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THEORETICAL AND EXPERIMENTAL RESEARCH CONCERNING THE MODIFICATION OF DISSOLVED OXYGEN CONCENTRATION IN AERATION TANKS EQUIPPED WITH SURFACE AERATORS

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In this paper is shown the modeling of oxygen transfer process from air to water in an aeration tank equipped with six surface aerators. The gas transfer and transport equation in a water mass and modeled using FlexPDE working medium is highlighted. The results of modeling are displayed.

Keywords: water aeration, surface aerators, oxygen concentration

1. Introduction

The process of aeration named also oxygenation “is a process of mass transfer of a gas into a liquid mass” [1]. This process applied to water, is based on air dispersion and is a complex one. The addition of air into water has as a result an increase of dissolved oxygen level [2,3].The aeration process can be achieved naturally but also artificially in water tanks using aeration equipments. The aeration equipment contributes to the forced introduction of atmospheric oxygen into the water, ensuring a homogeneous mixing of the aqueous medium [4].Wastewater treatment can be performed aerobically and/or anaerobically [5,6]. In the wastewater treatment plants provided with pneumatics aeration systems, the air, respectively the oxygen, is fueled through the diffusers, which are located below the water level, achieving the so-called bubble aeration; instead in the ones provided with mechanical aeration, the atmospheric oxygen is introduced into water by actuating the aerators, the surface aeration is accomplished [7]. The mechanical aeration represents the movement of the entire water volume in the tank and is made by mechanical devices that produce turbulence in the air-water contact surface [4]. The surface mechanical aerators are the most common reactors used almost universally for gas dispersion in biochemistry, fermentation and wastewater treatment industries. The mechanical aeration is achieved by the recirculation of the wastewater from the tank bottom and spreading it circularly with a vertical aerator. The mechanical surface aerators increase the entrainment

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of atmospheric oxygen into the aeration tank, by producing a high turbulence in the region around the aerator. The turbulence introduced through the rotation action of the aerator blades favors the complete homogeneous mixing, so that aeration occurs through the atmospheric oxygen and the water surface interface [8]. In the scientific literature various methods of aeration are described, but from all, the mechanical surface aeration has proved to be the best combination of low initial cost, installation costs, exploitation and reduced maintenance.

2. Modeling and simulation of the oxygen concentration in a treatment plant tank equipped with mechanical surface aerators

The mathematical modeling is an important step in the implementation of wastewater treatment processes. The considered model in the presented research case is the aeration tank from the SC. EcoAqua SA. Călăraşi, subsidiary - Urziceni, Ialomiţa wastewater treatment plant. The aeration tank is a parallelepiped with the following dimensions: length L = 25.5 m, width B = 17 m and height H = 2.9 m, equipped with a mechanical aeration system that includes 6 propeller aerators type 75 ART. These aerators provide a 92% treatment degree.

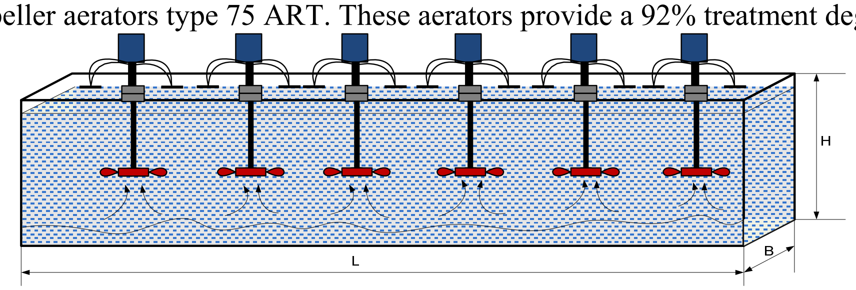

Fig. 1. The principle scheme of the aeration tank

The mechanical aerators pulverize the water as drops and drive the atmospheric air through the jet effect on the water mass re-entry in the tank. One of the most important parameters in the aeration system control is the dissolved oxygen in water.

The equation that describes the oxygen dispersion transferred to the aqueous medium a through the water-air interface, is the following [1,9]:

$$\frac{\partial \bar{C}}{\partial t}+\frac{\partial}{\partial x}\left(\bar{u}\,\bar{C}\right)+\frac{\partial}{\partial y}\left(\bar{v}\,\bar{C}\right)+\frac{\partial}{\partial z}\left(\bar{w}\,\bar{C}\right)=\frac{\partial}{\partial x}\left(\varepsilon_x\frac{\partial \bar{C}}{\partial x}\right)+\frac{\partial}{\partial y}\left(\varepsilon_y\frac{\partial \bar{C}}{\partial y}\right)+$$
$$+\frac{\partial}{\partial z}\left(\varepsilon_z\frac{\partial \bar{C}}{\partial z}\right)+D_m\left(\frac{\partial^2 \bar{C}}{\partial x^2}+\frac{\partial^2 \bar{C}}{\partial y^2}+\frac{\partial^2 \bar{C}}{\partial z^2}\right)+S(x,y,z,t) \quad (1)$$

where:

- x, y, z represent the considered point coordinates in the aeration tank; u, v, w - the three directions velocities;
- C (x, y, z, t) is the oxygen concentration in the aqueous medium;
- ε_x, ε_y, ε_z represents the longitudinal, transversal and vertical dispersion coefficients;
- D_m - the molecular diffusion coefficient of the oxygen from air to water;
- S (x, y, z, t) - the source term.

The manner in which an agitated liquid is moving in the tank depends on several factors: the rotor type, the liquid characteristics, its viscosity in particular, and the tank dimensions [10].

The liquid velocity at any point in the tank has three components, and the general flow model in the tank depends on these three velocities variations [11].

The first component is the radial velocity and acts in a perpendicular direction to the rotor axis.

The second component is acting in the longitudinal direction and parallel with the shaft.

The third component is tangential or rotational and acts in a direction tangential to a circular path around the shaft. In the usual case of a vertical shaft, the radial and the tangential components are in a horizontal plane and the longitudinal component is vertical.

The radial and longitudinal components are useful and necessary and ensure the mixing action flow rate [10,11].

Considering the above, the dispersion equation becomes:

$$\frac{\partial \bar{C}}{\partial t} + \frac{\partial}{\partial x}\left(\bar{u}\,\bar{C}\right) + \frac{\partial}{\partial z}\left(\bar{w}\,\bar{C}\right) = \frac{\partial}{\partial x}\left(\varepsilon_x \frac{\partial \bar{C}}{\partial x}\right) + \frac{\partial}{\partial z}\left(\varepsilon_z \frac{\partial \bar{C}}{\partial z}\right) + D_m\left(\frac{\partial^2 \bar{C}}{\partial x^2} + \frac{\partial^2 \bar{C}}{\partial z^2}\right) + S\left(x,z,t\right) \qquad (2)$$

For the numerical integration of equation 2 the Flex PDE program was used [12]. This is software for general use to obtain numerical solutions to partial differential equations in two or three dimensions.

Flex PDE performs the operations required to transform a system description of partial differential equations in a finite element model, it solves the system and presents the results graphically.

The equation constants are determined using the design parameters of the aeration tank or using the literature available correlations.

1) The transversal velocity equal to:

$$u = R \cdot \frac{\pi \cdot n}{30} = 1 \cdot \frac{3.14 \cdot 1500}{30 \cdot 60} = 2.61 (m/s)$$

where: R = aerator radius; n = rotation number

2) The vertical velocity equal to, [9]:

$$w = 0.65 \cdot w_b \ (m/s)$$

where: w_b= the lifting velocity of the air bubble in m/s and is given by:

$$w_b = \sqrt{\frac{2 \cdot \sigma}{\rho \cdot d_b} + 0.5 \cdot g \cdot d_b}$$

where: σ = water surface tension, $\sigma = 0,0726\ N/m$

ρ = water density, $\rho = 1000\ kg/m^3$

d_b= bubble diameter, $d_b = 3\ mm$

$$w_b = 0.2512 m/s \Rightarrow w = 0.163 m/s$$

The wastewater flow rate is considered Q_{ww} = 144 m^3/h.

3. Results

To model the oxygen concentration evolution one starts from an initial value of 0 mg/l oxygen concentration. In Fig. 2 the calculation mesh built automatically by the program and used for the numerical integration of equation 2 can be observed.

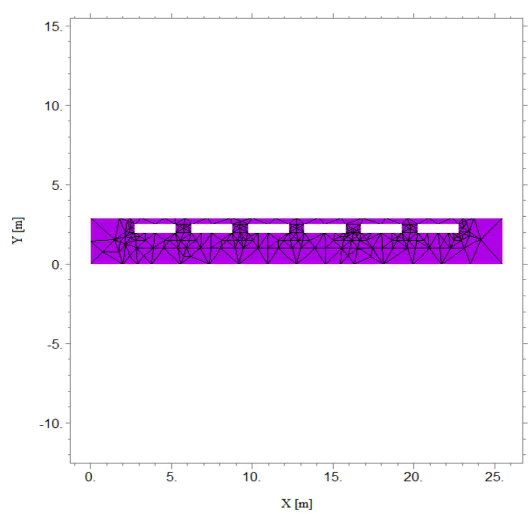

Fig. 2. The calculation mesh built by Flex PDE for two-dimensional domain

Fig. 3 shows the distribution of oxygen concentration in the aeration tank for a 144 m^3/h wastewater flow rate. One can observe that the maximum concentration (C_s = 6 mg_{O2}/l) is at the top of the tank, in the mechanical surface aerators area.

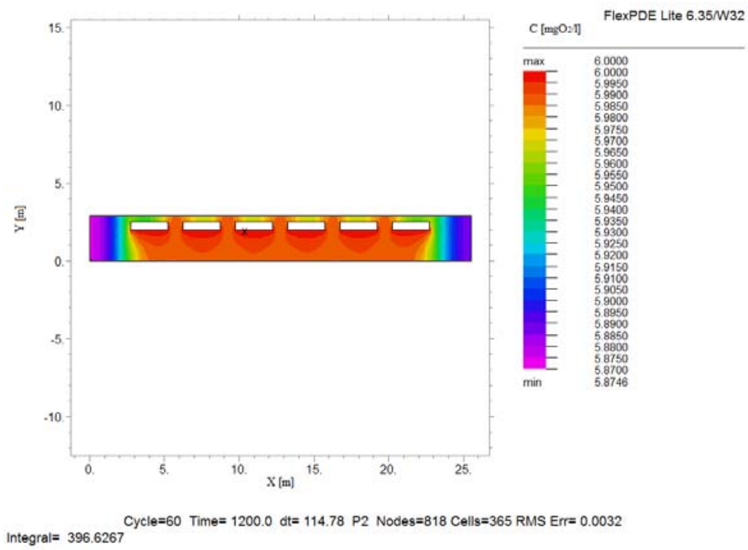

Fig.3. The repartition of oxygen concentration in the aerators area

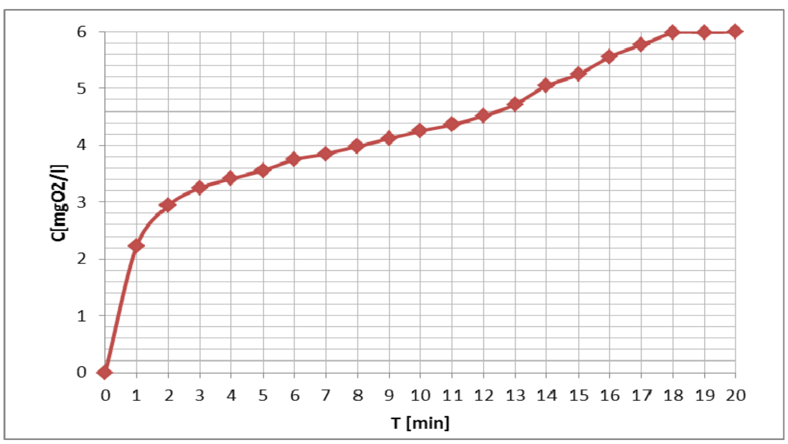

Fig. 4. The dissolved oxygen concentration in water function of time

Fig. 5 presents the results of the mathematical modeling of dissolved oxygen concentration.

On the graph (fig. 4) is the oxygen concentration (mg/ l) function of time (s) at various points along the center line.

One observes that the maximum concentration is reached in about 20 minutes of operation.

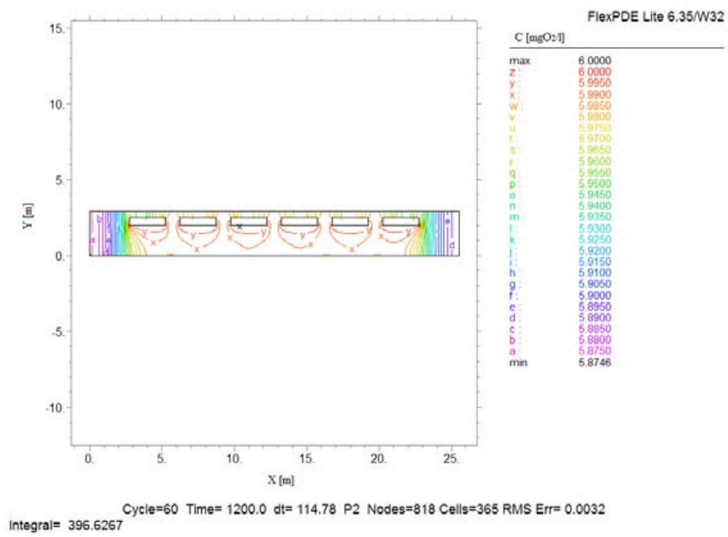

Fig.5. The evolution of dissolved oxygen concentration in the tank

Fig. 5 show the evolution of dissolved oxygen concentration in the aeration tank. The concentration of dissolved oxygen in the water is higher in the aerators area propagating in time to the aeration tank bottom.

4. Experimental researches

Table 1 presents the results of experimental research conducted in waste water with 19˚ C. In the table thr following notations are made:

- Number of measurement – No. crt;
- Aeration Time - T [min];
- The concentration of dissolved oxygen in water - C [mg/l].

Table 1

Measured values

No.crt.	T[min]	C[mg/l]
1	0	0,00
2	1	2,02
3	2	2,64
4	3	2,88
5	4	3,05
6	5	3,18
7	6	3,35
8	7	3,55
9	8	3,74
10	9	3,87
11	10	4,05

12	11	4,18
13	12	4,32
14	13	4,58
15	14	4,85
16	15	5,1
17	16	5,35
18	17	5,58
19	18	5,78
20	19	5,95
21	20	6,00

Based on data in Table 1 the function C = f (T) is plotted (Fig. 6).

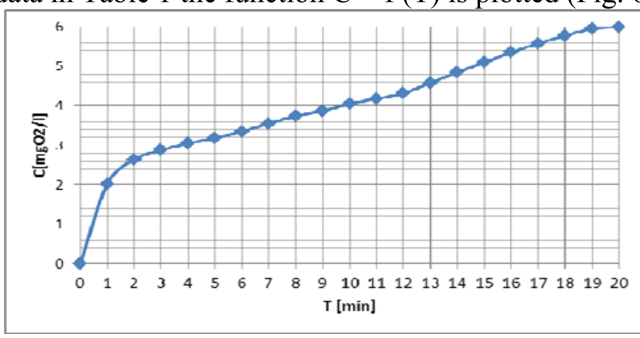

Fig. 6 The variation of dissolved oxygen concentration in waste water function of time

The variation curve of dissolved O_2 concentration in waste water function of time shown in Figure 6 was experimentally determined.

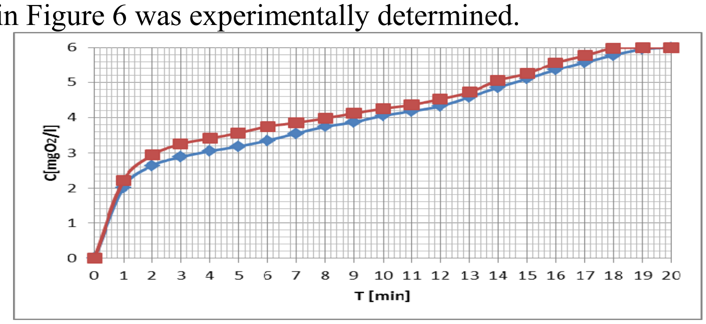

Fig. 7 The variation of oxygen concentration in waste water function of time

theoretical results

experimental results

Fig. 7 presents the comparison of experimental results with the theoretical results for the of dissolved oxygen concentration in waste water.

5. Conclusions

The model presented in this paper is based on a real aeration tank from a wastewater treatment plant in Romania, SC.EcoAqua SA. Călăraşi, subsidiary - Urziceni, Ialomița. The mathematical modeling was performed to determine the performance of surface aerators from the wastewater treatment plant, with the help of FlexPde program, observing that the dissolved oxygen concentration at saturation is reached after 60 cycles.

One can observe how the dissolved oxygen concentration in water increases faster in the first part of the aeration process, entering on a linear line after about 20 minutes of operation, when the maximum dissolved oxygen concentration in water is achieved. Various studies have been conducted on the results obtained by this type of aeration systems [13,14].

In the future, the experimental determination of the dissolved oxygen concentration in water, as well as the comparison of the obtained results, are the subject of a PhD thesis.

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