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A computational method of a convective activated sludge model (ASM) in reaction tanks of wastewater treatment plants

Yasuo Obikane

Mechanical Engineering Department, Sophia University, Tokyo, Japan
Tel. +81 (3) 3238-3302; Fax +81 (3) 3238-3302; email: y-obikan@sophia.ac.jp

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ABSTRACT

Electricity is used to power the blower in wastewater treatment plants in populations of more than twenty thousand. The small upgrade efficiency yields a large amount of energy since, in some trains, the blowers are operated for 24 h. To estimate the temperature and the amount of air, we developed a computational method that predicts the state variables of inhomogeneous activated sludge, such as dissolved oxygen (DO), in reaction tanks and final stabilization ponds. We propose a model for sludge that is less the size of the computer cell for N and Pa. The computer model includes ASM to predict the SS, the organic SS, and the growth rates of the density. The flows in the large scale computational domain are computed to form sedimentation. The benchmark computations were successful in separating the density and form sedimentation.

Keywords: Activated sludge model; Aeration; Turbulence; PFM

1. Introduction

Saving electricity and less discharge in the air surrounding residential areas are the two main environmental policy issues. The sewage-treatment-plant yields save electricity for aeration pumps which operate 24 h. The present research will contribute to the operation plans for the aerations. Our main purpose is to find a computational method to predict the state variables of activated sludge in reaction tanks and final stabilization ponds. A similar classical model for the ASMs of IWA was tested during the 1980s for the purpose of predicting the water quality in brackish lakes in Japan. This yielded several problems, such as the parameterization of plankton's growth rate and simultaneous adjustments parameters for N and P. In most cases, the parameterization was successful for only one of the components. It was successful for weak concentrations because it was almost proportional to the rates of the upwelling. Many new reports of the ASM models have similar results. However, there are some discrepancies when compared to the observation, as well as the classical models. The activated sludge process includes several time and length scales; it was modeled on one set of equations in the ASM. Though the detail mechanism of the processes is not known in the present work, we can remove some uncertainty with advance computational fluid dynamics (ACFD) technology by introducing a phase field model. In the present work, a new computational model is proposed and a mathematical formulation is presented to apply a simple activated sludge reclamation system.

2. ASM model in convective flows

We must remark that the ASM proposed by IWA [1] includes the effect of convection in the constants in the

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model. So, we need to modify all constants. As shown in Fig. 1, we use a scale in micron where the bacteria are activated with SS, including N and P. The activated sludge comes in two states: sediment (As) or bulky (Af). The states depend on the temperature and flow conditions, as well as aeration. In the present model, the temperature variation does not explicitly include the model. The convective activated sludge model (ASM) is given by the following equation:

$$\partial \rho X_p / \partial t + \left(\rho u_i X_p\right)_i = M_{pq} X_p \tag{1}$$

where p is taken from 1 to 13. The full representation ASM [1] follows the IWA ASM1 model in [1]. The production term, the annihilation term, and the source terms are compared with other nitrogen conservation models as the following:

$$N_i = X_9 + X_{10} + X_{11} \tag{2}$$

$$X_{14} = f\left(\varphi_q\right) \tag{3}$$

where φ_q is the q-th order parameter, X_5 is bacteria, and X_{12} is organics NO.

Let A be activated sludge. This can be split as An and Ap of activated sludge. The normalized aeration rate is Va (0–1). Then the form becomes:

$$dAp / dt = Va\, G1\left(Ap\right) - \text{decay } 1 \tag{4}$$

$$dAn / dt = \left(1 - Va\right) G2\left(An\right) - \text{decay } 2 \tag{5}$$

where $G1$ and $G2$ are the production function known as the plankton growth model. The shape and size of the bundle of sludge are given by the integral form of the air particle's history. Thus, we need to convert the Lagrangian form to the Euler formation with relative velocity in the cell. Let As denote the concentration of air and dissolved air. To determine either floating or falling, we model the switch by parameter As in the next instant. The example of the computation is in Fig. 1. The sludge SS and Vss grow in the convective flow by sucking N, P at a rate that depends on aeration. Hereafter, we only consider the sedimentation state, since the method is the same in the computational modeling and actual computation technology.

3. Sedimentation process with the interface by the PFM

Sedimentation and the floating foam of large structures of ASM can be described by the PFM equation. The temperature in the chemical potential is simply replaced by Ac in the chemical potential. As the flow is turbulence, the PFM equation with the Reynolds decomposition is given by the following form:

$$\frac{\partial \phi}{\partial t} = \Gamma_0 \left(\phi_i \zeta\right)_i - \Gamma_0 k_2 \left(\phi \phi_{qq,i}\right)_i + \delta F_r \tag{6}$$

where the order parameter ϕ is the order parameter representing SS. The turbulence part δF_R is shown by the following:

$$\delta F_R = \Gamma_0 \overline{\left(\phi_i' \varsigma'\right)}_i - \Gamma_0 k_2 \left[\overline{\left(\phi_i' \phi_i'\right)}_{jj} + \overline{\phi_{ii}' \phi_{jj}'} - \frac{1}{2} \overline{\left(\phi' \phi'\right)}_{iijj} \right] \tag{7}$$

The ς_i is the diffusive function defined in [2,3].

4. Large-scale flow model

We introduce the order parameters that determine the rate of the production of the organic nitrogen substance and bacterial substance. We put one more variable, say X_{14}, into the first ASM model (1985) and made a modification to preserve the total production of the organic nitrogen and in-organic nitrogen in the system. For the confirmation, we wrote the full representation of the system in the gravitation field where aeration is operated continuously:

$$\rho = \rho_w + \rho_{ss} + \rho_{air} \tag{8}$$

$$\partial \rho \partial t + \left(\rho u_i\right)_i = \left(\text{rate of phase change}\right) \tag{9}$$

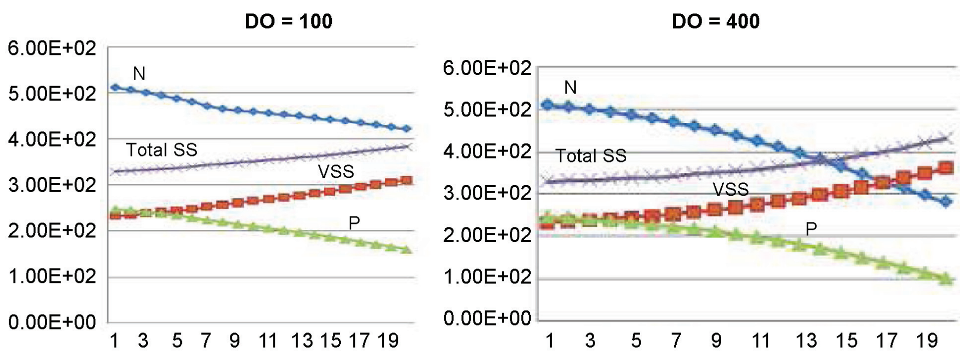

Fig. 1. Typical ASM model with different DO.

$$\rho \partial u_i / \partial t + \rho \left(u_i u_j \right)_j = -p_i + \mu \left(u_{i,j} + u_{j,i} \right)_j + g\rho \qquad (10)$$

The H-C PFM equation in [2] is:

$$\rho \partial \phi / \partial t + \rho u_i \phi_i = \Gamma F(\phi) + \text{source} \qquad (11)$$

The equation system also includes the turbulence modeling of the density gradient model and the Reynolds stress closure in [5]. The formation of sedimentation is computed in the gravity field.

5. Computation procedure

We took the long computational steps shown below:

- Step 1: compute the velocity field
- Step 2: compute growth rate of N, SS, BOD, COD
- Step 3: compute the falling sedimentation
- Step 4: compute the sedimentation

6. Flow computation models and convective ASM computations

The result of aeration is shown in Fig. 2. In the final stage, we performed a test on the aeration in the center of the domain. We used a typical case of a water treatment plant in Japan. The water quality of influent and COD is average 800 ppm and the COD in the final pond is less than 6 ppm to discharge to the river. In the benchmark computation, we assumed a distribution of the COD for X_1, X_2, X_3, and X_4. DO is also assumed by the aeration rate. As shown in Fig. 3, the stabilization pond will need more space to fall. There it is still convecting at the end where the large space had sedimented. The computation shows the separator is quite effective.

7. Conclusion

Though the bench mark computations for each time scale were performed separately, the sedimentaion of SS was formed successfully.

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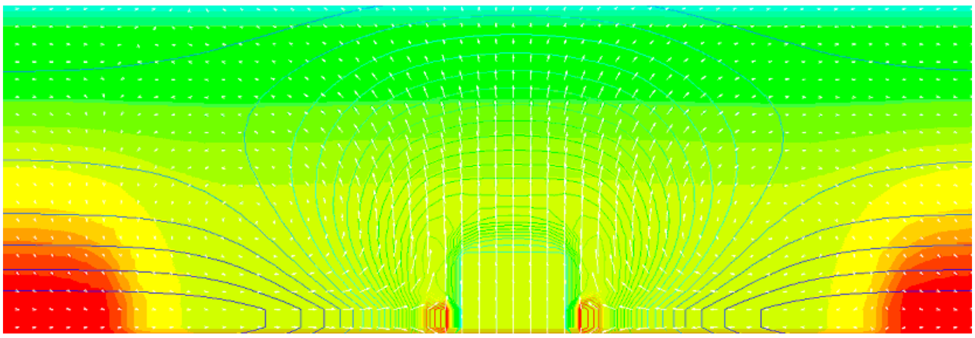
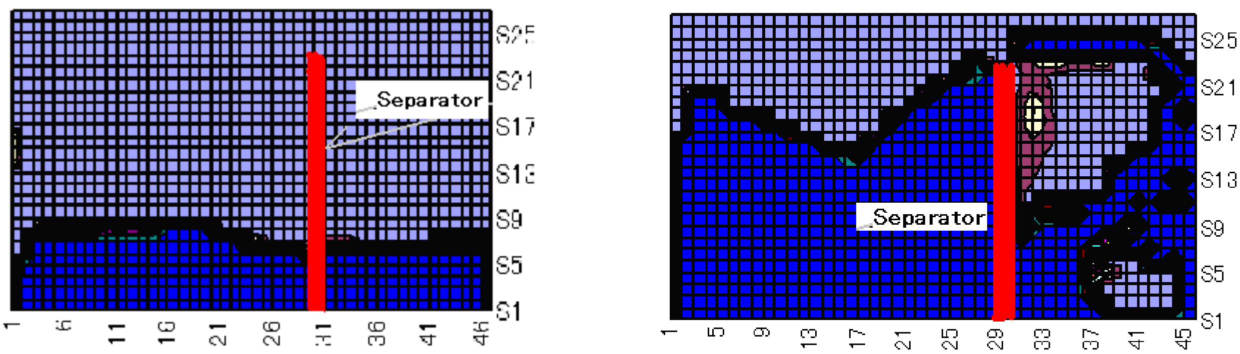


Fig. 2. Flow pattern near the aeration jet in the upstream of the tank.



(A) Early stage

(B) Final stage

Fig. 3. Forming of the sedimentation A, B.

References

[1] Activated Sludge Models ASM1, ASM2, ASM2, and ASM, Scientific and Technical Report No. 9, IWA Publishing, London, 2000.

[2] N. Takada, A. Tomiyama and S. Hosakawa, Numerical simulation of drops in a shear flow by a lattice-Bolzmann binary fluid model, Comput. Fluid Dynamics J., 12 (2003) 475–481.

[3] Y. Obikane, A frequency dependence of the phase field model in laminar boundary layer with periodic perturbation, JP65000, ICAMSC 2010, International Conference Applied Mathematics and Science Computing, Tokyo, Japan, May 2010.

[4] Y. Obikane and S. Ikeo, Application of invariant turbulence modeling of the density gradient correlation in the phase change model for steam generators, ICCFD 6, St. Petersburg, [year??].

[5] Y. Obikane, Research on the correlation of the fluctuating density correlation of the compressible flows, WASET Proc., 60(137) (2009) 79–793.