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Original article

Verification of the flow field in rearing rectangular tank using flow visualization

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Introduction

Flow structures are generated in rearing tanks owing to interference between water and the air bubbles released from aerators. The survival rate of larval fishes is considered to be sensitive to these structures [1]. However, only a few studies have been conducted on the estimation of flow fields in rearing tanks.

In general, the geometry of rearing tanks is circular, rectangular, or octagonal. In recent years, it has been reported that the survival rates obtained from the rearing experiments for circular and rectangular tanks are different [2]. Therefore, it is significant to study the flow field in rectangular tanks.

We estimated flow patterns through numerical simulation and verified the patterns using a flow visualization. The visualized flow patterns were approximately consistent with those obtained through numerical simulation. This report focuses on the visualization of the flow field in a rearing tank.

Materials and methods

Figure 1 shows the schematic drawing of the experimental apparatus. The long side (2r) of the rectangular tank is 345.5 mm in length. Aspect ratio (AR) is defined as the ratio of water depth (H) to the half of the long side (r). The amount of air (Q) supplied by an air pump was strictly controlled using a mass flow controller. Flow visualization was performed using suspension method and tuft methods. The specific weight and average diameter of the tracer used for the suspension method were 1.1 and 10 μm respectively.

The flow field for the numerical simulation was considered to be two-phase (gas–water) flow. Kuwagi et al. [3] showed the equations used for the numerical simulation and the calculation method.

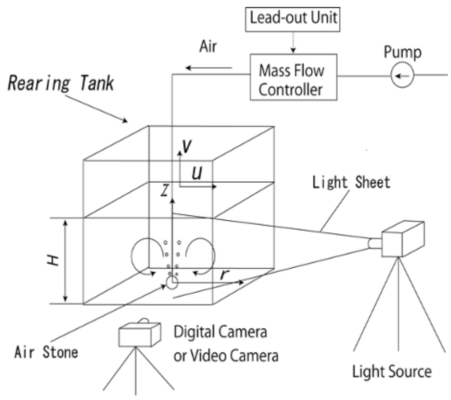

Fig. 1. Schematic of the experimental apparatus.

Results

Figure 2 shows the three-dimensional streamline distributions for AR = 1.0 and 2.0. Flow rises owing to the bubbles released from the air-stone and reaches the vicinity of the free surface. Then, the direction of flow changes to horizontal. The flow in the vicinity of the upper side wall flows down toward the direction of the bottom wall. Along the diagonal, the fluid traverses to the center along the bottom wall. In addition to the diagonal, there were various and considerably complex directions of flow. For example, the streamline close to the diagonal changes roughly 45 degrees and move to along the long side. The flow pattern for AR = 2.0 was consistent with that for AR = 1.0. We have reported that the number of the large vortexes increases as AR increases from 1.0 to 2.0 in circular tank [4]. However, the number of large vortexes in the rectangular tank did not change with AR. It is considered that the survival rates in circular tanks may be different from those in rectangular tanks.

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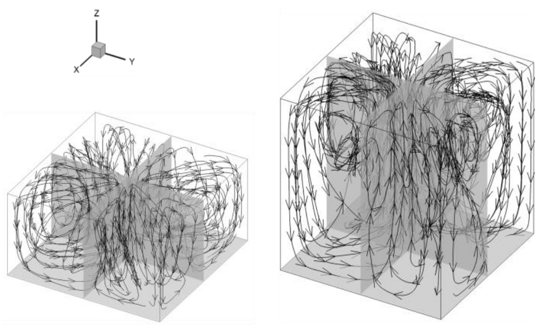
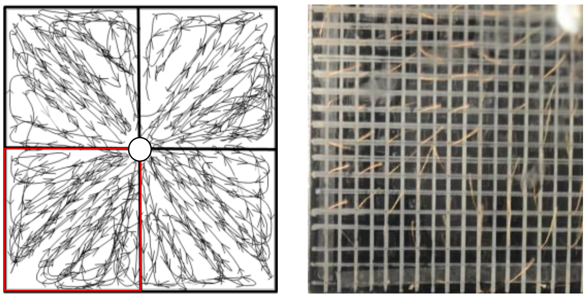


(A) AR = 1.0 (B) AR = 2.0

Fig. 2. Three-dimensional streamline distributions.

Figure 3 shows three-dimensional streamline distributions and visualization results close to the bottom wall. We have confirmed that the streamline distributions for AR = 1.0 are qualitatively consisted with those for AR = 2.0. The streamline distributions are verified through visualization using the tuft method in Fig. 3 (B).



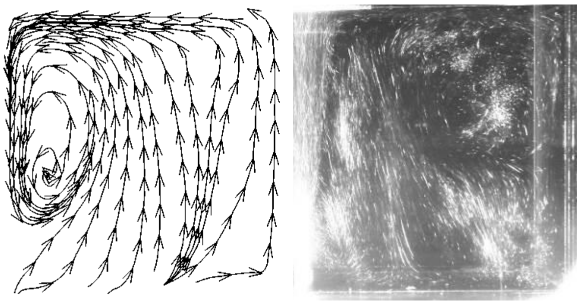
(A) Three-dimensional streamline distributions close to the bottom wall (top view).

(B) Flow visualization in the red region of Fig. 3(A).

Fig. 3. Three-dimensional streamline distributions close to the bottom wall and visualization result.

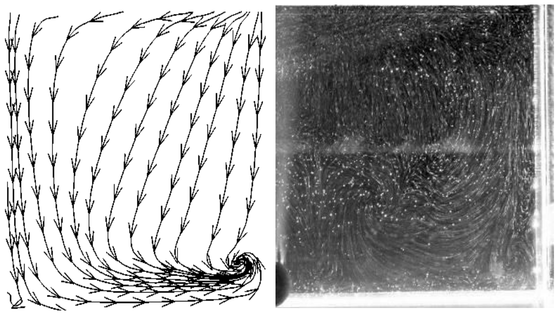
The comparison of the results of numerical simulation and flow visualization at the center plane for AR = 1.0 is shown in Fig. 4. A large vortex is observed in the results of numerical simulation and flow visualization. Even though the position of the large vortex is not different, these flow patterns are approximately consistent.

Figure 5 shows the flow pattern obtained through numerical simulation and flow visualization close to the side wall for AR = 1.0. It is seen in Fig. 5 (A) that the fluid in the vicinity of the free surface flows to the bottom wall, center along the bottom wall and consists of a vortex on the side wall. In Fig. 5 (B), a large vortex is observed on the side wall. Because the position of this large vortex is different from that in Fig. 5 (A), both flow patterns are qualitatively consistent.



(A) Simulation result (B) Visualization result

Fig. 4. Comparison of results of numerical simulation and flow visualization close to the wall plane for AR = 1.0.



(A) Simulation result (B) Visualization result

Fig. 5. Comparison of numerical simulation result and flow visualization one at near wall plane in AR=2.0.

Discussion

In this study, we performed numerical simulation and flow visualization in a rectangular tank. The results obtained are as follows;

(1) The three-dimensional flow structure is estimated using numerical simulation.
(2) The visualized flow patterns are approximately consistent with those obtained through numerical simulation. Therefore, the validity of numerical simulation results is ensured.
(3) Aspect ratio is not affected to the flow field in the rectangular tank.
(4) The flow pattern in the rectangular tank is different from that in a circular tank. It is considered that the flow pattern influences survival rate. Hence, the survival rates in circular and rectangular tanks may not be the same.

References

1. Masuma S et al. (2011) Aquaculture 315: 2–8
2. Cook MA et al. (2015) Aquacultural Eng 69: 43–49
3. Kuwagi K et al. (1999) Int. J. Multiphase Flow 25: 175–182
4. Sumida T et al. (2013) Aquacultural Eng 57: 24–31