Developing a micro-bubble generator and practical system for purifying contaminated water

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Abstract

This paper is about the development of a system that purifies contaminated water with micro-bubbles for solutions of water pollutions such as industrial waste water, rivers, lakes, dams, ground water and ocean. The system is able to generate micro-bubbles from contaminated water by a micro-bubble generator. This micro-bubble generator injects micro-bubbles into contaminated water in a contaminated tank and the micro-bubbles separate the pollutants from clean water in a surface tank. For other systems, it is impossible to generate micro-bubbles into contaminated water directly, the inflow must be separate. However, the system introduced in this paper simplifies the process and makes direct injection possible.

Key words

micro-bubble, micro-bubble generator, method of pressurized dissolution, purifying contaminated water system, free radical

1. Introduction

In this paper, the technology of re-cycling the environment is discussed. Especially, water pollution is highlighted. Water is necessary for humankind, but it is said that only 0.8 % of the whole earth water supply is possible for use. Developing countries do not have enough water supply systems and environmental hygiene. Infectious diseases are spread by contaminated drinking water. The largest amount of mortality and illness is caused by water problems (The United Nations, 2003). A part of South East Asia faces shortage of water supply, because the population is over-concentrated in the cities for urban development.

Moreover, water pollution is made worse by domestic sewage and industrial waste along urban development. During the high-economic growth period in Japan, production activity wreaked water pollution and produced diseases such as Minamata disease and 'ouch-ouch' disease one after another. In 1971, the Water Pollution Prevention Act was regulated. Company activities and regulations reduced industrial displacement (Hosoda, 2011). However, requesting a solution to domestic sewage is important, because about 70 % of water pollutions are caused by domestic sewage from everyday life.

A micro-bubble generator that makes contaminants in liquids rise in order to purify contaminated water is shown in Figure 1. It is an effective way to separate contaminants by the micro-bubble generator and drain contaminated water directly into the micro-bubble generator itself. According to Takahashi's (2009) research, following the disappearance of micro-bubbles, there is still the existence of nano-bubbles and free radical.

Research on a device for generating micro-bubbles with a pressurized dissolution method to purify water was developed. As result, an effective system to generate micro-bubbles uniformly was simplified.

In this paper, through studies on micro-bubbles, a device for quality water purification that paid attention to a pressurization dissolution method to generate a high-concentration of micro-bubbles for the effective and practical use of the micro-bubble was developed. As a result, it is possible to generate stable and uniform micro-bubbles which improve the ability for generation and the simplification of the system.

Inject of contaminated water → Micro-bubbles into contaminated water → Pollutants rise to the surface → Pollutants emerge rapidly → Pollutants are completely separated from clean water.

Figure 1: Progress of the separation of contaminants from clean water

It is possible to apply the new system to various fields such as purifying a closed water area, stagnant water area, aquarium glass tank, circulative water in the aqua-culture industry, seawater desalination, and productivity of emulsion oil.

2. Micro-bubble

Micro-bubble defines a bubble under a diameter of 50 µm. Common bubbles rise to the water surface and explode. However, micro-bubbles rise to the water surface and shrink equally and then disappear in the liquid (Figure 2). Micro-bubbles are adhesive to an object rising to the surface in a liquid. Figure 3 shows contaminated water poured directly into the micro-bubble generator to generate micro-bubbles. However, a typical micro-bubble generator uses an air pump to supply air. Then, bubbles are formed when the hole is opened across the water flow. For that reason, when the air supply route is blocked it becomes unusable. Table 1 summarizes the specific characteristics of micro-bubbles.

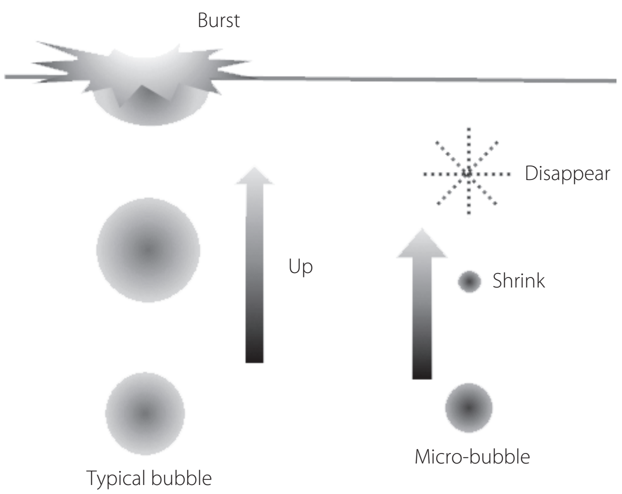

Figure 2: Characteristic of micro-bubble

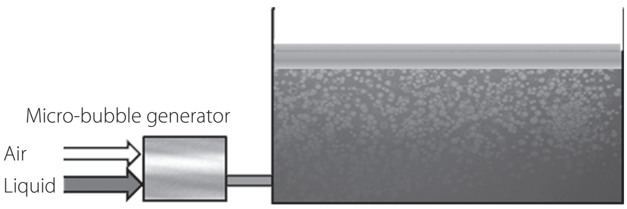

Figure 3: Contaminated water purification system by micro-bubbles

Three keys to actualize micro-bubble practice.

- Provision of stable, uniform micro-bubbles
- Higher productivity of micro-bubbles
- Simplification of system

There are two ways to generate micro-bubbles, the pressurized dissolution method and the two-phase rotation method. Typically, the two-phase rotation method is accepted, but this paper is focused on highly concentrated micro-bubbles through the pressurized dissolution method (Figure 4). Therefore, there is improvement of air turbulence and pressurizing solubility solve shear solution in superiority to the two-phase rotate method.

Table 1: Characteristics of micro-bubbles

	Characteristics
Size	Micro-bubbles are able to go through a capillary vessel or narrow route.
Area	Gaseous absorption in liquids is effective per unit area.
Surface	Low buoyancy allows the bubble to stay longer in liquids.
Surface tension	It can easily spread out horizontally for huge surface tension. As result, upward flotation is late.
Other	It is easy to influence impurities such as surfactant. It means a rapid decrease of rising adsorption velocity, displaying the Marangoni effect.

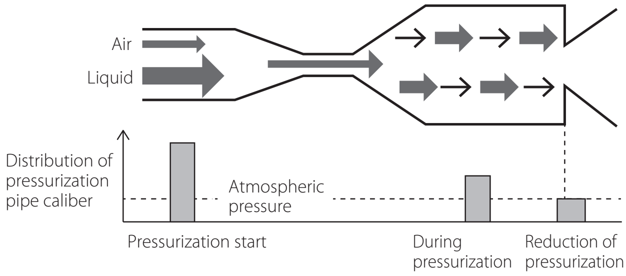

Figure 4: Pressurization dissolution method micro-bubble generation device

Reynolds discovered changes to the stream condition by velocity of a flowing fluid of fine cells poured into a glass tube in a water tank. Also, irregular stream changes appeared when one limited condition was exceeded even when the external condition was the same. These stream changes relate to velocity *U*, length *L*, coefficient of kinematic viscosity (μ/ρ). These quantities are a dimensionless quantity.

$$\frac{\text{custom clause}\quad (u\frac{\partial u}{\partial x}+\frac{\partial u}{\partial y}+\frac{\partial u}{\partial z})}{\text{adhesive clause}\quad (v\nabla^2 u)} = \frac{(U.UL)}{(vU/L^2)} = \frac{UL}{v} = \text{Re}$$

Over the limit of this ratio becomes turbulence. Concerning laminar flow and turbulence flow, the solution in a unanimously straight circle pipe route is organized by laminar flow (low Reynolds quantity) equals Hagen-Poiseuille flow from Navier-Stoke theory. On the other hand, turbulence flow (high Reynolds quantity) is not equal. It has a totally different stress effect (Reynolds stress) in the case of adding irregular changes. It organizes Reynolds theory to re-establish the Navier-Stokes theory.

These large systematic activities keep the turbulence. It is called bursting about turbulence activities at nearby wall (Figure 5).

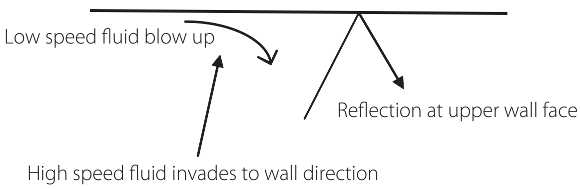

Figure 5: Laminar flow and turbulence

The activities' role heightens an effect of an occurrence of Reynolds stress, heat from the wall face and substance transportation. Critical velocity of the turbulence stream is in direct proportion to viscosity of liquid and in inverse proportion to liquid consistency run into the center of the vortex from the tube face (Figure 6).

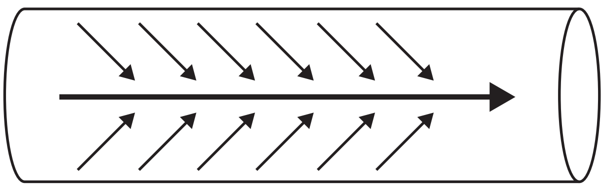

Figure 6: Outbreak of Reynolds stress

As a result, the two-phase rotation method is not necessary because of rising pressure in the tube. Additionally, a device to inject a gaseous body for a stream with a higher concentration of micro-bubbles can be planned.

3. Micro-bubble generator structure and contaminated water purifying system

3.1 Micro-bubble generator structure

In other current systems, micro-bubbles are generated by opening the hole directly into the wall face fixed as a stream route. This becomes a subject of discussion, if contaminated water is poured directly into the generator, it would block the exit of the air providing route (Figure 7).

In this paper, development is concerned with connecting

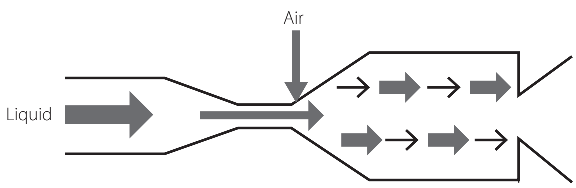

Figure 7: Current micro-bubble generation device

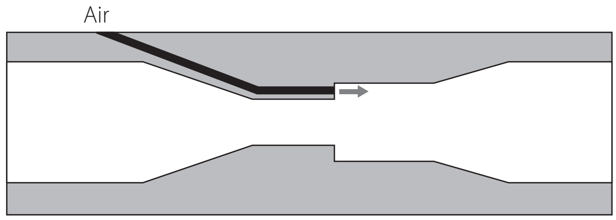

Figure 8: SepaTech micro-bubble generator

the pressurized liquid entrance route and generated micro-bubbles with the liquid exit route. The air providing route, liquid exit and the entrance are equipped in a narrow space inside of tube angle.

In the new micro-bubble generator introduced in this paper, the air-route opening is along side of the liquid stream (Figure 8).

The air providing route prevents backward flow. It does not allow flowing liquid backward with typical operation and prevents contaminated objects from blocking up the system. As a result, it allows contaminated water to be poured into the micro-bubble generator directly and generate from the contaminated water.

3.2 Contaminated water purifying system

This newly developed contaminated water purifying system (SepaTec micro-bubble system: applied for patent No2013-219791) can be used for a composition of both contaminated tank from contaminated water (liquid) and discharged micro-bubbles into a separated surface tank. A common generator must perform both contaminated water tank and micro-bubble tank separately. It can be said that the SepaTech system is simplified.

Next, the system uses Bernoulli's theory for controlling static pressure by increasing the connected pipe area of the cross section. It is an extraction for mixing vapor liquid, pressurized dissolution vapor liquid to transform liquid and decompression at the same time. The system is composed of aspirator

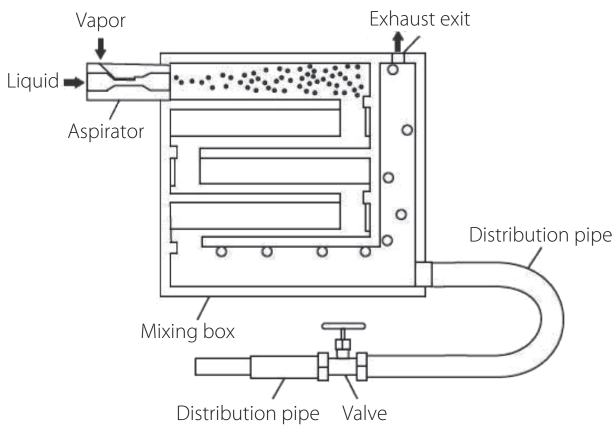

Figure 9: SepaTech system

parts, mixing parts and the valves (Figure 9).

The aspirator parts are composed of a unification entrance, angle, absorption, and air entrance route. The mixing box is composed of upper pressurizing pipes to flow liquid backward. The inside of the mixing box are short clear pipes. The length of the pipes, width and water depth are planned for effective vapor liquid dissolution in a short time.

Also, at the standing pipe, mixing box exhaust vapor liquid dissolves. The bubbles are about decompression. A liquid not including vapor bubbles must be poured. Liquid bubbles dissolve vapor liquid under solubility. The exhaust pipes are placed away from the mixing box. These reasons prevent a reduction in the amount of vapor bubbles caused by mixing macro-bubbles and bubbles around the point of generating micro-bubbles.

4. Conclusion

A singular phenomenon occurring is radical for micro-bubbles. Inside of the bubble pressure rise suddenly by radical reduction (applying pressure) is in inverse proportion to bubble diameter. That velocity is enough, the inside bubble temperature rises suddenly by insulated compression. When it disappears, it forms pressure of thousands atmospheres field. This limit reaction (hot spot) is a minute area, but it strongly decomposes internal gas molecules under compulsion. As a result, it occurs as a free radical such as OH. In this manner, ultra-high temperature and a free radical utilize floating objects in the water to rise to the surface separately. These are the reasons that the SepaTech system can help and contribute to purifying water pollution, de-salting seawater, emulsion energy which consists of a mixed ration of heavy oil, light oil and water for environmental issues and developing nations.

Author's note

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