Controllable Air-bubbles Size Generator Performance with Swirl Flow

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Abstract
Bubbles are widely used for various purposes such as products cleaning, medical treatments, food processing, fishery operations, etc. In a number of recent patents, micro/nano-bubbles generated by a swirl flow have been used in several applications because this method involves low cost and simple design. In addition, it provides high performance as well as the ability to generate very small bubbles. In this research, the controllable bubble size generator, which enables the bubble size to be changed according to the sequence of operations, was devised, and then the performance was investigated. This generator, which is operated with two fluids of air and water, makes bubbles that are divided into smaller bubbles by applying the shear stress with the swirl flow. The generating air bubbles which radiated a light sheet through slit, was taken a picture with the digital camera, and was measured. The relation between the swirl strength and the bubble size/numbers was investigated.

Keywords: Visualization, Bubbles generator, Swirl flow, Bubbles size, Control

1 Introduction

There are several ways to produce smaller bubbles, including the use of venturi tube cavitation, pressure discharges, ultrasonic waves, and swirl flows. The use of micro/nano-bubbles generated by swirl flows appears is advantageous because this method is economical. It also provides high performance and a simple design, and it is capable of generating very small bubbles [1]. The controllable bubble size generator which can vary the bubble size according to sequence of operations, has recently been proposed [2]. This swirl-type generator can vary both the bubble size and rate. Application of air bubbles is used increasingly [3], [4] for the wide range and various purpose such as not only engineering but medical treatment, food processing and a fishing farm, etc. In such application, according to the purpose of using the liquid with air bubbles or air bubbles mixed, it was desirable that various regulation of the generating form of air bubbles was carried out. There was the necessity for an improvement in the regulation method [5].

In this research, the performance of the bubbles generator which can control the size and the number of air bubbles were presented, and the effect was proved. This generator makes air bubbles smaller by using shear stress that was caused by swirl flow. The air bubbles are supplied from the axial inlet at the vortex chamber wall and the water is supplied from the tangential inlet of the circumference. The flow

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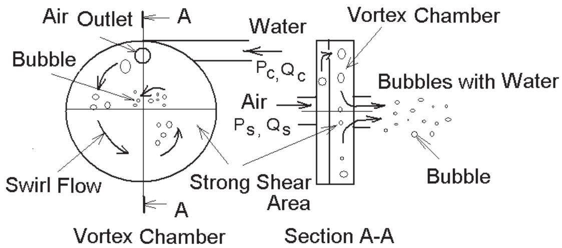


Figure 1: Principle of controllable bubbles generator with Swirl Flow.

d_e	d_s	d_f	d_o	h	d_m	α
10	8	8	62	4	8	30 °

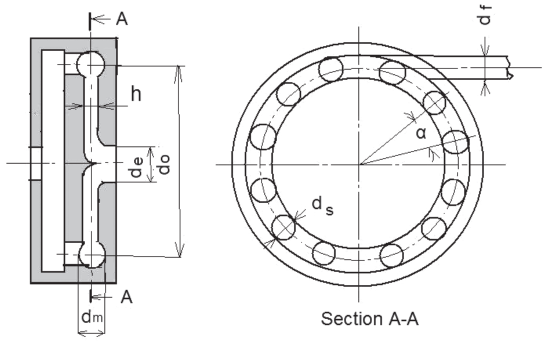
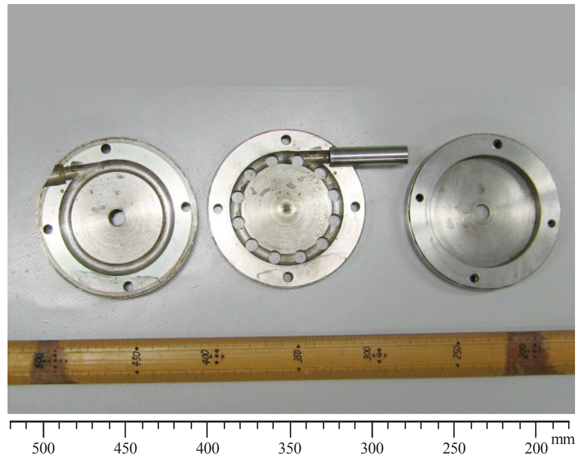


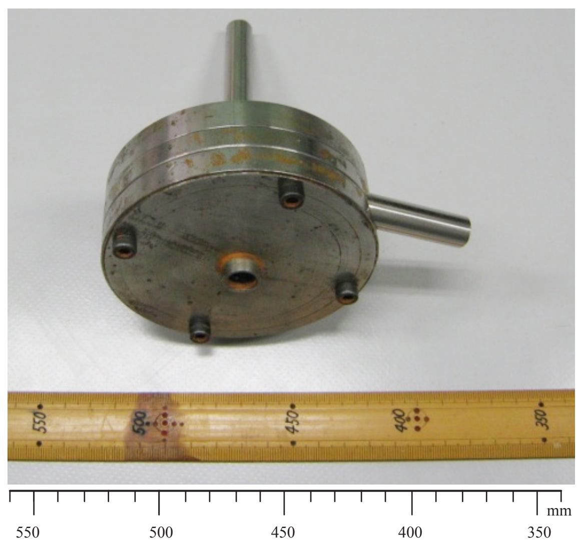
Figure 2: Generator geometry.

characteristics of this device are referred to the vortex amplifier well known as the fluidics [6]. The generating processes of small air bubbles are radiated a strong bright light through a slit, and the bubbles are taken pictures with the digital camera. The bubbles size is measured with the microscope.

The control method and the principle of small air bubbles formation are shown in Figure 1. Water is supplied to a swirl chamber from tangential inlet, and flows through the swirl chamber and the exit where swirl flow is formed. The swirl strength in the chamber is increased with the tangential flow (*Qc*) or the pressure (*Pc*) that causes the shear stress. The air bubbles entering the vortex chamber are divided into the smaller bubbles by the shear stress. The bubble-formation rate will be increased by the axial air flow (*Qs*) or the pressure (*Ps*) if the swirl strength is sufficient. Then, it causes the shear stress to divide the bubbles into smaller bubbles. There is a variety of swirl-type generators including pre-mixing of air into water. It uses a venturi tube or/and enhances the shear stress by placing an impellor in the vortex chamber and a cutting device at the vortex chamber outlet [2].



(a)



(b)

Figure 3: (a) Adjustable bubbles generator parts and (b) a constructed bubbles generator.

2 Experimental Setup and Method

The generator dimension is schematically shown in Figure 2. The important parameter is d_e and d_o, which strongly dominate the swirl strength in the vortex chamber. The axial air inlet provided 12 ports.

The photos of the controllable bubbles generator which is manufactured for the test are shown in Figure 3.

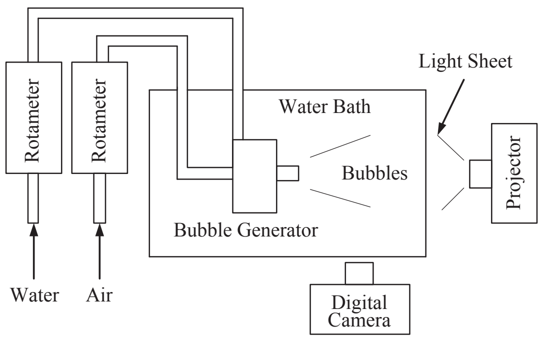


Figure 4: Experimental setup.

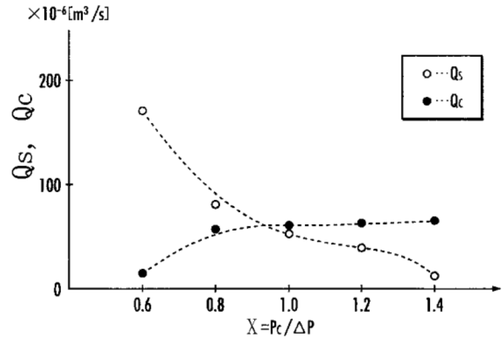


Figure 5: *Qs*, *Qc* with pressure ratio, *X*.

The experimental setup is shown in Figure 4. The size of a tank is 180 mm × 300 mm × 220 mm. The water is directly supplied from a water supply and the filled water will overflow from the tank upper surface. The photographs are taken at 1/250s or 1/2500s of shutter speeds respectively in order to observe the issued bubble trace and size/shape from the exit.

3 Results and Discussion

The results of measurement on operating are shown in Table1. The measurement was carried out at the circum condition constant of Ps = 2.5 kPa. At the initial stage, when the water valve is shut, Qc = 0. Then, when X = 0.6, Qs becomes 193. The relations between Qs, Qc and X are shown in Figure 5. It is obvious that, X = 1.4 creates the strongest swirl and makes the smallest bubbles.

Table 1: Data of measured flow rate

$X = Pc/Ps$	0.6	0.8	1.0	1.2	1.4
Qc ($\times 10^{-6}$m^3/s)	0	56	57	58	60
Qs ($\times 10^{-6}$m^3/s)	193	82	53	42	11

At the low shutter speed, 1/250s, the issued bubbles from the exit are shown in Figure 6. The white curve is the trace of the bubbles. For X = 1.4, it shows that there is the strongest swirl at the outlet. The issued bubbles at the high shutter speed are shown in Figure 7. For X = 1.4, the smallest bubbles are observed and their shape is almost globular.

Each one of bubbles in the photograph as shown in Figure 7 was measured with the micro scope. The distribution of the bubbles' size for the pressure ratio X is shown in Figure 8. For X = 0.8, the size of bubbles' range is wider. This is why the shear stress caused by swirl flow is not enough to divide up the bubbles smaller. For X = 1.0, 1.2 and 1.4, the size of bubbles range is narrow when the shear stress is significantly strong. The distribution of the number of bubbles for the pressure ratio X is shown in Figure 9. The ranges of bubbles' size generated for X = 0.8, 1.0, 1.2, and 1.4 are Ra = 0.5–2.0 mm, 0.25–0.30 mm, 0.15–0.20 mm, and 0.05–0.10 mm, respectively.

The number of bubbles was calculated from the volume of bubbles. The ranges of the number of bubbles are Na = 2.5 to 157 × 10^3 particles/s, 469 to 801 × 10^3 particles/s, 1300 to 2970 × 10^3 particles/s, and 2630 to 21000 × 10^3 particles/s for X = 0.8, 1.0, 1.2, and 1.4, respectively. Therefore, bubbles' size and the number are able to be controlled by setting up the pressure ratio, X, suitably. The bubble size and numbers are summarized in Table 2.

Table 2: Bubble size and particle number

$X = Pc/Ps$	0.8	1	1.2	1.4
RL (mm)	0.5	0.25	0.15	0.05
RH (mm)	2	0.3	0.2	0.1
NL (k particle/s)	156.7	801	2972	21020
NH (k particle/s)	2.448	468.8	1296	2630

where,

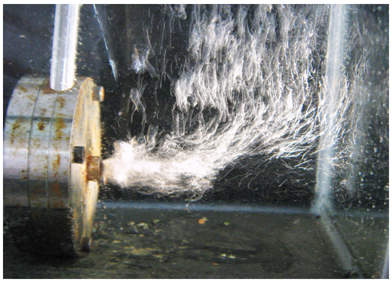
RL = Radius of smallest bubble,
RH = Radius of biggest bubble,
NL = Number of smallest bubbles,
NH = Number of biggest bubbles.

Thus

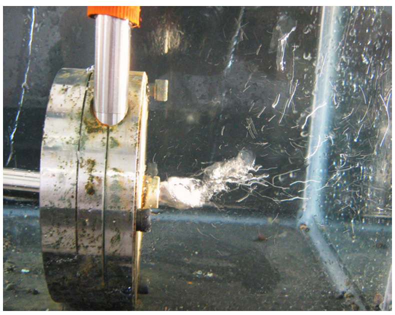
$$NH = 4/3\pi RH^3,$$

and,

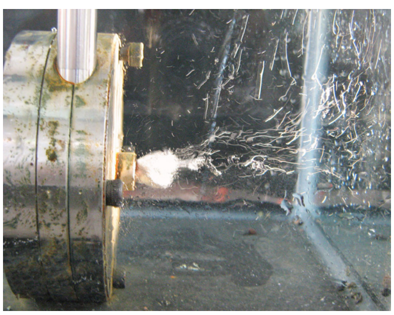
$$NL = 4/3\pi RL^3.$$



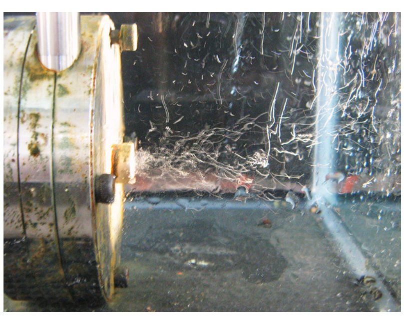
(a) $X = 0.8$ and $Qc = 56 \times 10^{-6} m^3/s$ and $Qs = 82 \times 10^{-6} m^3/s$, Shutter speed = 1/250s



(b) $X = 1.0$ and $Qc = 57 \times 10^{-6} m^3/s$ and $Qs = 53 \times 10^{-6} m^3/s$, Shutter speed = 1/250s



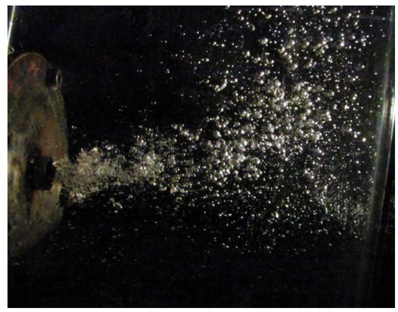
(c) $X = 1.2$ and $Qc = 58 \times 10^{-6} m^3/s$ and $Qs = 42 \times 10^{-6} m^3/s$, Shutter speed = 1/250s



(d) $X = 1.4$ and $Qc = 60 \times 10^{-6} m^3/s$ and $Qs = 11 \times 10^{-6} m^3/s$, Shutter speed = 1/250s

Figure 6: Streamline of bubbles issued from exit.

(a) $X = 0.8$ and $Qc = 56 \times 10^{-6} m^3/s$ and $Qs = 82 \times 10^{-6} m^3/s$, Shutter speed = 1/2500s



(b) $X = 1.0$ and $Qc = 57 \times 10^{-6} m^3/s$ and $Qs = 53 \times 10^{-6} m^3/s$, Shutter speed = 1/2500s

(c) $X = 1.2$ and $Qc = 58 \times 10^{-6} m^3/s$ and $Qs = 42 \times 10^{-6} m^3/s$, Shutter speed = 1/2500s

(d) $X = 1.4$ and $Qc = 60 \times 10^{-6} m^3/s$ and $Qs = 11 \times 10^{-6} m^3/s$, Shutter speed = 1/2500s

Figure 7: Bubbles size and shape issued from exit.

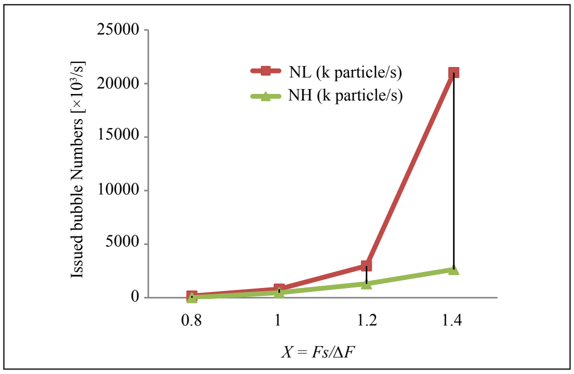


Figure 8: Bubbles Size distribution for *X*.

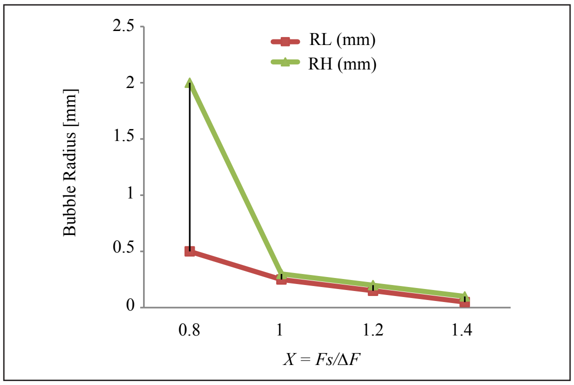


Figure 9: Distribution Number of Bubbles for *X*.

4 Conclusions

As seen that implementing this device with various cellular can generate the equipment to develop a revolution style that has already been practically used. In addition, this research proved that the devised cellular could generate the equipment which is able to adjust the magnitude and the amount of emergence of air bubbles. It is considered that the application range of the conventional air bubbles can be extended by this equipment after installation since the size and the amount of emergence of air bubbles have been changed. Furthermore, it seems that the maintenance cost is noticably decreased without changing the form of cellular that generates equipment even though the size and the amount of emergence of air bubbles is easily changed. Therefore, when this device is integrated with a pipe circuit, many application for this will be more potential.

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