Proceeding Paper

The Effect of Twisted Baffle on the Microbubble Generator Swirl Ventury Type †

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Abstract: Due to their unique physical properties, microbubbles have received a lot of attention in waste treatment, aquaculture, and food processing. The demand for high-efficient and low-power consumption microbubble generators has become a challenge today. Swirling flow has been widely proven that it can improve bubble formation. Numerous researchers have developed designs to produce swirl flow and strengthen the turbulence fluid flow. In this study, we present a swirl venturi microbubble generator with a 60° twisted baffle fin on the inlet section. The performance of the microbubble generator swirl venturi type was tested experimentally using parameters such as distribution of bubble size, hydraulic power (Lw), and bubble-generating efficiency (ηb). A microbubble generator was installed in the transparent test pool with 672 L of water. A high-speed video camera was employed to visualize the flow behaviour. The water and gas flow rates varied between 40–60 lpm and 0.1–0.5 lpm, respectively. The data were analyzed by MATLAB R2022b with the technique image processing method. The results show that most bubbles with 100–300 µm were generated. An increased water flow rate (QL) will increase the hydraulic power by 22–27 W, while an enlargement of gas flow rate (QG) will only enlarge 1 W. As the water flow rate increases, bubble-generating efficiency decreases. The lowest bubble-generating efficiency of 0.04% occurs at a QL of 60 lpm and QG of 0.1 lpm. In conclusion, we can conclude that the microbubble generator swirl ventury type is an efficient device for generating microbubbles.

Keywords: ventury microbubble generator; swirl; pressure drop; hydraulic power; bubble generating efficiency

1. Introduction

Microbubble has been enormous applied due to their reliable physical properties. A larger gas-liquid interfacial area, slow-moving in the water, and high self-pressurizing effect are unique microbubble characteristics. The advantages of microbubbles are suitable to enhance dissolved oxygen in the water. It can be used to purify water, aquaculture, and agriculture [1]. The technology that can generate microbubbles is called a microbubble generator. Venturi is one type of microbubble generator. Venturi has no complicated structure, low energy consumption, and no internal rotating parts [2]. Bubbles will form due to self-suction due to vacuum pressure in the throat and reduction in cross-sectional area. The bubbles formed will then be deformed into small shapes.

The fluid flow rate affects the performance of the microbubble generator [3,4]. Several modifications, such as the addition of spiral fins [5], porous media [6], combined with orifices [7], have been made to increase the efficiency of the ventury. Several modifications on the divergent and convergent sides of the microbubble generator have been conducted.
by the researchers, but modifications at the inlet are still not widely carried out. For this reason, this research will evaluate the performance of the microbubble generator on bubble diameter, pressure drop, hydraulic power, and bubble-generating efficiency.

2. Materials and Methods

Figure 1 depicts the experimental apparatus used in this study. Four twisted fin baffles with a 60° angle twisted on the inlet section ventury were employed in this study, as shown in Figure 2. It has a 29 mm inlet diameter and is placed 0.2 m from the bottom of an aquarium. A total of 15 tests were run by varying water flow rate (Q_L) from 40–60 lpm and gas flow rate (Q_G) from 0.1–0.5 lpm.

This study used a high-speed video camera (Phantom Miro M310) to visualize bubble behaviour under several testing conditions. The camera was set at a resolution of 768 × 480 with a recording speed of 3000 fps. The experimental data was obtained using an image processing technique adapted by previous research [7]. A differential pressure transducer Validyne P55D was installed at the ventury inlets and outlets section to evaluate pressure drop. To collect pressure data, Advantech data acquisition is used. Pressure drop, hydraulic power, and bubble-generating efficiency parameters can be calculated using this equation [8]:

\[ \Delta P = P_2 - P_1 \]  

\[ L_w = (P_1 + \rho_L \cdot v^2)Q_L \]
\[ \eta_B = (\rho_L \cdot g \cdot H \cdot Q_2) L_w \]  

where subscripts 1 and 2 mean inlets and outlets. \( \rho_L \) is the water density, \( v_{L1} \) represents the water velocity before entering the reduction area, and \( H \) is the position microbubble generator from the water surface.

3. Results and Discussion

This chapter will discuss the analysis by parameter bubble size distribution, pressure drop, hydraulic power \((L_w)\), and bubble-generating efficiency \((\eta_B)\) from obtained experimental data. Bubble size distribution was analyzed with an image processing toolbox in MATLAB R2022b. Meanwhile, hydraulic power and bubble-generating efficiency were analyzed from differential pressure data. Variation water and gas flow rates were conducted in this study.

3.1. Distribution of Bubble Size

The size of the bubble is an important indicator in a microbubble generator. This section thoroughly compared the effects of liquid-gas flow rates on bubble size distribution. Figure 3 provides the distribution of bubble sizes in distinct flow scenarios. The visualization shows that the water flow rate of 60 lpm produces smaller and more uniform bubbles than the water flow rate of 40 and 50 lpm.

![Figure 3. Bubble distribution at (a) Q_L = 40 lpm; (b) Q_L = 50 lpm; (c) Q_L = 60 lpm.](image)

The distribution of bubble size will express in the probability density function (PDF). From Figure 4, it was found that the bubble had generated in 100–300 \( \mu \)m diameter. A higher probability graphic reached 0.385 at \( Q_L = 60 \) lpm. An increase in water flow rate increases water velocity and inertia forces. When inertia surpasses Weber’s force, a larger
shear stress is applied to the bubble and breaks it into pieces. In addition, enlarging the water flow rate will inhibit initial bubble formation so that the average bubble diameter will decrease.

In the meantime, enlargement of the gas flow rate should diminish bubble stability while increasing the effect of bubble coalescence. Coalescence is defined as forming large bubbles from small ones [9]. Coalescence decreases probability curve distribution. This statement is in line with previous work [4,6].

Figure 4. Bubble size distribution at (a) $Q_G = 0.1$ lpm; (b) $Q_L = 60$ lpm.

3.2. Pressure Drop ($\Delta P$)

Data pressure from physical experiments will be calculated by Equation (1). A combination of $Q_L$ and $Q_G$ has a distinct response. Figure 5 demonstrates that pressure drops are linearly increased with increasing water flow rates. The tiniest pressure drop occurred at a 40 lpm water flow rate. In contrast, the enhancement of gas flow rate is not significantly affected pressure drop. It can be seen where the curves during the variation of gas flow rates created an identical graphic.

Figure 5. Pressure drop at (a) $Q_G$ constant; (b) $Q_L$ constant.

3.3. Hydraulic Power ($L_w$)

Figure 6 compares the calculated hydraulic power for $Q_G$ and $Q_L$ variations. Higher hydraulic power occurred at $Q_L = 60$ lpm by 79.04 W. $L_w$ increased linearly with pressure drop and water flow rates. An increased water flow rate ($Q_L$) will increase the hydraulic power by 22–27 W, while an increase in gas flow rate ($Q_G$) will only increase 1 W and conduct almost the same graphic. So, we can conclude that the water flow rates more significantly affected $L_w$ than gas flow rates.
Hydraulic power represents stored energy in the water flow in a microbubble generator. The lower the hydraulic power, the better the performance, and it is easy to select a water circulation pump [8].

3.4. Bubble-Generating Efficiency (ηB)

Bubble-generating efficiency means the energy received by air from water flow rates. Figure 7 displays the relationship between variation Q_G and Q_L by bubble-generating efficiency. It can be seen that the smallest bubble-generating efficiency occurred at Q_L 60 lpm on Q_G 0.1–0.5 lpm. On the other hand, ηB proportionally with the increment of gas flow rates. The highest ηB reached 0.05% at Q_G 0.5 lpm.

If compared, the bubble-generating efficiency in this study has lower ηB than the spherical body and porous venturi microbubble generator [6,9]. Bubble-generating efficiency decreases with an increase in hydraulic power. The lower ηB indicates that energy inside the water is used to break air into a tiny bubble in the microbubble generator rather than suck air into it [8].

4. Conclusions

The addition of the twisted baffle on the venturi microbubble generator was analyzed by examining the bubble size distribution, pressure drop (ΔP), hydraulic power (Lw), and bubble-generating efficiency (ηB). As a result, we found that bubbles with a diameter of 100–300 µm were generated. Bubble size diameter increase as Q_G increase, while inversely with Q_L. Hydraulic power increase linearly with pressure drop and Q_G. The higher Lw decrease in ηB improved the performance of the microbubble generator. Further
investigation is required to discover dissolved oxygen concentration, SAE, SOTR, and SOTE.

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**Data Availability Statement:** The information reported in this study will be made available upon request.

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