FISH SWIMMING MODIFIES FLOW PATTERN IN AQUACULTURAL TANKS

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Introduction

Circular tank geometry is very common in aquaculture because it provides more stable flow patterns, more homogeneous distribution of oxygen and metabolites, better self cleaning features, and higher average velocities than rectangular tanks, thanks to the rotating flow characteristics. In a tank with a rotating flow pattern, like circular tanks, the average water velocity (V_{avg}) is controlled by the inlet impulse force (Fi) (Eq. 1).

$$F_i = \rho Q\left(V_{in} - V_{avg}\right) \qquad \text{Eq. 1}$$

where ϱ: water density, Q: injected water flow rate, and V_{in}: jet inlet velocity.

Average velocity in tanks with rotating flow pattern will be proportional to the square root of the impulse force (Oca and Masaló, 2007).

In addition to the average velocity, also the distribution of velocities is important, since velocity gradient from the outer to the inner area of the tank is found in circular tanks.

Oca and Masaló (2013) proposed a model for determining the distribution of velocities in circular tanks (Eq. 2) by determining the angular momentum per unit mass (β) in different radius of a tank (β in a radius r can be defined as β=V·r). Variables needed to determine velocity (V) in any radius from r=0 to R (R tank radius) are the angular momentum per unit mass near the tank wall (βw) and around the central axis (βo).

$$V = \frac{1}{r}\beta_0^{(1-{r}/{R})}\beta_w^{({r}/{R})} \qquad \text{Eq. 2}$$

Next to the tank wall (r=R), the velocity is determined by βw (V=βw/r) and when r decreases βo takes more importance in the determination of the velocity. Nevertheless, Eq. 2 cannot be applied in the center of the tank (r=0), were V should tend to infinite. A forced vortex, characterized by velocities proportional to radius is formed in the vicinity of the tank center, due to the increasing importance of friction forces. Therefore, the distribution of velocities in this area is not described by Eq. 2. A linear relationship was found between βw and the square root of Fi, and a linear relationship between angular momentum in the proximity of the tank's center (βo) and Q. The diameter of the forced vortex formed in the tank center was very small

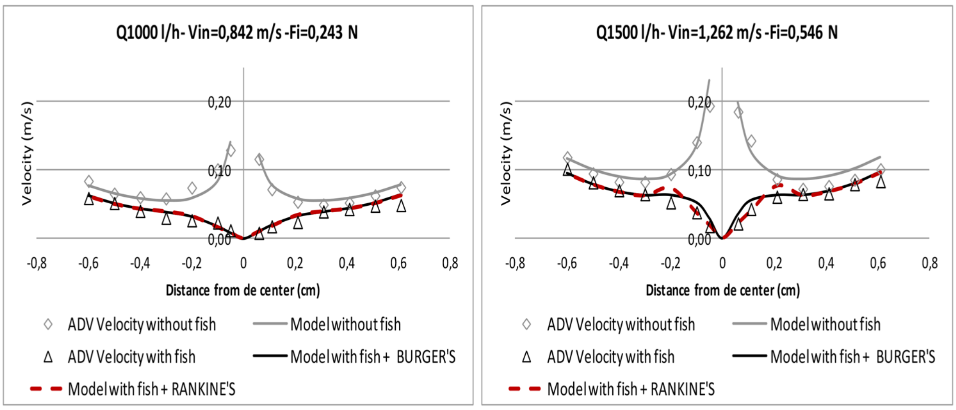

Fig 1. Water velocity profiles obtained and predicted (modeled) with different Fi and Q with fish of 153.90 ± 30.90 g at 14 kg/m^3.

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in a tank without fish. Nevertheless, in a tank with fish, where turbulence due to fish movement is introduced, turbulent viscosity will contribute to increase the relative importance of friction forces and to enlarge the area affected by the central forced vortex.

In the literature different distribution of velocities in the central area, where V/r will be constant, are described, eg. Rankine or Burger's model.

The objective of the work is to determine how fish affect velocity distribution in a circular tank, and set up a model to predict water velocity distribution in a tank with fish, applying Oca and Masaló (2013) model together with Rankine's and Burger's models to adjust velocities around the central area of the tank.

Material and methods

Different tank configurations are evaluated with Sea bass of different weight (303.41 ± 72.01 and 153.90 ± 30.90 g) and at different densities (14 and 25.5 kg/m^3).

Water velocities were measured with an ADV probe in 14 points, in a diameter of a circular tank (R=0.75 m and water height H=30 cm). Five flow rates (550, 800, 1000, 1500 and 1900 L/h) and three inlet diameters (Di: 13, 20.5 and 32 mm) were used.

With measured velocities, β_w and β_0 was determined in each experiment, and velocities at different radii were calculated in experiments without fish using Eq. 2.

[illegible] and Rankine's (Eq 4) models were introduced.

$$V = \frac{1}{r}\beta_0^{(1-r/R)}\beta_w^{(r/R)}\left(1 - e^{-\alpha r^2}\right) \quad \text{Eq. 3}$$

where: α $ar^2/2\theta$ α $ar^2/2\theta$, being a the strength suction and θ θ the kinematic viscosity.

The Rankine's model (Eq. 4) is applied in the inner part of the tank (r<0.3 m), where β is proportional to r^2, and in the outer part Oca and Masaló (2013) model were used.

$$V = N \cdot r \quad \text{Eq. 4}$$

Results and discussion

Velocities obtained in experiments with fish were always lowers than in experiments without fish. Comparing velocity profiles in experiments with and without fish (Fig. 1) it is shown that slight differences appear in the velocities near the wall, and higher differences are concentrated in the area close to the tank center.

In experiments with fish, alfa values (α, Eq. 3) and N (Eq. 4) estimated show a relation with impulse force (higher Fi imply higher α and N values).

Velocities modeled in experiments with fish fit well with velocities measured, and the models applied (Eq. 2, 3 and 4) are showed as a good tool to predict velocity distribution under different water inlet characteristics in tanks with fish.

Acknowledgments

References

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