15 50) are fitted and connected to each other, but they may also be fixed using

adhesive or the like. However, from the viewpoint of eliminating a possibility of adhesive fragments or the like being mixed into the gas-liquid mixture, it is preferable to design these components to be of a suitable size so as to be fitted snugly into the confluence pipe 10 without the use of adhesives, thereby achieving
5 sufficient fixing strength.

[0080]

As described above, according to the fine bubble generating device 1, the fine bubble generating device 1 mixes pressurized gas with the liquid flowing through the channel 70 inside the bubble generator 2, and can effectively
10 discharge a gas-liquid mixture containing fine bubbles with a nano-order-level diameter. In other words, the gas-liquid mixture flowing from the flow passage 70 generates fine bubbles in the generating portion 29. The flow path 70 can be easily formed by using the confluence pipe 10 as a casing and inserting the downstream inner pipe 30 and the upstream inner pipe 50 from the liquid supply
15 port 21. Therefore, the bubble generator 2 can easily be assembled.

Furthermore, since the downstream inner pipe 30 and the upstream inner pipe 50 can be strongly coupled inside the confluence pipe 10, it is not only resistant to external impacts but also has excellent pressure resistance against the fluid flowing through the flow passage.

5 [0081]

The present invention is not limited to the embodiments described above, and its technical scope also includes various design modifications that do not depart from the subject matter of the invention as described in the claims.

[0082]

10 The size of the fine bubble generating device and the number of the through holes are appropriately adjusted in accordance with factors such as the liquid flow velocity, the diameter of the flow passage, and the pressure of the gas being mixed. For example, when the fine bubble generating device is used in fields such as agriculture where it is necessary to release the gas-liquid mixture
15 containing a large number of fine bubbles, the bubble generator may have the

length H0 exceeding 30 cm and the width W0 exceeding 15 cm. Note that, if sufficient product strength can be ensured, the length H0 may be increased relative to the width W0 to ensure a longer gas-liquid mixing portion 72.

[0083]

5 Moreover, in the embodiment described above, the internal components are divided into two parts, such as the upstream inner pipe and the downstream inner pipe, but they may be divided into three or more parts and housed inside the confluence pipe.

[0084]

10 Next, a method for manufacturing the fine bubble generating device 1 according to the embodiment of the present invention will be described.

[0085]

 In this manufacturing method, the confluence pipe 10, the downstream inner pipe 30, and the upstream inner pipe 50 are each formed as independent
15 components, and then, in the assembly process, the downstream inner pipe 30 and

the upstream inner pipe 50 are housed inside the confluence pipe 10 to be assembled. In other words, this manufacturing method includes: forming a confluence pipe 10 as an independent component and including a liquid introduction portion 20 configured to supply liquid to an inside, a gas introduction portion 14 configured to supply gas to the inside, and an outlet portion 26 configured to generate fine bubbles and exhaust a gas-liquid mixture containing the fine bubbles; forming a downstream inner pipe 30 disposed on a downstream side in the direction of the flow of the liquid, as an independent component; forming an upstream inner pipe 50 disposed on an upstream side in the direction of the flow of the liquid and having a through hole 56 bored and formed for introducing gas supplied from the gas introduction portion 14, as an independent component; and assembling and housing the downstream inner pipe 30 and the upstream inner pipe 50 communicating with the downstream inner pipe 30 inside the formed confluence pipe 10 so that the formed upstream inner pipe 50 and the formed downstream inner pipe 30 are coaxially disposed and form a flow passage

for the liquid supplied from the liquid introduction portion 20 to flow to the outlet portion 26.

[0086]

According to the fine bubble generating device 1 manufactured by this method, the gas is mixed to the liquid flowing through the flow passage in the bubble generator 2, and the gas-liquid mixture containing the fine bubbles having a bubble diameter of a nano order level can be efficiently discharged. This bubble generator 2 is configured so that a casing formed of the confluence pipe 10 as an independent component, inside which internal components are disposed.

The internal components are assembled so that the upstream inner pipe 50 and the downstream inner pipe 30, which are formed as independent components, are housed and coupled inside the confluence pipe 10. Assembly operation of introducing long tubular members into the inside of another tubular member is extremely complicated, but assembling can be facilitated as internal component is divided into a plurality of components. Moreover, pressure resistance is

ensured by coupling the upstream inner pipe 50 and the downstream inner pipe 30 to each other inside the confluence pipe 10. Furthermore, since the bubble generator 2 is formed so that the internal components are housed inside the confluence pipe 10, the product strength is improved, and connection to the piping is also easier. Therefore, the fine bubble generating device 1 not only has low manufacturing costs, but also enables reduction in maintenance costs.

[0087]

The forming of the downstream inner pipe includes forming the upstream inner pipe 30 including a downstream coupling portion 32 coupled to the upstream inner pipe 50, a downstream end portion 35 connected inside the outlet portion 26, and a downstream reduced diameter portion 34 having an inner diameter reduced from the downstream coupling portion 32 towards the downstream end portion 34. The forming of the upstream inner pipe preferably includes forming the upstream inner pipe 50 including an upstream reduced diameter portion 54 having an inner diameter reduced towards the downstream side, an enlarged

diameter portion 55 having an inner diameter enlarged from the upstream reduced diameter portion 54 towards the downstream side, and an upstream coupling portion 57 coupled to the downstream coupling portion 32, and disposing the through hole 56 in the enlarged diameter portion 55.

5 [0088]

Preferably, the forming of the downstream inner pipe or the forming of the upstream inner pipe includes forming the minimum inner diameter of the downstream inner pipe 30 to be smaller than the minimum inner diameter of the upstream inner pipe 50. The forming of the confluence pipe includes forming

10 the outlet portion 26 so as to have at least a portion larger than the minimum inner diameter of the downstream inner pipe 30.

[0089]

Preferably, the assembling includes fitting and coupling the downstream end portion 35 of the downstream inner pipe 30 to the outlet portion 26 of the

15 confluence pipe 10.

[0090]

Preferably, the assembling includes coaxially disposing a central axis of the flow passage 70 in the downstream reduced diameter portion 24 of the downstream inner pipe 30 with a central axis of the flow passage 70 in the upstream reduced diameter portion 54 of the upstream inner pipe 50.

[0091]

Preferably, the assembling includes coupling the upstream coupling portion 57 so that an inner surface of the downstream coupling portion 32 of the downstream inner pipe 30 is substantially flush with an inner surface of the upstream coupling portion 57 of the upstream inner pipe 50.

[0092]

Preferably, the assembling includes coupling an end surface 53 of the upstream coupling portion 57 of the upstream inner pipe 50 to an end surface 33 of the downstream coupling portion 32 of the downstream inner pipe 30, the end

surfaces being substantially perpendicular to the central axis of the flow passage

70 in the upstream reduced diameter portion 54 of the upstream inner pipe 50.

[0093]

Preferably, the forming of the upstream inner pipe includes forming the
5 upstream inner pipe 50 so that the through hole 56 is inclined with respect to the
central axis of the flow passage 70 in the upstream reduced diameter portion 54
and passes through a pipe wall of the enlarged diameter portion 55.

[0094]

Preferably, the forming of the upstream inner pipe includes forming a
10 plurality of the through holes 56 disposed equidistantly along a circumferential
direction of the enlarged diameter portion 55.

[0095]

Preferably, the assembling includes forming a gap 80 between outer
surfaces of the upstream reduced diameter portion 54 of the upstream inner pipe
15 50 and the enlarged diameter portion 55 and an inner surface of the confluence

pipe 10 so that the plurality of through holes 56 extend from the gap to the flow passage 70.

[0096]

Preferably, the forming of the confluence pipe includes respectively

5 forming screw threads 21, 16, 28 to be threadedly engaged with other pipes in the liquid introduction portion 20, the gas introduction portion 14, and the outlet portion 26.

Example

[0097]

10 The present invention will be described in more detail below with reference to examples, but the present invention is not limited in any way by these examples.

[0098]

[Example 1]

1. Measurement (1) of particle diameter and the like of fine bubbles contained in gas-liquid mixture

A gas-liquid mixture M was generated using the fine bubble generating device 1 according to the present invention, and the particle diameter distribution of the fine bubbles contained in the gas-liquid mixture M was measured. A nanoparticle analysis system (model number: NanoSight NS300, made by Malvern Ltd., UK) was used to measure the particle diameter distribution of the fine bubbles. As the fine bubble generating device 1, the device according to the embodiment shown in Figure 1 was used, and measurements were performed by connecting the bubble generator 2 with the compressor 8 and the shower head 3 as the gas supply means.

[0099]

Specifically, the confluence pipe 10, the downstream inner pipe 30, and the upstream inner pipe 50 shown in Figure 2 were assembled and used as the bubble generator 2. The Confluence pipe 10 of the bubble generator 2 used

herein has a roughly hexagonal prism shape as shown in Figures 4 to 7, and is made of stainless steel with a length H0 (total length) of 55 mm and a depth D0 of 25 mm. The length H1 of the liquid introduction portion 20 is 10 mm, the length H2 of the main body portion 12 is 35 mm, the protruding length H3 of the outlet portion 26 is 10 mm, the inner diameter $\phi 1$ of the internal portion 10a of the main body portion 12 is 18 mm, the inner diameter $\phi 2$ of the internal portion 10a of the outlet portion 26 is 14 mm, the screw thread 22 of the liquid introduction portion 20 is a female screw of G1/2 (Japanese industrial standard), and the screw thread 28 of outlet portion 26 is a male screw of G1/2 (Japanese industrial standard). The confluence pipe 10 was formed by forming the gas introduction portion 14 on the main body 12 of this stainless steel pipe, which has the female thread 16 of Rc1/8 (Japanese industrial standard).

[0100]

Moreover, the downstream inner pipe 30 used herein is a stainless steel pipe having a cylindrical outer shape as shown in Figures 8 to 10, processed to

have the following configuration: the diameter $\phi 3$ is 18 mm, the length H4 of the downstream coupling portion 32 is 2 mm, the length H5 of the downstream reduced diameter portion 34 is 10 mm, the length H6 of the downstream end portion 35 is 3 mm, the diameter $\phi 4$ at the tip portion 36 is 14 mm, the inner

5 diameter $\phi 6$ at the downstream coupling portion 32 is 13 mm, the inner diameter $\phi 5$ at the downstream end portion 35 is 6.5 mm, and the radius of the arc traced by the second portion 31a of the inner surface 31a is 17.01.

[0101]

Moreover, the upstream inner pipe 50 used herein is a stainless steel pipe

10 having the diameter of $\phi 3$ of 18 mm and the wall thickness D3 of 2.5 mm, which has a cylindrical outer shape as shown in Figures 11 to 13 and is processed to have the following configuration: the length H7 of the upstream end portion 52 is 2 mm, the length H8 of the upstream reduced diameter portion 54 is 8 mm, the length H9 of the enlarged diameter portion 55 is 8 mm, the length H10 of the

15 upstream coupling portion 57 is 2 mm, the inner diameter $\phi 8$ of the upstream end

portion 52 and the upstream coupling portion 57 is 13 mm, the minimum inner diameter $\phi 7$ is 8 mm, the inner diameter $\phi 9$ of the four through hole 56 are respectively 3 mm, the inclined angle $\theta 1$ of each through hole 56 is 30° , and the distance H11 between the center O1 on the outer surface 51b of the through hole

5 56 and the position C0 of the minimum inner diameter $\phi 7$ is 2 mm.

[0102]

Moreover, an air compressor SR-045 (made by Fujiwara Sangyo Co., Ltd., model number: SRL04SPT-01) was used as the compressor 8 and connected to the bubble generator 2 through the pipe 5. A tap from the municipal water

10 supply was used as the faucet, and a hose was connected directly to the tap, which is then connected to the bubble generator 2 through the pipe 4. A shower head including a water spray plate with water discharge holes having a small diameter, that is, 0.3 mm (made by Arromic CO., LTD, product name: pro shower clear ProC-48N) was used as the shower head 5.

15 [0103]

Conditions of an experiment were such that a pressurized gas G is air, and a pressure of the pressurized gas caused by a compressor is 0.19 MPa. Moreover, the pressure of a liquid L supplied from the faucet 6 to the bubble generator 2, that is water pressure, was set to 0.15 MPa, and the flow rate of water was set to

5 20 L/min.

[0104]

[Comparison example]

2. Measurement (2) of particle diameter and the like of fine bubbles contained in gas-liquid mixture

10 As a comparative example, a gas-liquid mixture M was generated using the conventional fine bubble generating device described in Patent Literature 1 under the same experimental conditions as in the above-described example, and the particle diameter distribution of the fine bubbles contained in the gas-liquid mixture M was measured. In the comparative example, the fine bubble

generating device 101 shown in Figure 19 was used as the conventional fine bubble generating device described in Patent Literature 1.

[0105]

Specifically, for the bubble generator 102 of the fine bubble generating device 101, the first tubular body 130 used herein was made of rigid PVC pipe having the diameter of $\phi 103$ of 18 mm, the inner diameter of $\phi 108$ of 13 mm, and the wall thickness of 2.5 mm, and the second tubular body 150 used herein was made of rigid PVC pipe having the outer diameter of 24 mm, the inner diameter of $\phi 102$ of 18 mm, and the wall thickness of 3 mm. The total length H100 of the bubble generator 102 was 20.6 cm. The first tubular body 130 was formed by drawing down the outer periphery of the portion where the diameter is reduced on the upstream side until the minimum inner diameter $\phi 107$ was 8 mm. The downstream PVC pipe was then drawn down and cut so that the end portion having the minimum inner diameter $\phi 105$ of 6.4 mm was exposed. Moreover, four through holes 156 having the diameter of 2.5 mm were formed in the outer

wall of the first tubular body 130 at approximately 90-degree angle intervals.

The first tubular body 130 was inserted into the cylindrical casing 110, and the end portions of the cylindrical body were tightened with nuts 120 and spacers to securely fix the first tubular body 130 to the casing 110 in an airtight manner.

- 5 The pipe 4 connected to the faucet was connected to the first tubular body 130 through the liquid introduction portion 20, which is an adapter. Moreover, the pipe 5 connected to the compressor 8 was connected to the gas introduction portion formed in the casing 110. The pipe 6 connected to the shower head was connected to the second tubular body 150.

10 [0106]

In the examples and comparative examples, five measurements were taken for each gas-liquid mixture. The results are shown in Table 1.

[0107]

[Table 1]

Measurement item	Example	Comparison
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		example
Average bubble diameter (nm)	114.2 (± 3.3)	120.9 (± 4.9)
Standard deviation (SD) (nm)	39.0 (± 2.3)	47.1 (± 2.4)
D90 (nm)	167.0 (± 10.1)	185.1 (± 17.6)
Particle concentration (particles/mL)	7.14×10^7 ($\pm 2.15 \times 10^6$)	3.22×10^7 ($\pm 1.98 \times 10^6$)

[0108]

As shown in Table 1, it was found that by using the fine bubble generating device 1 according to the example, it is possible to obtain the gas-liquid mixture containing many fine bubbles at the nano-order level (bubble diameter less than 1 μm). Specifically, in the gas-liquid mixed water obtained with the fine bubble generating device 1 of the example, the average bubble diameter was 114.2 nm, the standard deviation (SD) of the bubble particle diameter in the measurement was 39.0, and these fine bubbles were present at an average particle concentration

of 7.14×10^7 particles per 1 mL. Moreover, in the examples, 90% of the bubbles in the gas-liquid mixture were not more than 167.0 nm. In contrast, the gas-liquid mixture obtained in the comparative example had an average bubble particle diameter of 120.9 nm, a standard deviation (SD) of bubble particle diameter in the measurement of 39.0, and contained these fine bubbles at an average particle concentration of 3.22×10^7 particles per 1 mL. In the comparative example, 90% of the bubbles in the gas-liquid mixture were not more than 185.1 nm.

[0109]

From these results, it was found that the fine bubble generating device 1 according to the example produces fine bubbles that are finer and more concentrated in the resulting gas-liquid mixture than the comparative example. Moreover, while the fine bubble generating device 101 in the comparative example has a total length H100 of 20.6 cm, the fine bubble generating device 1 according to the example has a total length H0 of 55 mm. Despite being smaller

by more than 30% compared to the conventional device, it was confirmed that it can withstand the pressure of air G and water M under similar conditions. Moreover, it was confirmed that the fine bubble generating device 1 according to the example has fewer parts and fewer manufacturing steps than the fine bubble
5 generating device 101 according to the comparative example.

Industrial Applicability

[0110]

The fine bubble generating device according to the present invention is
10 used to produce a gas-liquid mixture containing fine bubbles, and may be preferably used in the field of beauty and health, the field of agriculture and other fields.

Reference Signs List

15 [0111]

	1	fine bubble generating device
	2	bubble generator
	10	confluence pipe
	10a	internal portion
5	10b	pipe wall
	11a	inner surface
	11a0	stopper surface
	11a1	main body portion inner surface
	11a2	positioning surface
10	11a3	outlet portion inner surface
	11b	outer surface
	11b1	first surface
	11b2	second surface
	11b3	third surface
15	11b4	fourth surface

	11b5	fifth surface
	11b6	sixth surface
	11c1	first end surface
	11c2	second end surface
5	11c3	distal end surface
	12	main body portion
	14	gas introduction portion
	15	gas supply port
	16	screw threads
10	20	liquid introduction portion
	21	liquid supply port
	22	screw thread
	26	outlet portion
	27	discharge port
15	28	screw thread

	29	generating portion
	30	downstream inner pipe
	31	pipe wall
	31a	inner surface
5	31a1	first portion
	31a2	second portion
	31a3	third portion
	31b	outer surface
	32	downstream coupling portion
10	33	end surface
	34	downstream reduced diameter portion
	35	downstream end portion
	36	tip portion
	37	tip outer surface
15	38	stepped surface

	39	end surface
	50	upstream inner pipe
	51	pipe walls
	51a	inner surface
5	51a1	first portion
	51a2	second portion
	51a3	third portion
	51a4	fourth portion
	51b	outer surface
10	52	upstream end portion
	53	end surface
	54	upstream reduced diameter portion
	55	enlarged diameter portion
	56	through hole
15	57	upstream coupling portion

	58	end surface
	60	constricted portion
	70	flow passage
	71	first flow passage portion
5	72	second flow passage portion (gas-liquid mixing portion)
	80	gap
	3	shower head
	4, 5, 6	pipe
	7	liquid supply source
10	8	gas supply unit
	L	liquid
	G	pressurized gas
	M	gas-liquid mixture
	101	fine bubble generating device
15	102	bubble generator

110	casing
120	nut
130	first tubular body
150	second tubular body

Claims

1. A fine bubble generating device including a bubble generator configured to generate fine bubbles by mixing a liquid continuously supplied from a liquid supply source and a gas supplied from a gas supply unit, and to
5 discharge a gas-liquid mixture obtained by mixing the fine bubbles and the liquid with each other,

the bubble generator comprising:

a confluence pipe formed as an independent component and having a liquid introduction portion configured to supply the liquid to an inside, a gas
10 introduction portion configured to supply the gas to the inside, and an outlet portion configured to generate the fine bubbles and exhaust the gas-liquid mixture containing the fine bubbles; and

a tubular internal component assembled and housed inside the confluence pipe, and having therein a flow passage that allows the liquid supplied from
15 the liquid introduction portion to flow to the outlet portion, wherein

the internal component includes

a downstream inner pipe formed as an independent component and disposed

on a downstream side in a direction of flow of the liquid, and an upstream

inner pipe formed as an independent component and disposed on an

5 upstream side,

the upstream inner pipe has a through-hole bored and formed for

introducing the gas supplied from the gas introduction portion into the flow

passage,

the downstream inner pipe is coupled to the upstream inner pipe inside the

10 confluence pipe, and

the flow passage allows communication between the upstream inner pipe

and the downstream inner pipe substantially along the same axis from the

liquid introduction portion to the outlet portion.

2. The fine bubble generating device according to claim 1, wherein

the downstream inner pipe includes a downstream coupling portion coupled to the upstream inner pipe, a downstream end portion connected inside the outlet portion, and a downstream reduced diameter portion having an inner diameter reduced from the downstream coupling portion towards the downstream end portion,

the upstream inner pipe includes an upstream reduced diameter portion having an inner diameter reduced towards the downstream side, an enlarged diameter portion having an inner diameter enlarged from the upstream reduced diameter portion towards the downstream side, and an upstream coupling portion coupled to the downstream coupling portion, and the through hole is disposed in the enlarged diameter portion.

3. The fine bubble generating device according to claim 1, wherein a minimum inner diameter of the downstream inner pipe is smaller than a minimum inner diameter of the upstream inner pipe, and

the outlet portion has at least a portion larger than the minimum inner diameter of the downstream inner pipe.

4. The fine bubble generating device according to claim 2, wherein the downstream end portion is fitted and coupled to the outlet portion.
- 5 5. The fine bubble generating device according to claim 2, wherein a central axis of the flow passage in the downstream reduced diameter portion is coaxially disposed with a central axis of the flow passage in the upstream reduced diameter portion.
6. The fine bubble generating device according to claim 2, wherein the
10 downstream coupling portion is coupled to the upstream coupling portion so that its inner surface is substantially flush with an inner surface of the upstream coupling portion.
7. The fine bubble generating device according to claim 2, wherein an end
15 surface of the downstream coupling portion and an end surface of the upstream coupling portion are coupled to each other, the end surfaces being

substantially perpendicular to the central axis of the flow passage in the upstream reduced diameter portion.

8. The fine bubble generating device according to claim 2, wherein the through hole is inclined with respect to the central axis of the flow passage in the upstream reduced diameter portion and passes through a pipe wall of the enlarged diameter portion.
9. The fine bubble generating device according to claim 2, wherein a plurality of the through holes are disposed equidistantly along a circumferential direction of the enlarged diameter portion.
10. The fine bubble generating device according to claim 2, wherein a gap is formed between outer surfaces of the upstream reduced diameter portion and the enlarged diameter portion and an inner surface of the confluence pipe, and each through hole extends from the gap to the flow passage.

11. The fine bubble generating device according to claim 1, wherein screw threads to be threadedly engaged with other pipes are respectively formed in the liquid introduction portion, the gas introduction portion, and the outlet portion.
- 5 12. A method for manufacturing a fine bubble generating device, the fine bubble generating device configured to generate fine bubbles by mixing a liquid continuously supplied from a liquid supply source and a gas supplied from a gas supply unit, and to discharge a gas-liquid mixture obtained by mixing the fine bubbles and the liquid with each other, the method comprising:
- 10 forming a confluence pipe as an independent component including a liquid introduction portion configured to supply the liquid to an inside, a gas introduction portion configured to supply the gas to the inside, and an outlet portion configured to generate the fine bubbles and exhaust the gas-liquid mixture containing the fine bubbles;
- 15

forming a downstream inner pipe disposed on a downstream side in a direction of flow of the liquid, as an independent component;

forming an upstream inner pipe disposed on an upstream side in a direction of flow of the liquid and having a through hole bored and formed for

5 introducing the gas supplied from the gas introduction portion, as an independent component; and

assembling and housing the downstream inner pipe and the upstream inner pipe communicating with the downstream inner pipe inside the formed

confluence pipe so that the formed upstream inner pipe and the formed downstream inner pipe are coaxially disposed and form a flow passage for

10 the liquid supplied from the liquid introduction portion to flow to the outlet portion.

13. The method for manufacturing a fine bubble generating device according to claim 12, wherein

the forming of the downstream inner pipe includes forming the downstream inner pipe including a downstream coupling portion coupled to the upstream inner pipe, a downstream end portion connected inside the outlet portion, and a downstream reduced diameter portion having an inner diameter reduced from the downstream coupling portion towards the downstream end portion, and

the forming of the upstream inner pipe includes forming the upstream inner pipe including an upstream reduced diameter portion having an inner diameter reduced towards the downstream side, an enlarged diameter portion having an inner diameter enlarged from the upstream reduced diameter portion towards the downstream side, and an upstream coupling portion coupled to the downstream coupling portion, and disposing the through hole in the enlarged diameter portion.

14. The method for manufacturing a fine bubble generating device according to claim 12, wherein

the forming of the downstream inner pipe or the forming of the upstream inner pipe includes forming a minimum inner diameter of the downstream inner pipe to be smaller than a minimum inner diameter of the upstream inner pipe, and

5 the forming of the confluence pipe includes forming the outlet portion so as to have at least a portion larger than the minimum inner diameter of the downstream inner pipe.

15. The method for manufacturing a fine bubble generating device according to claim 13, wherein the assembling includes fitting and coupling the
10 downstream end portion of the downstream inner pipe to the outlet portion of the confluence pipe.

16. The method for manufacturing a fine bubble generating device according to claim 13, wherein the assembling includes coaxially disposing a central axis of the flow passage in the downstream reduced diameter portion of the

downstream inner pipe with a central axis of the flow passage in the upstream reduced diameter portion of the upstream inner pipe.

17. The method for manufacturing a fine bubble generating device according to claim 13, wherein the assembling includes coupling the upstream coupling
5 portion so that an inner surface of the downstream coupling portion of the downstream inner pipe is substantially flush with an inner surface of the upstream coupling portion of the upstream inner pipe.
18. The method for manufacturing a fine bubble generating device according to claim 13, wherein the assembling includes coupling an end surface of the
10 downstream coupling portion of the downstream inner pipe to an end surface of the upstream coupling portion of the upstream inner pipe, the end surfaces being substantially perpendicular to a central axis of the flow passage in the upstream reduced diameter portion of the upstream inner pipe.
19. The method for manufacturing a fine bubble generating device according to
15 claim 13, wherein the forming of the upstream inner pipe includes forming

the upstream inner pipe so that the through hole is inclined with respect to the central axis of the flow passage in the upstream reduced diameter portion and passes through a pipe wall of the enlarged diameter portion.

20. The method for manufacturing a fine bubble generating device according to claim 13, wherein the forming of the upstream inner pipe includes forming a plurality of the through holes disposed equidistantly along a circumferential direction of the enlarged diameter portion.
21. The method for manufacturing a fine bubble generating device according to claim 13, wherein the assembling includes forming a gap between outer surfaces of the upstream reduced diameter portion and the enlarged diameter portion of the upstream inner pipe and an inner surface of the confluence pipe so that the plurality of the through holes extend from the gap to the flow passage.
22. The method for manufacturing a fine bubble generating device according to claim 12, wherein the forming of the confluence pipe includes respectively

forming screw threads to be threadedly engaged with other pipes in the liquid introduction portion, the gas introduction portion, and the outlet portion.