OXYGENATION CONE DESIGN TO LEVEL UP OXYGEN IN A WASTEWATER STREAM

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1. Introduction

In a wastewater treatment plant (WWTP) the lack of dissolved oxygen results in an inefficient degradation of the organic matter by microorganisms, leading to the appearance of hydrogen sulphide in residual waters. This compound is responsible for odour in stagnant waters and corrosion of the plant pipelines. Thus it is necessary to create aerobic conditions with some kind of aeration system. The two most common systems are mechanical and subsurface. In the first system, wastewater is agitated by various means (e.g., propellers, blades, or brushes) to introduce air from atmosphere. In the other, air is introduced by diffusers or other devices submerged in the wastewater [1]. In the present work a subsurface system is proposed comprising a cone shaped vessel where pure oxygen is injected in a downward flow as represented by the scheme in Figure 1. With this type of solution dissolved oxygen is increased nearly 5-fold compared to air.

2. Model Design

Consider a bubble inside the cone subjected to three forces: weight (W), buoyancy (B) and drag force (FD). Applying Newton's 2nd law of motion and neglecting the bubble's weight one obtains:

$$m\frac{dv}{dt} = F_D + W - B \cong F_D - B \qquad (1)$$

Drag force is expressed as a function of fluid velocity relatively to the bubble velocity, $v_{fluid/bubble}$ as:

$$F_D = \tfrac{1}{2}\rho \cdot v^2_{fluid/bubble} \cdot C_D \cdot A \qquad (2)$$

Here, as usual, ρ is the fluid density, C_D the drag coefficient and A the bubble cross section. Defining v_{fluid_1} as the fluid velocity at the cone entrance and v the bubble velocity, the relative velocity can be computed as a function of z taking into account the continuity equation and trigonometric reasoning:

$$v_{fluid/bubble} = v_{fluid_1}\left(\frac{R_1}{R_1 + z \cdot \tan\theta}\right)^2 - v \qquad (3)$$

Substituting this expression into (2) and after that in (1) and remembering that $B=\rho \cdot g \cdot V_{bubble}$ results in:

$$m\frac{dv}{dt} = \tfrac{1}{2}\rho\left[v_{fluid_1}\left(\frac{R_1}{R_1 + z \cdot \tan\theta}\right)^2 - v\right]^2 C_D \cdot A - \rho \cdot g \cdot V_{bubble} \qquad (4)$$

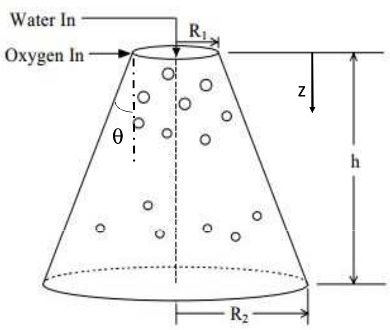

Figure 1 – Speece cone scheme [2].

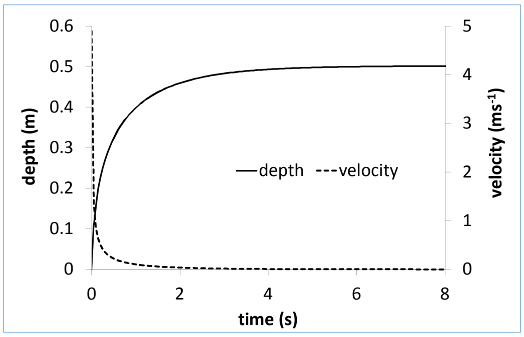

Figure 2 – Depth and velocity profiles.

3. Results and Discussion

The equation 4 together with velocity definition, $v = dz/dt$, were solved by a 4th and 5th order pair *Runge-Kutta* integration method with initial conditions of z=0 m and v=4.9 ms^{-1}. Assuming Newton's law regime ($1000<Re_{bubble}<350000$) a constant drag coefficient of 0.44 was considered and it was assumed a bubble volume of 0.5 cm^3. The depth and velocity profiles are presented in Figure 2.

4. Conclusions

It may be concluded that a cone shaped vessel of 2.54 cm of inlet mouth and 50 cm height is sufficient to stop a bubble that enters the cone at the same velocity of water. The maximum depth of the bubble corresponds to the condition that velocity and resultant force are both null. It still misses to determine dissolved oxygen in the water stream, leaving the vessel, as a function of relative amounts of oxygen and water.

5. References

[1] U.S. EPA, 1999. Wastewater Technology Fact Sheet: Fine Bubble Aeration. EPA-832-F-99-065.
[2] McGinnis, D. F.; Little, J. C. Bubble dynamics and oxygen transfer in a speece cone. Wat. Sci. Tech. 1998, 37(2), 285–292.