Ultrafine Bubble Generator

FIELD OF THE INVENTION

[0001]

The present invention relates to a member or tool for the generation of ultrafine bubbles in fluids or liquids.

BACKGROUND ART

[0002]

In recent years, attention has been directed to technology of making use of fine bubbles in a liquid. These bubbles-in-a-liquid are broken down into a micro-bubble, an ultrafine bubble (often called nanobubble) or the like. According to the ISO standard, the ultrafine bubble refers to an extremely fine bubble having a diameter in nanometer unit of no greater than or less than 1 μm (1/1000 mm) in a liquid. In the present disclosure, the term "ultrafine bubble(s) (or nanobubble(s))" is used in this sense.

[0003]

Recently, technology of using ultrafine bubbles in particular in various fields is under study and now in use as well. For instance, they are applied to showers for domestic or commercial use for the purpose of easily moisturizing the skin or cleaning the skin of dirt or smear, or they are used as a cooling fluid for a cutter of machine tools or a cooling fluid within the radiator of an engine for the purpose of enhancing cooling efficiency or providing an fuel injector of an engine with a ultrafine bubble generator for the purpose of passing a liquid fuel through it thereby enhancing the fuel efficiency of the engine. In addition, searches for potential applications of them to a variety of fields such as washing of vegetables, growth of agricultural crops and paint formulation are under way.

[0004]

To take advantage of ultrafine bubbles, technology (apparatus and method) of generating them is in need. The actual substance of ultrafine bubbles has yet to be completely clarified, and the structure of apparatus for generating them still remains complicated and its production cost (hence sales price) remains high as well. For this reason, apparatuses for generating ultrafine bubbles for research and industrial purposes are prima facie reduced down to practice, but ultrafine bubble generation equipment that can be used simply and easily in other fields, for instance, at home is not yet practiced.

[0005]

Some proposals are now made of how to form and generate nanobubbles in simpler and easier ways. For example, Patent Publication 1 proposes in [0027] that to "provide a nanobubble production apparatus capable of nanobubbles in a simple and easy way with no use of massive equipment", microbubbles having a diameter range of 4 to 100 μm are first generated under a given pressure, and nanobubbles having a diameter range of no greater than 100 nm are then generated in a liquid by the actions of a slit plate and an impinging plate spaced away from a given distance L (see [0033] and [0034]).

[0006]

For the proposal of Patent Publication 1, however, two units: microbubble production unit and nanobubble production unit must separately be provided because of two-stage nanobubble production comprising a first stage of generating microbubbles and a second stage of generating nanobubbles from these microbubbles.

[0007]

For instance, Patent Publication 2 comes up with an invention relating to the equipment to be attached to a faucet. However, this equipment too remains still massive as an ultrasonic element array substrate 20 is fixed within a liquid flow passage pipe 2 by way of a fixing means 212 to continue to apply ultrasonic vibrations from ultrasonic elements 30b and 30c.

[0008]

By the way, one possibility of ultrafine bubbles is that they are generated in a liquid at rest rather than such a flowing liquid as mentioned above, and used. This is used not only for a study of ultrafine bubbles *per se* but also searches for their application to cosmetics and cooking dressings in daily lives are recently under way. One possible application to mouthwash water is also under consideration.

[0009]

Fine bubble generation equipment of the gas/liquid mixing high shearing type or bubble generation equipment of the pressurized dissolution type is known as technology of generating ultrafine bubbles in a liquid at rest (Non-Patent Publication 1, pp. 59-62).

[0010]

In the former, a liquid within a water tank and air in the interior of a room are sucked by a vortex pump where a gas/liquid mixture fluid is vigorously crushed and mixed in the pump. Then, the resultant gas/liquid mixed phase and swirls and passes through a swirling liquid flow type bubble generator in the bubble generation equipment so much so that the gas is crushed by a strong shearing force for generation of fine bubbles. Subsequently, the gas/liquid mixed phase passes through a swirling liquid flow type bubble generator installed as dispersing equipment in the water tank to release off much finer bubbles in the form of microbubbles or nanobubbles.

[0011]

In the latter, a liquid is pumped from within a water tank by means of an eddy current pump, and air in the interior of a room is introduced in a self-contained manner. Then, the introduced air is dissolved by a pressure device within the equipment and depressurized by a depressurizing nozzle unit down to atmospheric pressure thereby separating off the saturated gas and converting it into fine bubbles.

[0012]

However, these equipments are originally designed with researches and industrial use in mind, so these structures remain complicated with large sizes and high costs. Hence, they are not suited for individual use or domestic use as such cosmetics or cooking dressings as mentioned above.

[0013]

For conventional equipment proposed as equipment for generating ultrafine bubbles in a liquid at rest, it is necessary to convert the generated microbubbles into nanobubbles, as disclosed typically in Patent Publication 3. In turn, this requires that the generated microbubbles be moved along the outer wall surface of a micro- or nano-bubble generator, etc., failing to make the bubble generation setup simple and, hence, use it in a simple and easy manner for such cosmetics or cooking dressings as mentioned above.

PRIOR PUBLICATIONS

Patent Publications

[0014]

Patent Publication 1: JP(A) 2013-34958

Patent Publication 2: JP(A) 2015-93205

Patent Publication 3: JP(A) 2014-231046

Non-Patent Publication

[0015]

Non-Patent Publication 1:
Commissioned by Ministry of Economy, Trade and Industry; Project for promoting international standardization for fiscal 2012 (Heisei 24); Strategic project for accelerating international standardization; "International Standard Joint Research and Development Project" International Standardization Report on Nano-Micro Bubble Technology; March 2013 (Heisei 25) http://www.meti.go.jp/meti_lib/report/2013fy/E003666.pdf

SUMMARY OF THE INVENTION

OBJECTS OF THE INVENTION

[0016]

The present invention has been made bearing the aforesaid problems in mind, and has for its objects to provide an ultra fine bubble generator capable of generating ultra fine bubbles in a liquid without recourse to any means of sucking and supplying a gas (e.g., air) to a liquid for fractionization and being applied to both a flowing liquid and a liquid at rest.

ASPECTS OF THE INVENTION

[0017]

To accomplish the aforesaid object, the present invention relates to the ultra-refinement of air and oxygen contained originally in a liquid.

According to the first aspect, the present invention provides a ultrafine bubble generator comprising a shaft, a cylindrical member mounted on the shaft, and a plurality of triangular column-like protrusions located on an outer periphery of the cylindrical member, characterized in that the ultrafine bubble generator is located inside of a pipe for supplying a liquid;

the triangular columnar-like protrusions are spirally located on the cylindrical member such that a liquid flows spirally around the cylindrical member, and located such that an edge of each triangular column-like protrusion, positioned at a tip end with respect to a spiral liquid flow, is located substantially perpendicularly with respect to the spiral liquid flow, and

a liquid flowing inside of the pipe for supplying a liquid collides with the plurality of triangular column-like protrusions whereby air contained in the liquid is made ultrafine without supplying air from outside the pipe for supplying a liquid to generate ultrafine bubbles.

According to the second aspect, the present invention provides an ultrafine bubble generator comprising a shaft, a cylindrical member mounted on the shaft, and a plurality of triangular column-like protrusions located on an outer periphery of the cylindrical member, characterized in that:

the ultrafine bubble generator is located inside of a tubular member located in a liquid in a vessel and having an opening in at least one end,

the triangular columnar-like protrusions are spirally located on the cylindrical member such that a liquid flows spirally around the cylindrical member, and located such that an edge of each triangular column-like protrusion, positioned at a tip end with respect to a spiral liquid flow, is located substantially perpendicularly with respect to the spiral liquid flow, and

the shaft is rotated by driving a motor using a dry battery or a storage battery as a power source thereby rotating the cylindrical member so that a liquid entering the inside of the tubular member collides with the plurality of triangular column-like protrusions whereby air contained in the liquid is made ultrafine without supplying air from outside the vessel to generate ultrafine bubbles.

According the third aspect, the present invention provides an ultrafine bubble generator, wherein the cylindrical member is formed of a plurality of discs laminated one upon another.

According to the fourth aspect, the present invention provides an ultrafine bubble generator, wherein each triangular column-like protrusion is in proximity to the inner wall of the pipe or tubular member for supplying a liquid and located inside of the pipe or tubular member for supplying a liquid such that collision of the liquid with the triangular column-like protrusions is enhanced.

According to the fifth aspect, the present invention provides an ultrafine bubble generator, wherein the tubular member is provided on its side with an opening for circulating a liquid within and without the tubular member.

ADVANTAGES OF THE INVENTION

[0018]

According to the invention, ultrafine bubbles can be generated in a liquid without recourse to separate suction or supply of a gas such as air, and in both a flowing liquid and a liquid at rest.

BRIEF EXPLANATION OF THE DRAWINGS

[0019]

Fig. 1 shows one embodiment of the invention.

Fig. 2 explains a liquid flow in the invention.

Fig. 3 shows one embodiment of the invention.

Fig. 4 shows one embodiment of the invention.

Fig. 5 shows what state where one embodiment of the invention (Fig. 1) is used in.

Fig. 6 shows one modification of the invention.

Fig. 7 is a view of a disc member in one modification according to the invention.

Fig. 8 is a view of a disc member in one modification according to the invention.

Fig. 9 shows another embodiment of the invention.

Fig. 10 shows yet another embodiment of the invention.

Fig. 11 shows what state another embodiment of the invention is used in.

Fig. 12 shows one example of the shaft in the invention.

Fig. 13 is illustrative of how to generate nano-bubbles in the invention.

Fig. 14 shows one embodiment of the invention.

Fig. 15 is a view of an exemplary protrusion (other than the triangular one) according to the invention, as viewed from above.

Fig. 16 shows an ultrafine bubble generator used in an exemplary experiment according to one embodiment of the invention.

MODES FOR CARRYING OUT THE INVENTION

[0020]

Some embodiments of the ultrafine bubble generator of the invention will now be explained specifically with reference to the accompanying drawings.

[0021]

<u>Embodiment 1</u>

This embodiment relates to the generation of ultrafine bubbles in a liquid flowing inside of a pipe (especially the one for supplying a liquid) such as a water service pipe, a shower pipe, and a hose.

[0022]

As shown in Fig. 1, an ultrafine bubble generator 1 according to the invention comprises a shaft 2 and a cylindrical member 3 attached thereto. A plurality of triangular column-like protrusions 5 (as viewed from above) are provided on the surface (outer periphery) 4 of the cylindrical member 3.

[0023]

For conventional generation of ultrafine bubbles, it was necessary to rely on means for gas generation and gas/liquid mixing in order to maintain provision of ultrasonic vibrations or mix the sucked gas with a liquid to crush the gas under a strong shear force or, alternatively, dissolve the self-contained air and reduce the air down to the atmospheric pressure for precipitation of the saturated gas, as described above. In the invention, on the contrary, the air and oxygen dissolved in the liquid are made ultrafine for the generation of ultrafine bubbles.

[0024]

As well-known in the art, a constant amount of air is dissolved in a liquid. For instance, about 2% by volume of air per volume of water is dissolved in water at 20℃ and 1 atm., or about 24 mg of air as based on weight are dissolved in 1 L of water. Thus, there is a flow created in the liquid with air or oxygen dissolved in it, causing the air or oxygen in the liquid to collide with one another.

[0025]

That is, as shown in Fig. 2, for each of a plurality of triangular column-like protrusions, one edge (indicated by reference numeral 6 in Fig. 2) is located oppositely to the liquid flowing direction, whereupon the liquid is divided by the tip of the edge 6, as indicated by arrow 7. The divided liquids flow along the sides 8 of the triangular column-like protrusion; however, the sides (the ones along the flowing direction) 8 are terminated at the next edge 9 with the result that around these edge 9, the liquid flows turn into turbulences containing flow components flowing in different directions. With the triangular column-like protrusion, the angle of the edge 9 forming both sides 8 and a side 12 opposite to the flowing direction could be narrower than those defined by a rectangular or other polygonal column-like protrusions, making such turbulences 10 likely to occur.

[0026]

Similar flow division and turbulence occur along and around the adjacent triangular column-like protrusions.

[0027]

Because a liquid flows through a pipe (its interior), there is a certain limitation imposed on the moving range. In other words, the flowing direction is limited by the pipe (the liquid is not diffused).

[0028]

Therefore, the liquid collides with a plurality of triangular column-like protrusions 5 where it is divided or sheared, keeping flowing. The resultant liquid flows and turbulences collide repetitively with one another during which process ultrafine bubbles would be formed. Note here that the molecular structure of the liquid may possibly become unstable in this process so that fine bubbles resulting from further collisions and divisions take on minus charges. In turn, this would cause an abrupt shrinkage or contraction of the fine bubbles for transformation of them into ultrafine bubbles.

[0029]

The use of the triangular column-like protrusions could make the liquid flow likely to be divided and get turbulent, as described above. This is the reason that the triangular column-like protrusions 5 are used for the generation of ultrafine bubbles in the invention. While the triangular column-like protrusions 5 may be lined up on the outer periphery of the cylindrical member, as shown in Fig. 3, it is preferable that they are positioned such that the liquid flows and turbulences are easy to collide with one another. Various such configurations are possible, but preference is given to a slightly displaced configuration as shown in Fig. 1.

[0030]

As shown in Fig. 4, a plurality of triangular column-like protrusions could also be located spirally toward the longitudinal direction of the cylindrical member 21, making the liquid flows and turbulences likely to collide with one another.

[0031]

As the distance between the adjacent triangular column-like protrusions becomes too short, it could possibly give rise to interruption of the generation of turbulences or enhanced collisions, resulting in no enhancement of the generation of ultrafine bubbles. With reference to Fig. 13(a), a liquid flow 7a along a triangular column-like protrusion 5a gets turbulent 10a around an edge 9a. As this turbulence 10a is too close to the triangular column-like protrusion 5b, a liquid flow 7b could possibly become weak under the influence of the turbulence 10a with the result that turbulence 10b generated around the edge 9b becomes small. For this reason, it is preferable that the plural triangular column-like protrusions are located at a distance enough to prevent the generated turbulences from getting weak.

[0032]

As shown in Fig. 13(b) as an example, the triangular column-like protrusions 5 may be spaced away from each other at a given distance, for instance, at a distance (A+A/2) in the longitudinal direction of the cylindrical member, which distance is about 1.5 times as long as the perpendicular from an edge 6 of a triangular column-like protrusion 5 to an opposite side face B in the flowing direction, and at a distance (B/2) in the circumferential direction, which distance is about half one side B of the side face of the triangular column-like protrusion 5 opposite to the flowing direction.

[0033]

Alternatively, it is preferable for an enhanced generation of turbulences that the triangular column-like protrusions are configured and located such that the liquid swirls around and passes along the cylindrical member. As shown typically in Fig. 14, the triangle of the triangular column-like protrusion is defined by a vertically oriented isosceles triangle, and a passage through which a liquid passes has a spiral configuration.

[0034]

Preferably in this case, the cylindrical member is provided with blades 24. If the blades are spirally provided, it is then possible to guide or enhance the flow because the liquid swirls around and passes along the cylindrical member.

[0035]

If the blades are mounted on the tip side of the cylindrical member (the tip end direction of the shaft as indicated by reference numeral 13) as shown in Fig. 14, it is then possible to guide the aforesaid flow. Note here that the blades are not necessarily mounted on that tip side; they may be mounted at a central or other portion of the cylindrical member for the purpose of further guiding or enhancing the generated flow.

[0036]

The blade may be continuous (see Fig. 14) or

discontinuous (it may have a break). In either case, the blade may be formed of plural portions.
[0037]
The triangular column-like protrusions configured and located as mentioned above allow the liquid to swirl around and pass along the cylindrical member, and to collide almost vertically with the edges of the triangular column-like protrusions as it flows. By this swirling flow, the generation of turbulence could be enhanced.
[0038]
If the angle, number and size of the triangular column-like protrusions are varied depending on the viscosity, throughput, flow rate, and pressure of the liquid, it is also possible to obtain ultrafine bubbles in any desired (or nearly desired) amount.
[0039]
Referring to the shape of the protrusions, while the triangular column shape is described as one preferable example capable of dividing the liquid flow and turning it into turbulences as well as enhancing the generation of ultrafine bubbles, yet the shape (in section) of the protrusion may not strictly be limited to the precise triangle if it conforms with this purpose; the protrusion may have such a shape as shown typically in Fig. 15.
[0040]
One example of the shaft according to the invention is depicted in Fig. 12. A shaft 2 is preferably provided with a curvature R at its tip end 13 such that upon striking of a liquid flow on that tip end, it flows directly toward the outer periphery of the triangular column-like protrusion 5 for easy collision with it. As shown typically in Fig. 1, it is preferable that the conical portion 14 of the shaft 2 and the outer periphery 4 of the cylindrical member 3 form together a continuum with no step (for instance, such that the diameter of the conical portion 14 is not smaller than the diameter of the cylindrical member 3).
[0041]
Fig. 5 shows an example wherein the ultrafine bubble generator according to the embodiment described herein is located inside of a pipe 15 through which a liquid flows (the pipe is longer than the longitudinal size of the cylindrical member). When a liquid 16 flows through the pipe under a given pressure, it collides with the triangular column-like protrusions as it passes the

generator of the invention so that ultrafine bubbles are generated by way of the aforesaid action. As the triangular column-like protrusions are surrounded by the pipe 15, the liquid passes through a passage created by the triangular column-like protrusions in a confined space at so high speeds that a liquid flow is generated and then collides with the inner wall of the pipe 15, leading to enhanced collision of the divided flows with turbulences and, hence, enhanced generation of ultrafine bubbles. For the purpose of enhancement of such collisions, it is preferable to bring the triangular column-like protrusions proximate to the inner wall of the pipe.

[0042]

Modification 1

The cylindrical member may be formed by connection or lamination of a plurality of disc members 17, as shown typically in Fig. 6

[0043]

Usually, the longer the length of the cylindrical member provided thereon with the triangular column-like protrusions 5, the more the number of collisions of the liquid and air, etc. in the liquid is and, hence, the more the number of generation of ultrafine bubbles is. The shorter this length, the less the number of generation of ultrafine bubbles is. When the cylindrical member is made up of a plurality of disk members 17, the number of generation of ultrafine bubbles may be adjusted by adjusting the number of the disc members mounted.

[0044]

Fig. 7 is a view of a disc member 17 as viewed from three directions. As shown in Fig. 7, the disc member is provided in a central portion with a hole 18 through which the shaft extends, and a portion of this hole 18 adjacent to an outer peripheral portion is provided with a plurality of engaging holes 19 and engaging projections 20 for engaging said disc member with another disc member. Plural triangular column-like protrusions are provided to the outside of the engaging holes to form the disc member.

[0045]

As depicted in Fig. 8, the centers 22 and 23 of the bosses of the engaging holes 19 and engaging projections 20 may be displaced by a certain angle. For instance, when about 10 to 20 disc members 17 are successively joined to one another, they are formed such that the centers 22 and 23 of the bosses of the engaging holes and engaging projections are displaced by about 4.5 to 4.8 degrees. As plural disc members are engaged with one upon another, it causes the outer peripheral protrusions on the adjacent disc members to be so displaced by that angle that the arrangement of the triangular column-like protrusions on the cylindrical member comprising plural disc members will have a spiral configuration.

[0046]

The cylindrical member may be produced by plastic molding, press molding or the like. As the cylindrical member is constructed of a plurality of disc members, it is likely to bring about an outstanding production cost merit as compared with the price of conventional nano-bubble generator in terms of mass production and high cost performance.

[0047]

The disc members may be joined to one another by optional means; for instance, they may be bonded together by means of adhesives or ultrasonic waves.

[0048]

Modification 2

The ultrafine bubbles may also be formed in another embodiment relying upon the principles of the invention. For instance, a plurality of triangular column-like protrusions may be directly attached to, or mounted on, the inner wall of the pipe through which a liquid flows.

[0049]

Embodiment 2

This embodiment relates to the generation of ultra-fine bubbles in a liquid at rest such as cosmetics, dressings or mouthwashes contained in containers.

[0050]

In this embodiment too, the cylindrical member, triangular column-like protrusions and shaft described with reference to Embodiment 1 may be used. An ultrafine bubble generator 101 is configured by attaching to a shaft 102 a cylindrical member 103 having a plurality of triangular column-like protrusions 105 on its outer periphery 104. Note here that this cylindrical member may be formed by laminating disc members one upon another.

[0051]

To allow a liquid to collide with the triangular column-like protrusions 105, the shaft 102 is rotated by a motor 100 thereby rotating the cylindrical member 103 attached to the shaft 102. Such rotation causes the liquid to collide with the triangular column-like

protrusions provided on the cylindrical member 103.
[0052]
There is no large power needed to drive the motor 100 because the ultrafine bubble generator of the invention is constructed of the shaft, cylindrical member and disc members, all reduced in weight. According to the invention, the motor may be driven as by batteries or storage batteries of low source, low power and low voltage (by way of example but not by way of limitation, about 1.2 V). Note here that the power source is not limited to batteries, and the motor may be driven by domestic power sources usually employed at home because low power sources serve well. Referring to one example, when an ultrafine bubble water generator for mouthwash is constructed using a 1.2 V battery, the whole assembly inclusive of that battery may be designed in a weight of about 300 grams and a size of about 10 cm×10cm×15 cm. According to the invention, it is thus possible to make the ultrafine bubble generator smaller in size and weight and more portable than ever before.
[0053]
As mentioned above, as a liquid flows within a pipe, it imposes some limitation on the liquid-moving range. To put it another way, the direction in which the liquid flows is limited by the pipe (the liquid is not diffused). Therefore, there are some sections provided in this embodiment too, in which sections repetitive division and collision of the liquid with a plurality of triangular column-like protrusions are enhanced.
[0054]
With this in mind, the triangular column-like protrusions 105 are surrounded by a tubular member whereby a liquid flow can be generated within a confined space. This in turn enables a fast passage of the liquid through a flow path defined by the triangular column-like protrusions thereby causing effective enhancement of collision of the generated liquid and turbulences within the wall of the tubular member and, hence, enhancing the generation of ultrafine bubbles. For enhancement of this collision, it is preferable that the tubular member is configured to have a longitudinal size enough to cover the triangular column-like protrusions on the cylindrical member or, alternatively, the triangular column-like protrusions is in proximity to the inner wall of the tubular member.
[0055]
It is to be understood that the term “pipe” used

herein includes the so-called piping such as the one used in Embodiment 1, and that the “tubular member” in this embodiment includes a tubular covering member 9.

[0056]

One example of the ultrafine bubble generator 101 according to this embodiment is shown in Fig. 9, and an example wherein a tubular member 107 is used in combination with this is shown in Fig. 10. The tubular member 107 has an opening in its upper surface or bottom surface (lower or bottom surface side 108 in Fig. 10), through which opening a liquid enters inside.

[0057]

As shown in Fig. 10, the tubular member is preferably provided with an opening 109 through which a liquid circulates within and without the tubular member so that the liquid inflow from one surface of the tubular member 107 (lower or bottom surface 108 in Fig. 10) swirls around the cylindrical member and ascends, leaves the opening 109, and again enters the interior of the tubular member from the bottom surface 108 (ascending flow pattern). Alternatively, the liquid inflow from the opening 109 swirls around the cylindrical member and descends, exits out of the bottom surface 108, ascends outside the tubular member, and again enters the tubular member through the opening 109 (descending flow pattern).

[0058]

Such repetitive circulation of the liquid flow provides much more increases in the number of generation of ultrafine bubbles.

[0059]

It is to be noted that the ascending and descending flow patterns may be varied by the inclination of the triangular column-like protrusions. In the ascending flow pattern, the apex of each triangular column-like protrusion (the edge thereof first colliding with the flow) is inclined below the horizon such that an angle between the perpendicular from this apex down to the bottom surface and the horizon becomes about 15 degrees as an example. If the apex of each triangular column-like protrusion is inclined above the horizon, on the contrary, the liquid then flows in the descending flow pattern.

[0060]

Fig. 11 shows one example using the ultrafine bubble generator of the invention together with the tubular member 107, wherein the tubular member surrounding the cylindrical member is submerged in a liquid 112 in a container 110. An arrow 115 stands for the direction of rotation of a motor, and an arrow 114 stands for the direction of a liquid flow. Fig. 11 shows the ascending pattern comprising a repetitive cycle in which a liquid enters the tubular member 107 from the bottom surface 108 in the direction which the arrow 114 stands for and leaves the upper opening 109.

[0061]

In Embodiment 1, the ultrafine bubbles may possibly be less likely to be generated depending on whether or not the liquid throughput is small and the liquid flow rate is low; in this embodiment, however, this problem may be addressed by the regulation of the speed of rotation of the motor.

[0062]

The generation of ultrafine bubbles according to this embodiment may be used for the mixing or stirring of a liquid. For instance, if the generator of the invention is operated with a container having a liquid dressing put in, then it makes vinegar/oil mixing easier.

[0063]

Modification

In this modification too, the cylindrical member may be formed of a plurality of disc members, and may be produced as by plastic molding.

[0064]

The triangular column-like protrusion may be configured such that upon collision with one edge, a liquid keeps flowing while being divided, and the resulting liquid flow and turbulence collide repetitively with it. Alternatively, in addition to those as shown in the drawing, a triangular notch or cutout may be provided on a base or bottom surface with a liquid-striking edge as an apex.

[0065]

It is to be appreciated that while the invention makes it possible to generate ultrafine bubbles without pouring gas into a liquid, the pouring of gas or the like may be used in combination. In other words, the generator and method of the invention may be operated in combination with the pouring of gas such as nitrogen, carbon dioxide or ozone into a liquid.

[0066]

The invention will now be explained with reference to experimental examples of generating ultrafine bubbles.

[0067]

Experimental Example 1

Set out below is an experimental example using Embodiment 1.

(1) An ultrafine bubble generator of the invention was constructed by lamination of 16 disc members, each one having eight triangular column-like protrusions, as shown in Fig. 16, and located in a liquid supply pipe. Through this pipe, industrial purified water stored in a water tank (Reagent: D (Delta) 40) was circulated and supplied 40 times for supply to the ultrafine bubble generator, using the following Circulation Pump: Model NO FP-5S manufactured by Tsurumi Pump Co., Ltd. with a pumping height of MAX 5.5 m and a discharge amount of MAX 35 L

(2) The following was used as the measuring equipment. LM System LM10-HSBT 14 EMCCD Camera, Blue Laser, manufactured by NanoSight Co., Ltd., UK

(3) As can be seen from the following results, the generation of a sufficient number of ultrafine bubbles has been found.
Total Particle Concentration of Ultrafine Bubbles: 1.36×10^{8}/mL
Average Diameter: 217±13.7 nm
Mode Diameter: 152 ±17.8 nm

[0068]

The following is an experimental example using a modification to Embodiment 2.

(1) Cylindrical Member
The cylindrical member was assembled by lamination of 4 disc members, each one having 8 triangular column-like protrusions, and location of each triangular column-like protrusion as shown in Fig. 9 (note here that the number of lamination is different from Fig. 9).

(2) Type and Amount of the Liquid
Industrial purified water was used in an amount of 75 ml.

(3) Flow Rate
The motor was rotated at 20,000 rpm/min. A cycle of rotating the motor for 1 minute and then leaving it for 30 seconds was repeated 10 times with a total operating time of 10 minutes.

(4) Subjects
The number, diameter mode and average diameter of ultrafine bubbles in the liquid were measured.

(5) Measuring Equipment
Use was made of Nanoparticle Analyzer (LM10)

manufactured by Malvern Instrument, UK.

[0069]

The results of experimentation are set out in Table 1.

Table 1

	Embodiment 2 of the Invention, Modification
Total Number of the Ultra-fine Bubbles, mg/L (Note)	7.39×10^8
Model Diameter, nm	100.2
Average Diameter, nm	122.6

Note here that the aforesaid number of ultrafine bubbles is described in terms of the measurements obtained in a 10-fold diluted solution after the generation of ultrafine bubbles.

[0070]

As set out in Table 1, it has been found that there are at least 7.39×10^8/ML (in the 10-fold diluted solution) of ultrafine bubbles (having an average diameter of 122.6 nm and a model diameter of 100.2 nm) obtained in the invention; in another parlance, about 74×10^8 ultrafine bubbles were generated in 1 ml of the liquid (industrial purified water).

[0071]

For the invention disclosed herein, it would be important that turbulence is easy to occur in a liquid flowing along the sides of the triangular column-like protrusions for repetitive collisions of liquid flows and turbulences. To let turbulences occur easily, it would be desirable that the angle between both the edges forming each side and the side opposite to the flowing direction (edges other than the tip edge for dividing the flow of the liquid) remains small. Although this may have some relation to the angle of the tip edge, yet it would be preferable that the angle of one of both edges is less than the right angle (90 degrees). For instance, when the triangular column-like protrusion is lozenge-shaped, the aforesaid turbulence would then be less likely to occur.

[0072]

In the invention disclosed herein, the liquid flows between the triangular column-like protrusions and between the inner wall of the pipe and the protruding points of the triangular column-like protrusions. Although the inner wall of the pipe is somewhat in proximity to the protruding points of the triangular column-like protrusions, yet the liquid is able to flow well between the protrusions due to their triangular column shape, making pressure losses and flow rate reductions less likely to occur. For this reason, the liquid is capable of swirling sufficiently, making division of the liquid and turbulences likely to occur and, hence, ultrafine bubbles likely to be generated. When the projection is lozenge-shaped, on the contrary, there is limitation on the flow path, resulting in pressure losses and flow rate reductions, as compared with the triangular column-like protrusion.

APPLICABILITY TO THE INDUSTRY

[0073]

According to the present invention, ultrafine bubbles so far assumed that they are generated using massive apparatus can be generated very simply and easily and, hence, technologies making use of ultrafine bubbles can be used in many domestic and consumer fields to say nothing of industrial and research fields.

[0074]

According to the present invention, it is possible to generate ultrafine bubbles not only in a flowing liquid but also in a liquid at rest contained in a container.

[0075]

Thus, the applicability of the invention to the industry is very high.

Explanation of the Reference Numerals

[0076]

1, 11, 21, 101: Ultrafine bubble generator
2, 102: shaft
3, 103: Cylindrical member
4, 104: Surface (outer periphery) of cylindrical member 3 or 103
5, 105: Triangular column-like protrusion
6, 9: Edge of Triangular column-like protrusion 5
7: Divided liquid flow, and liquid flow
8: Side of triangular column-like protrusion 5 along the flow direction
10: Turbulence
12: Side of the triangular column-like protrusion opposite to the flow direction
13: Tip end of the shaft
14: Conical portion of the shaft
15: Pipe
16: Liquid flow

17: Disc member
18: Hole through which the shaft passes
19: Engaging hole
20: Engaging projection
22, 23: Center
23: Blade
107: Tubular member
108: Bottom surface side of the tubular member
109: Opening
110: Container
112: Liquid
113: Ultrafine bubble
114: Flow direction of the liquid
115: Direction of rotation of the motor

WHAT IS CLAIMED IS:

1. A ultrafine bubble generator comprising a shaft, a cylindrical member mounted on the shaft, and a plurality of triangular column-like protrusions located on an outer periphery surface of the cylindrical member, characterized in that the ultrafine bubble generator is located inside of a pipe for supplying a liquid;

the triangular columnar-like protrusions are spirally located on the cylindrical member such that a liquid flows spirally around the cylindrical member, and located such that an edge of each triangular column-like protrusion, positioned at a tip end with respect to a spiral liquid flow, is located substantially perpendicularly with respect to the spiral liquid flow, and

a liquid flowing inside of the pipe for supplying a liquid collides with the plurality of triangular column-like protrusions whereby air contained in the liquid is made ultrafine without supplying air from outside the pipe for supplying a liquid to generate ultrafine bubbles.

2. An ultrafine bubble generator comprising a shaft, a cylindrical member mounted on the shaft, and a plurality of triangular column-like protrusions located on an outer periphery surface of the cylindrical member, characterized in that:

the ultrafine bubble generator is located inside of a tubular member located in a liquid in a vessel and having an opening in at least one end,

the triangular columnar-like protrusions are spirally located on the cylindrical member such that a liquid flows spirally around the cylindrical member, and located such that an edge of each triangular column-like protrusion, positioned at a tip end with respect to a spiral liquid flow, is located substantially perpendicularly with respect to the spiral liquid flow, and

the shaft is rotated by driving a motor using a dry battery or a storage battery as a power source thereby rotating the cylindrical member so that a liquid entering the inside of the tubular member collides with the plurality of triangular column-like protrusions whereby air contained in the liquid is made ultrafine without supplying air from outside the vessel to generate ultrafine bubbles.

3. The ultrafine bubble generator according to claim 1 or 2, wherein the cylindrical member is formed of a plurality of discs laminated one upon another.

4. The ultrafine bubble generator according to any one of claims 1 to 3, wherein each triangular column-like protrusion is in proximity to the inner wall of the pipe or tubular member for supplying a liquid and located inside of the pipe or tubular member for supplying the liquid such that collision of the liquid with the triangular column-like protrusions is enhanced.

5. The ultrafine bubble generator according to claim 2, wherein the tubular member is provided on its side with an opening for circulating a liquid within and without the tubular member.

ABSTRACT OF THE DISCLOSURE

An object of the invention is to provide an ultrafine bubble generator that is capable of generating ultrafine bubbles in a liquid without separately sucking or supplying a gas such as air and being applied to both a flowing liquid and a liquid at rest. The generator comprises a shaft and a cylindrical member attached to the shaft. The cylindrical member is provided on its outer periphery surface with a plurality of triangular column-like protrusions. The ultrafine bubble generator is located inside of a pipe or tubular member through which a liquid flows. Without sucking or supplying air into or to the liquid, the air contained in the liquid collides with the plurality of triangular column-like protrusions to generate ultrafine bubbles.

Fig. 1

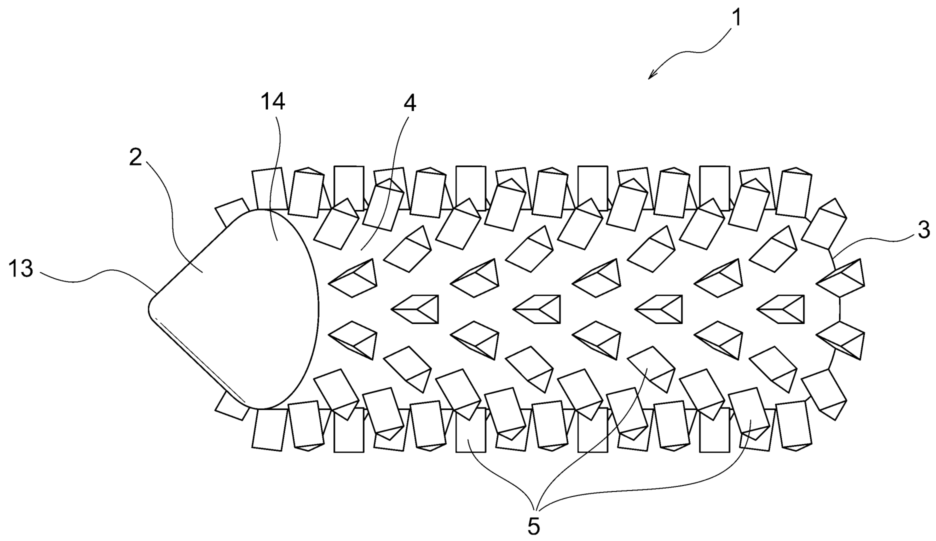


Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

(a)

(b)

(c)

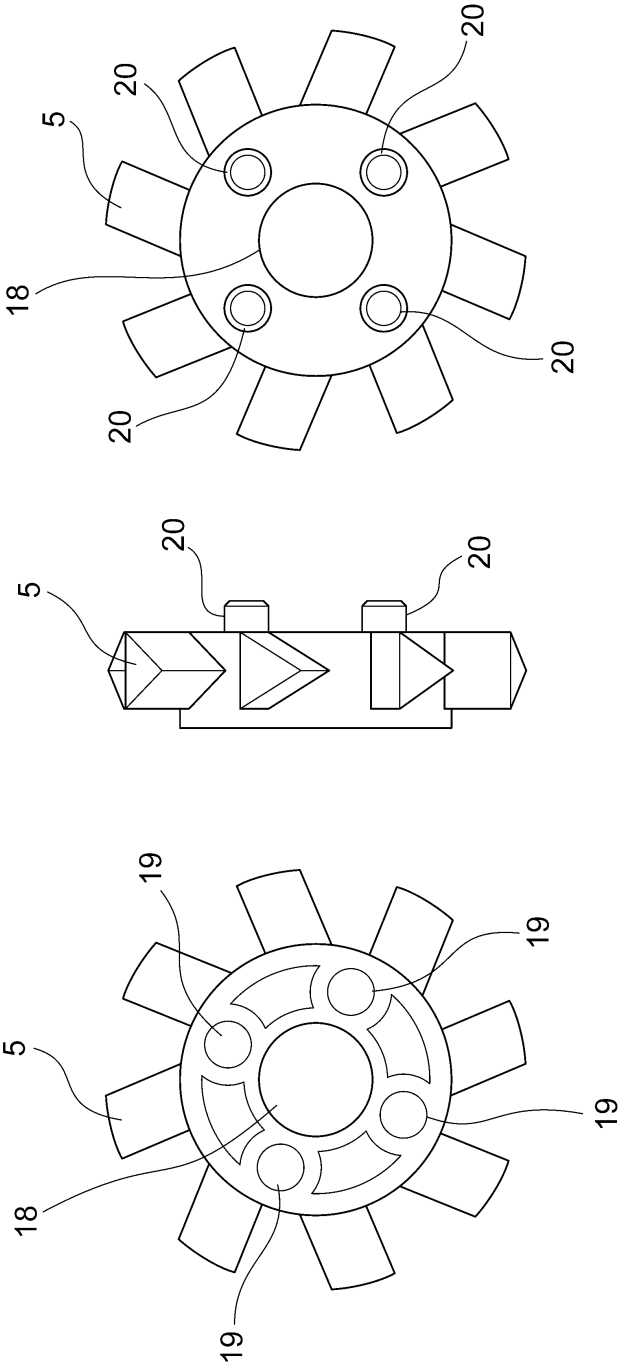


Fig. 8

Fig. 9

Fig. 10

Fig. 11

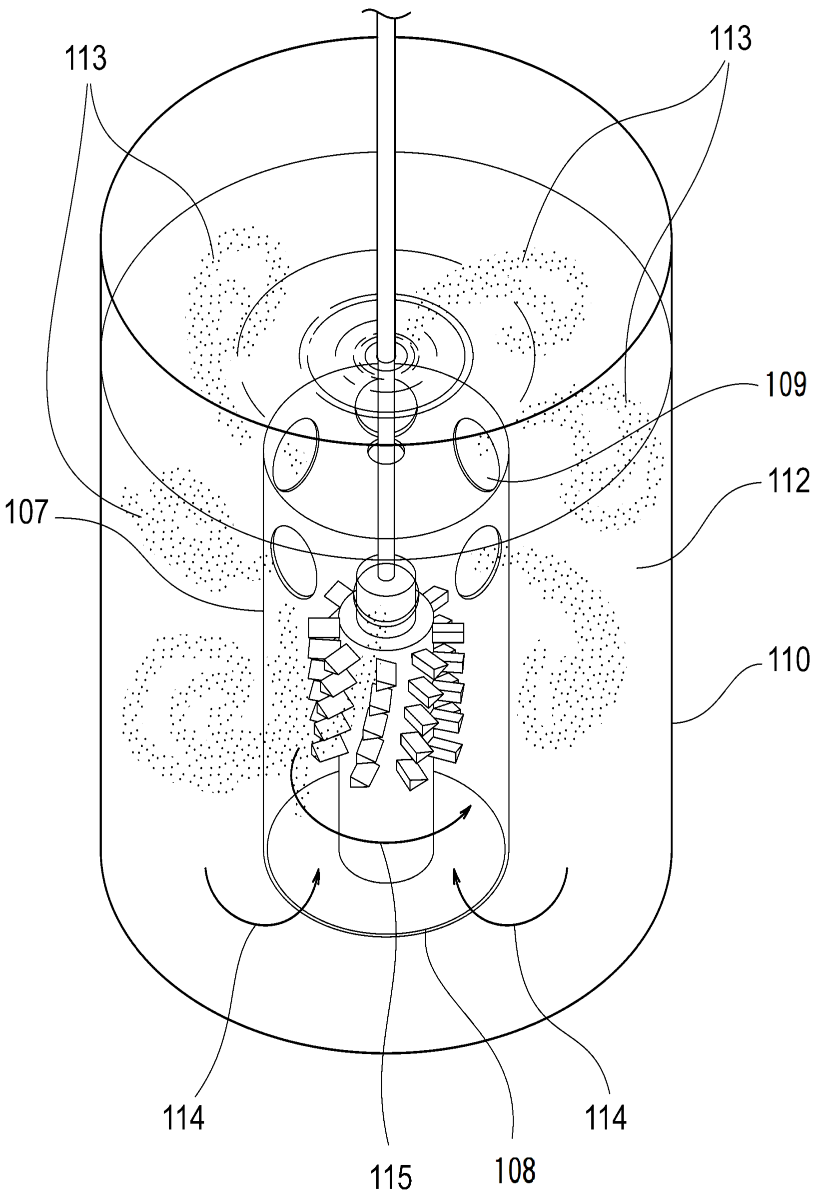
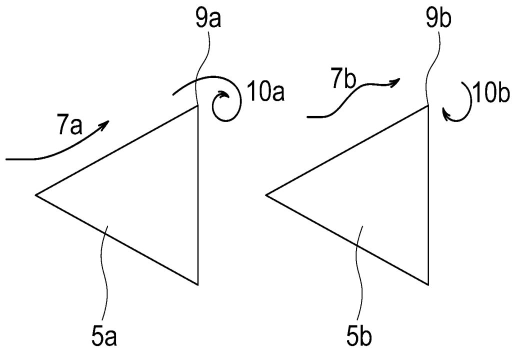


Fig. 12

Fig. 13

(a)



(b)

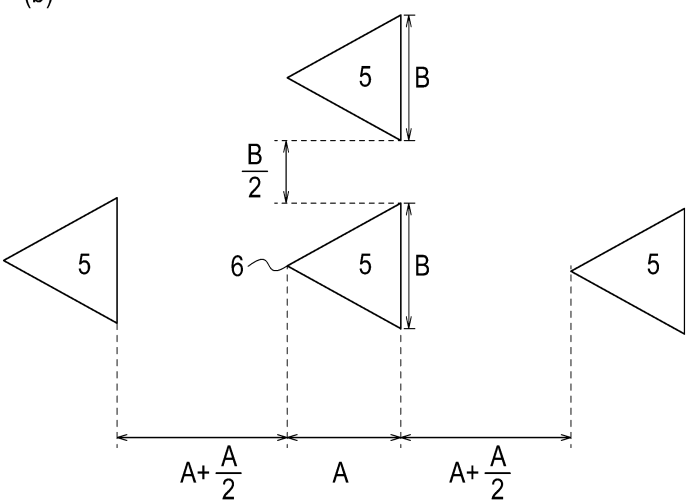


Fig. 14

Fig. 15

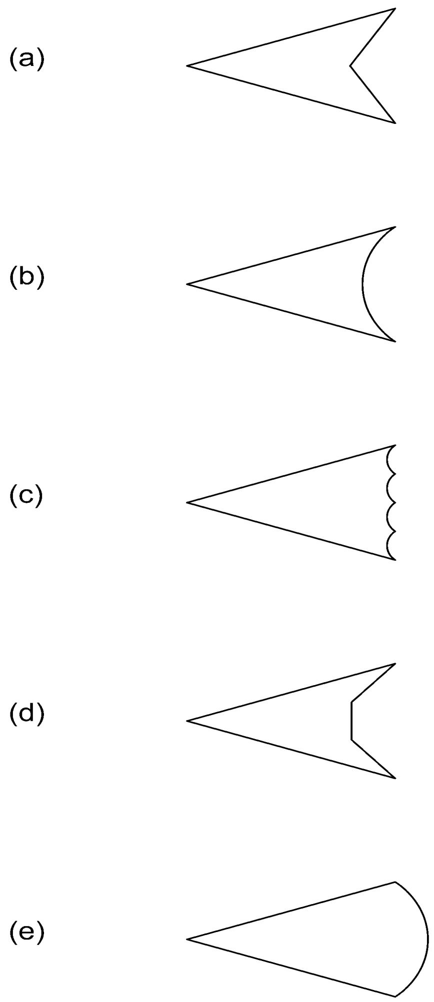


Fig. 16