# "Experimental Study on Optimization Axial Position of the Spherical Body on the Micro-bubble Generatorin a Flowing Water Tube"

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**Abstract**

A microbubble generator is a tool that is used to produce micro-sized bubbles ( 200μm). Based on the microbubble generator design by Sadatomi (2005), we conducted a further study to optimize the performance of the microbubble generator. The micro-bubble generator is placed at a depth of H = 40 cm from the surface of water in the aquarium ( 75 cm x 50 cm x 40 cm).The research conducted focused on analyze the effect of the axial position of airways from the position of the ball, from $x$ = +2 to $x$ = -4 mm . An axial ball positioner was used to set up the position of the ball within the microbubble generator. The study revealed that that the greater the distance of the ball from the air holes, the differensial pressure will decrease due to the wider area which formed between solid ball and pipe wall. From these experiments, we succeeded in producing microbubble sizes ranging between 50 to 200 μm.

**Keyword:** *Microbubble, microbubble generator, suction volume, air flow rate, pressure drop*

1. Introduction

Micro-bubble is a tiny bubble having size less than 200 μm in diameter. Due to this size, microbubble has unique characteristics: high specific interfacial area, slow rise velocity, high inner pressure and high surface tension (Pan li, 2006). These unique characteristics make microbubbles can be utilized in many different applications, such as on the fishery, the waste water treatment, and the medical application.

A further investigation to create an effective tool for producing microbubble (microbubble generator), has been done for a long time. There are many various methods to create microbubbles, Pan li (2006) has classified the methods into three different micro bubble types. Those are pressurization type, cavitation type and rotating-flow type.

In reference to Sadatomi's microbubble generator spherical body design (2005), we conducted a further study to optimize the performance of the microbubble generator. This paper focuses on the effect of the axial position of the spherical body in microbubble generator. An axial ball regulator was used to set up the position of the ball within the microbubble generator.

To produce the microbubble, we applied rotational flow to induce greater shear flow. This rotational flow is obtained through introducing pressurized water via an inlet perpendicular to the x-axis (main outlet axis) of the microbubble generator. The water flows into a narrow gap which is formed due to the presence of solid ball in the center of the microbubble generator. In connection with the theory of mass conservation, the pressure within the narrow gap would be negative. This negative pressure will take the air from the outside into the fluid flow through a few small holes on the pipe wall within the low pressure area. Because the downstream flow is the turbulent shear flow, so the inhaled air is automatically split into micro sized bubbles.

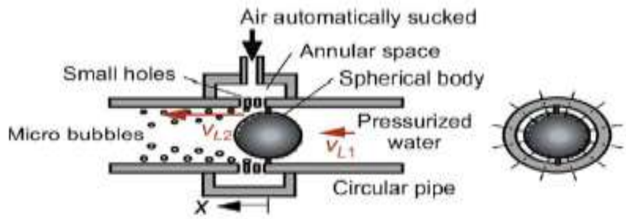



Figure 1: *Micro-bubble generator by Sadatomi (2004).*

2. Experimental methods

Figure 2 shows the experimental apparatus we used to analyze the characteristic of microbubble generator. The micro-bubble generator (8) is placed at a depth of 40 cm from the water surface in the aquarium ( 75 cm x 50 cm x 40 cm). Three different pressure transducers (3) were placed around the microbubble generator body to analyze the inlet water pressure $P_L$, the air suction pressure, $P_{G,}$ and the pressure at the outlet of microbubble generator,$P_{3.}$ The output signals from the above sensors were sent to a personal computer (1) via an A/D converter (2) to determine the respective time-averaged values. Water was supplied from centrifugal pump (10) from $Q_L$= 1 $m^3$/s until $Q_L$= 2.5 $m^3$/s,and air suction rate $Q_G$, the water flow rate ,$Q_G$, and the air suction rate, $Q_L$, were measured by calibrated flowmeter (5) and controlled by gate valve (7).

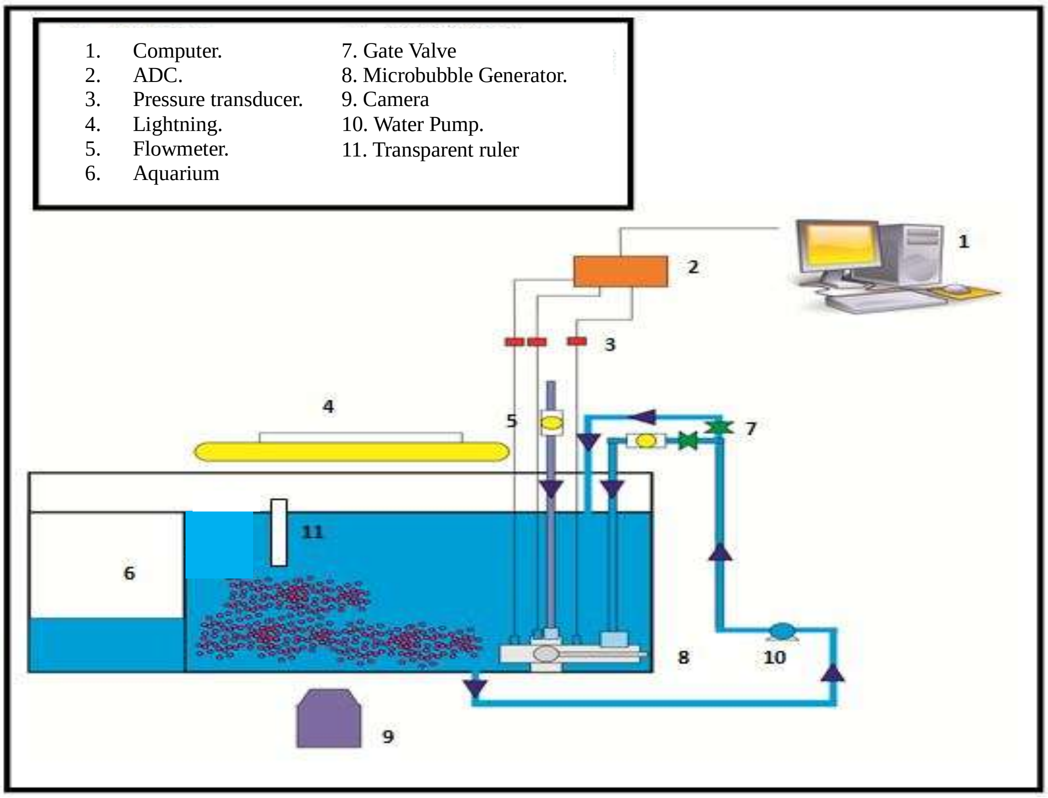



Figure 2 : *Experimental apparatus of microbubble generator.*

To measure the bubble diameter, we used a transparent ruler (11) and DSLR camera Canon EOS D550 (9) with additional lens EF 100 f/ 2.8 macro, to capture the microbubble.

Figure 3 and Table 1 display the specification of the tested microbubble generator. The number of air suction holes is 6,the spherical body diameter, d = 16 mm, the inlet pipe diameter, D=18 mm, the diameter of suction air room is 40 mm, and the diameter of air suction holes are 0.75 mm.

Table 1 Specification of tested microbubble generator.

| No | Serial Number | Diameter of suction air room | Axial position of sphere ball |
|---|---|---|---|
| 1 | GM01-00 | 40 mm | X= 0 |
| 2 | GM01-2 | 40 mm | X= -2mm |
| 3 | GM01-4 | 40 mm | X= -4 mm |
| 4 | GM01+2 | 40 mm | X= +2 mm |

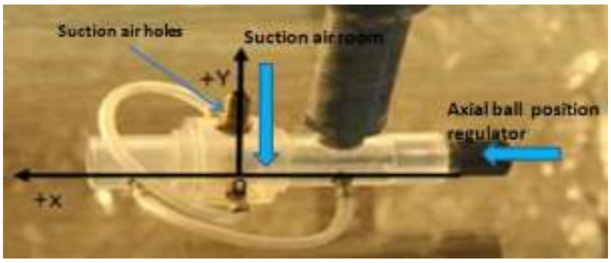
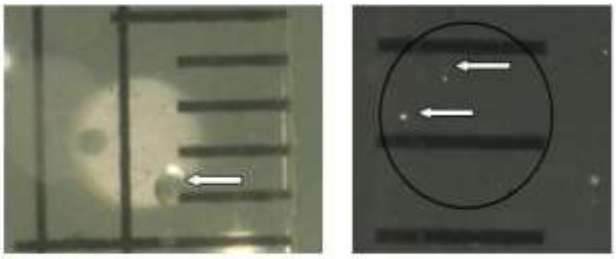



Figure 3: *The configuration of Microbubble Generator*

3. Results and Discussions.

3.1. Bubble generating condition.

In this study, an investigation of bubbles generating conditions in 4 variations axial positions of spherical body on microbubble generator was analyzed. Bubble type classification was based on the definition of Sadatomi's (2005) on micro-bubbles in the bubble which are less than 200 μm.



a) Milibubbles b) microbubbles

Figure 4: *Comparation between microbubbles and milibubbles.*

The bubbles were measured by using a CANON EOS 550 D camera with shutter speed of 1/4000 and ISO 3200. The measured bubbles were bubbles passing through a transparent ruler mounted on the direction of the microbubble generator flow. This study was conducted by taking 4 time captures from each session. The diameters of the 4 captured images of the bubbles were measured to map in Graph $Q_L$ vs $Q_G$.

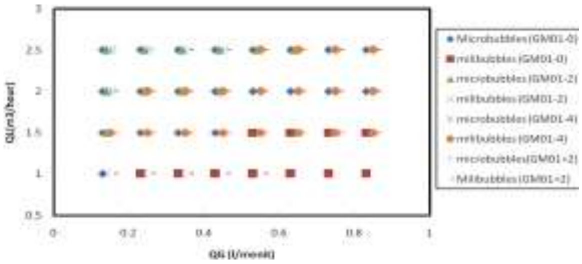


Figure 5: *Bubble generating condition of microbubble generator*

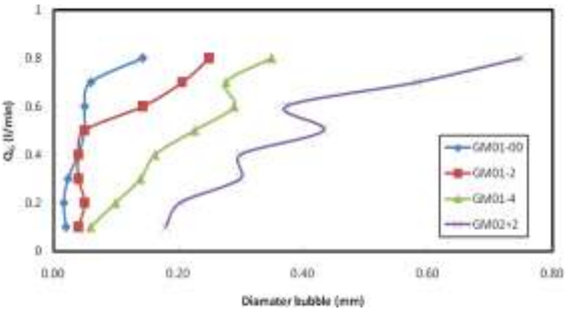



Figure 6 : *$Q_G$ againts bubble diameter at $Q_L$ 2.5 $m^3$/hour under various axial position of shperical body .*

Fig 5. and Fig 6 depict the bubble generating condition for many different axial positions of the spherical body, that is, the greater the axial distance of the ball is, the smaller the range to be able to produce a micro-bubble is needed. This is due to the decrease in the number of pressure drop caused by the decline of the vacuum suction pressure $P_G$ in the suction air room. Besides, the microbubble generator investigated is the type of cavitation microbubble generation utilizing the existing amount of pressure drop. Therefore, if the pressure drop is not able to achieve the desired number, it will be difficult to form microbubble. In addition, it is harder to make $P_G$ negative when the position of the spherical body farther . The best axial position to generate the microbubble is x=0.

3.2. Visualization of the flow pattern characteristics on microbubble generator.

In this research, an observation of the pattern of micro-bubble flow characteristics that occur in the outlet of the micro-bubble generator was conducted. The observation of micro-bubble flow visualization was limited on QL 1 m3/hour, 2 m3/hour, and 2.5 QG m3/hour at 0.1 to 0.2 in 4 variations of axial position of the spherical body of the micro-bubble generator. The different restrictions of this problem were based on the experiments of $Q_L$ and $Q_G$ revealing microbubbles.

From visual observations, it was known that the type of flow that occured in the micro-bubble generator is the rotational flow. This rotational flow occurred as a result of the pressurized water flow in the stream in a perpendicular x-axis of micro-bubble generator (Ohnari, 2001). As a consequence, the fluid flow moved through the wall of microbubble generator rotate in a spiral towards the outlet of microbubble generator.

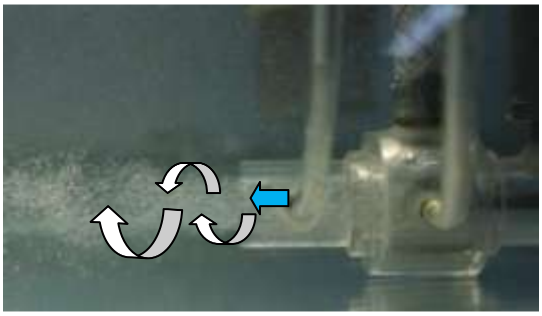


Figure 7 : *Visualization of rotational flow at the outlet of microbubble generator.*

In addition, from visual observations, it is found that the greater the distance the ball from the water suction holes is, the less bubble generation intensity is produced by micro-bubble generator. It is associated with a decrease in pressure drop in the micro-bubble generator.

3.3. Evaluating the performance of microbubble generator

To evaluate the performance of micro-bubble generator with position, the experiments were done based on the constant value of $Q_G$ = 2 m3/hour, and $Q_L$ range remains the same ie from 0.1 l / min to 0.6 l / min.

3.3.1. Effect of the axial position towards the pressure.

3.3.1.1. Inlet Pressure

Initial pressure ($P_L$) refers to the pressure of the water before it enters the narrow gap formed between the solid ball and the pipe wall.

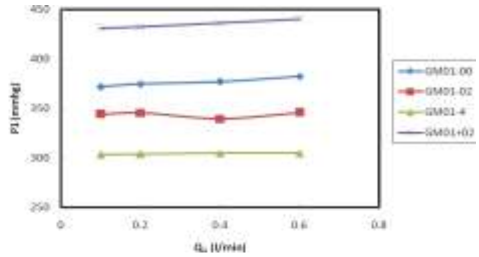


Figure 8 : *Initial Presure Vs $Q_G$ under various axial position of shperical body .*

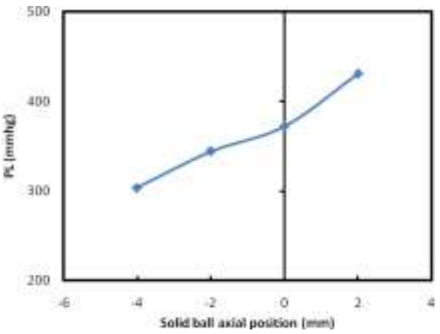



Figure 9 : $P_L$ *against Solid ball axial position at* $Q_L$ *= 2 m3/hour and* $Q_L$ *=0.1 l/min*.

From the Figure 8 and Figure 9, it is identified that the greater the distance of the ball from the water inlet is, the greater the value of $P_L$ is happening. This is because the pressurized water entering the pipe has more stable pressure. This more stable condition happens because when the water enters the water inlet channel having the smaller diameter when compared with the one of the pipe, it produces the pressure drop in the inlet. Then, this pressure drop reaches the steady pressure in the pipe compatible with the existing law of conservation of mass. With regard to the aforementioned explanation, it can be concluded that the greater the ball distance is from the water inlet, the more maximum the initial pressure can be received.


Figure 10 : *Water inlet of microbubble generator.*

3.3.1.2. Vacuum Pressure

Vacuum pressure refers to the pressure which is measured using a pressure sensor SMC which is positioned on suction air room. Suction air room is a room that serves as a place for the entry of air taken into the microbubble generator

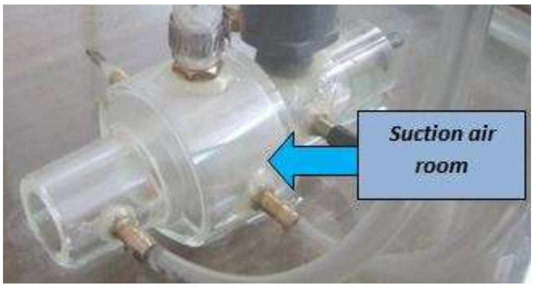



Figure 11 : *Suction air room.*

The figure 12 below shows that the closer the solid ball with axial suction water holes is, the smaller the number $P_G$ is. Besides, as the microbubble generator used is the microbubble generator using vacuum pressure, the better performance is obtained. It can be seen in Figure 5, where the position x = 0, the bubble diameter becomes smaller in size.

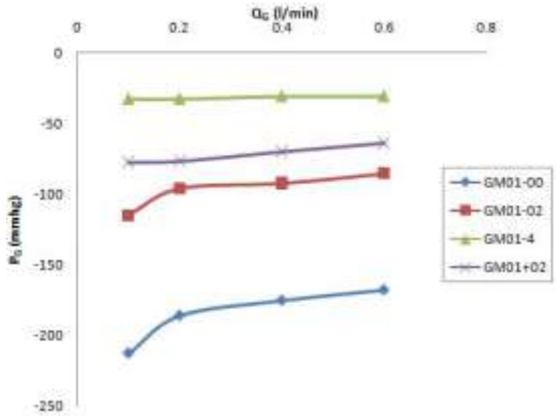



Figure 12 : $P_G$ *against* $Q_G$ *under various axial position of shperical body .*

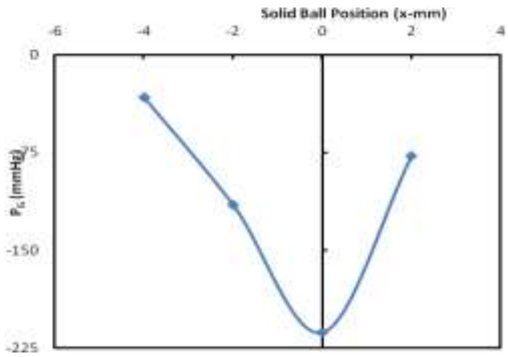



Figure 13 : $P_G$ *against Solid ball axial position at* $Q_L$ *= 2 m3/hour and* $Q_L$ *=0.1 l/min.*

3.3.1.3. Diffrential pressure

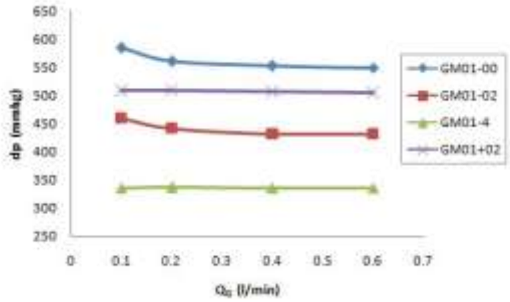



Figure 14 : *dp against $Q_G$ under various axial position of shperical body .*

Differential pressure is the magnitude of the pressure difference between the initial pressure value and that of the suction air pressure room. We can see in the chart above that the greatest number differential pressure (dp) is located on the Micro-bubble generator that has the shortest distance between the solid ball and the water suction room. Although the Figure 9, depicts the greatest distance (x + 2mm) is the greatest distance to the value of initial pressure, but in Figure 13 shows that the smallest value of vacuum pressure is attained from the closest distance to the water suction holes (x = 0) and from the magnitude of dp at x = 0 that reaches the highest value. In short, the optimum number of the axial position of the ball to the water suction holes occurs when x = 0.

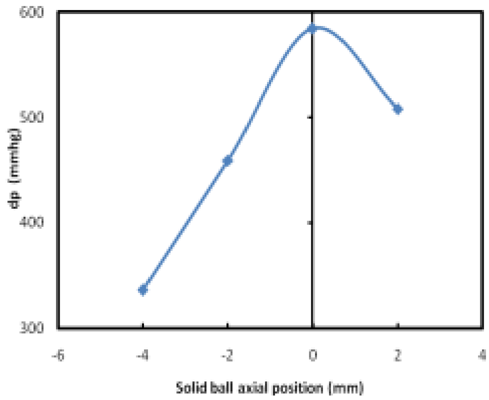



Figure 15 : *dp against Solid ball axial position at $Q_L$ = 2 m3/hour and $Q_L$ =0.1 l/min*

3.3.2. Effect of the axial position toward the hydraulic power.

Hydraulic power indicates the power used in a microbubble generator to work. The hydraulic power is formulated by

$$L_w = (p_1 + \rho_L v_{L1}^2/2)Q_L.$$

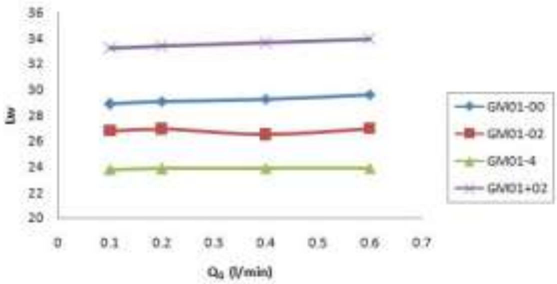



Figure 16 : *Lw against $Q_G$ under various axial position of shperical body*

As stated in the prior formula, the hydraulic power is the sum of the initial pressure and the average speed of the fluid at the inlet of the generator. In reference to the relationship of the initial pressure discussed earlier in Figure 9, it is shown that the greater the distance the ball from the water inlet is, the greater the initial pressure occurs. Moreover, since the Hydroulic power is the sum of the average speed of the fluid at the inlet of the generator, the greatest value of Lw is in the position x = +2.

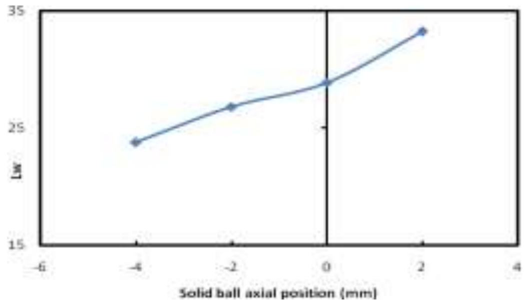



Figure 17 : *Lw against Solid ball axial position at $Q_L$ = 2 m3/hour and $Q_L$ =0.1 l/min*

4. Conclusions

a. From the results of the study, it is found that the axial position of the optimal solid ball is at x = 0 mm of suction air holes.
b. The optimum position for the ball sphere to achieve the optimum value of the initial pressure is at the distance x = 2 from the water suction holes.
c. At the microbubble generator spherical body, the farther distance of the solid ball from the suction holes is, the smaller the pressure drop value is obtained and the smaller vacuum suction pressure to the suction air room is.
d. The farther the ball distance from the water suction holes is, the less bubble generation intensity is produced by the microbubble generator. It is regarding the decrease in the pressure drop value in the microbubble generator.

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## 6. Nomenclature.

| | |
|---|---|
| $Q_L$ | = water flow rate ($m^3$/hour) |
| $Q_G$. | = Gas Flow Rate ( l/min) |
| $L_w$ | = Hydrolic power |
| *PL* | = Initial Pressure ( mmhg ) |
| *PG* | = Vacuum Pressure (mmhg) |
| *dp* | = Differential pressure (mmhg) |
| $\mu$ | = liquid viscocity (Pa.s) |
| $\rho$ | = liquid density (kg/$m^3$) |

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