RESEARCHES REGARDING THE REDUCTION OF THE WATER OXYGENATION TIME

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Abstract. The purpose of this paper is to introduce a type of fine bubble generator that reduces two times the water oxygenation time. Originally, a fixed fine bubble generator, fixed, having 37 nozzles of Ø0.5mm, is introduced in a water tank: the air flow introduced into water and the hydrostatic load are maintained constant; the saturation concentration of the O_2 dissolved in water is reached in two hours. Consequently, in the same conditions, a fine bubble generator that has the nozzle plate involved in a rotational motion is tested. It is remarked that the water oxygenation time is reduced by one hour.
Keywords: fine bubble generator, water oxygenation.
Rezumat. Scopul lucrării este de a prezenta un tip de generator de bule fine care reduce timpul de oxigenare a apelor de două ori. Inițial, într-un rezervor cu apă se introduce un generator de bule fine, imobil, având 37 de orificii cu Ø0,5mm: Se mențin constante debitul de aer introdus în apă si sarcina hidrostatică; concentrația la saturație a O_2 dizolvat în apă se atinge în două ore. Ulterior, în aceleaşi condiții, se încearcă generatorul de bule fine care are placa cu orificii antrenată în mişcare de rotație şi se constată reducerea cu o oră a timpului de oxigenare a apei.
Cuvinte cheie: generator de bule fine, oxigenarea apei.

1. INTRODUCTION

The water oxygenation is a physical process through which the oxygen spreads from the atmosphere in a water volume having an open surface, as lakes, oceans or rivers.

The dissolution speed of the oxygen (or the absorption speed of the water) is inversely proportional with the saturation degree of the water in the dissolved oxygen and directly proportional with its shortage [1] [2].

The oxygenation devices used for the dissolution of the air in water can be: mechanical devices, pneumatic devices, mixed devices, using air or pure oxygen, ozone. The most used are the pneumatic ones, because of their increased efficiency. [3].

The oxygenation systems using fine bubble generators with the diameter of the bubbles $d_b < 1$ mm assure the highest oxygen transfer from air into water and have an efficiency of $E = 1.5 \div 3.6$ [kgO_2/kW·h]. In the case of the FBG, the diameter of the air bubble is altered by the air flow that circulates through the generator, the bubble increasing its dimension when the air flow rate increases through the equipment [1].

The stationary water oxygenation is very important and has many technological applications: wastewater treatment plants, tanks, fisheries etc.

One of the modalities of increasing the mass transfer from air to water consists in rotating the fine bubble generators; this operation can be done in several ways, using several systems, depending on the geometry and the dimensions of the tank, lake or pond in which the aeration is needed. For this purpose a new type of fine bubble generator, whose perforated plate is involved in a rotational motion, was conceived and constructed.

The purpose of this experimental research is to prove that the oxygenation plants with fine bubble generators involved in a rotational motion are more performant than the classical ones, with fixed fine bubble generators.

2. THE DESCRIPTION OF THE EXPERIMENTAL PLANT

* Originally, a fine bubble generator, in a fixed position, having the water layer over it at a height of H = 500 mm, was introduced in the tank 11 from figure 1; the initial concentration of the oxygen dissolved into water was of C_o = 3.12 mg/l. Compressed air was introduced in the FBG at the pressure (p_1):

$$p_1 = \rho \cdot g \cdot H + \frac{2\sigma}{r_0} + \Delta p \ \ [\mathrm{N/m^2}] \qquad (1)$$

where: $\rho g H$ is the the hydrostatic load; $2\sigma/r_0$ – the pressure due to the surface tension; σ – the coefficient of the surface tension of the water; r_0 – the radius of a nozzle; Δp – the pressure losses that appear when the air circulates through the FBG.

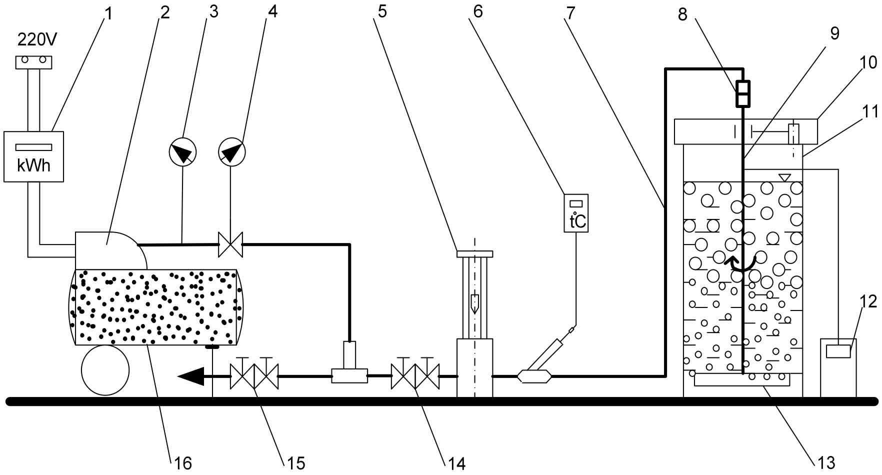

Fig. 1. The general sketch of the experimental plant:
1 – electricity meter; *2* – compressor; *3* – manometer; *4* – pressure reducer; *5* – rotameter; *6* – digital thermometer; *7* – compressed air pipe; *8* – mobile sealing; *9* – driving rod of the FBG; *10* – platform for the driving mechanism of the FBG rod; *11* – water tank ; *12* – digital manometer; *13* – nozzle box; *14* – control valves for the air flow towards the FBG.; *15* – valves for the evacuation of the additional air; *16* – compressed air tank.

The fine bubble generator (FBG) has 37 nozzles with Ø 0.5 mm; therefore $r_0 = 0.25 \cdot 10^{-3}$ m, and it is known from previous researches [4] that Δp has the value of 20 mmH_2O.

Figure 2 presents the sketch of the fine bubble generator immersed into water.

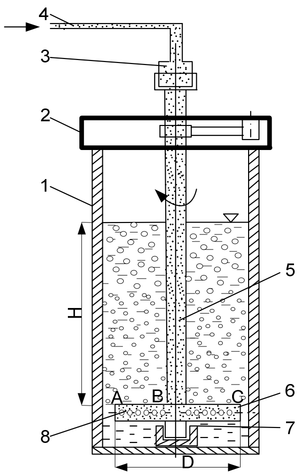

Fig. 2. The sketch of the FBG. immersed into water:
1 – water tank; *2* – platform for the driving mechanism of the FBG rod; *3* – mobile sealing; *4* – compressed air pipe; *5* – FBG rod; *6* – nozzle box; *7* – axial bearing; *8* – nozzles with Ø0.5 mm.

The mobile sealing (*3*) allows the rod (*5*) to execute a rotational motion; the upper part of the mobile sealing (*3*) is firmly fixed on the pipe (*4*), and the lower part is mobile, solidary with the rod (*5*) and the nozzle plate (*6*).

Compressed air is introduced through the rod *5* (fig. 2). The rod is involved in a rotational motion by a mechanism. The details of this mechanism are presented in figure 3.

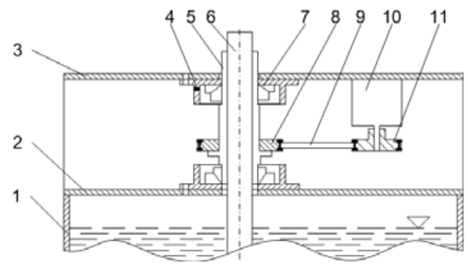

Fig. 3. Device used to involve the FBG rod in a circular motion:
1 – water tank; *2* – base plate; *3* – upper plate; *4* – casing for bearing cone; *5* – central nut; *6* – rod; 7 – bearing cones; *8* – gear wheel; *9* – gear belt; *10* – stepping motor; *11* – gear wheel coupled with the motor axle.

The electric motor (*10*), through the gear belt (*9*), involves the gear wheel (*8*) solidary with the rod (6); in this way the rotational motion of the nozzle plate is provided.

3. EXPERIMENTAL RESEARCHES

The experimental researches were done in two versions:

– in the version 1, the FBG is fixed;

– in the version 2, the nozzle plate of the FBG is involved in a rotational motion by an electric motor.

* In version 1, the water temperature was of $t = 24$ °C, the initial concentration of the oxygen dissolved into water: $C_o = 3.12$ mg/l; for the same temperature, the saturation concentration is of $C_s = 8.3$ mg/l [5]. The air flow rate introduced was

of 600 l/h; after two hours the concentration of oxgen dissolved into water increased, modified as represented by the curve of figure 4, reaching the value of C_s.

This graphic was traced using experimental data.

It can be remarked from figure 4 that the value of C_s tends to be reached in about two hours.

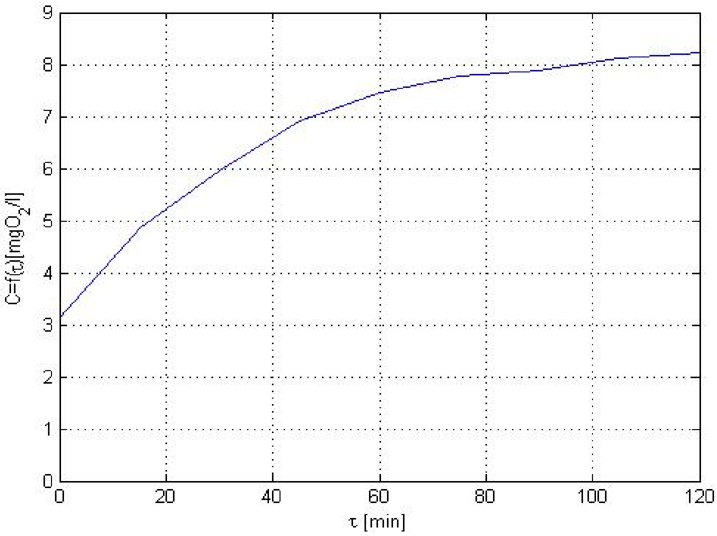

Fig. 4. The variation of the concentration of the oxygen dissolved into water function of time for the version one.

** A FBG whose nozzle plate was rotated with a speed of 0.392 m/s was introduced later in the same water tank. The air flow rate and the air pressure were maintained constant and equal with those of the previous experiment. The air bubbles have the output direction opposite to the displacement direction of the FBG in its rotational motion. (fig. 2).

Consequently: on the sector AB the air bubbles get out from the paper plan and on the sector BC they enter the paper plan.

The air bubble speed at the FBG output is determined using the relation [5]:

$$w_i = \sqrt{\frac{2\Delta p}{\rho}} = \sqrt{\frac{2g\Delta h}{\rho}} \qquad (2)$$

where: ρ is the air density [kg/m^3]; Δh – the pressure loss that appears when the air circulates through the nozzle plate; from previous research [5] it was established that Δh = 20 mmH_2O.

$$w_i = \sqrt{\frac{2 \cdot 9.81 \cdot 20}{1.2}} = 18.083 \text{ m/s} \qquad (3)$$

The motion of the air bubble in the water layer will be a composed motion, the resulting speed will be the vectorial sum of three speeds:

$$\vec{w} = \vec{w_i} + \vec{w_r} + \vec{w_a} \qquad (4)$$

where: w_r – the speed of the bubble at the FBG output as consequence of the rotational motion.

$$w_r = \omega \cdot R \; [\text{m/s}] \qquad (5)$$

where: ω is the angular velocity; $\omega = \frac{2\pi n}{60}$, n = 30 rpm; R – rotation radius, namely the distance from the rod axis (5) (fig. 2) to the output nozzle of the bubble; w_a – the ascending speed of the bubble, which will be determined using the relations from the specialty literature [6, 7].

The increase of the concentration of oxygen dissolved into water can be studied in figure 5.

This graph was traced using experimental data. If graphs from figures 4 and 5 are superposed, figure 6 is obtained.

It can be remarked from figure 6 that, in the case of the second version, the saturation concentration C_s = 8.3 mg/l is reached in about 60 minutes, therefore the saturation time is two times reduced. This is due to the fact that the imaginary cylinder full of water, of diameter D and height H (fig. 2), is at every moment scanned by a bubble screen in movement (fig.7).

The results of the researches coincide in a satisfactory way with similar data from the specialty literature [8, 9].

The trajectory of the air bubble in the water layer will be a spatial curve, whose equation and length will be established in the following papers.

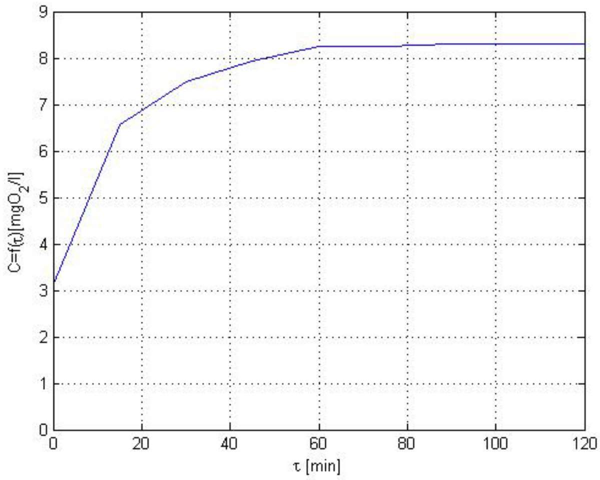

Fig. 5. The variation of the concentration of the oxygen dissolved into water function of time for the second version.

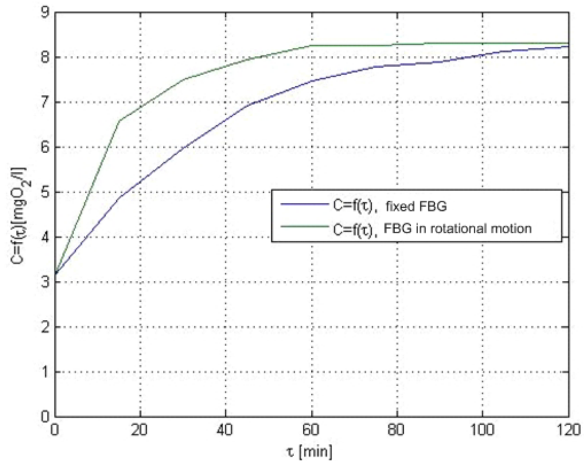

Fig. 6. The variation of the concentration of the oxygen dissolved into water function of time for the two studied versions.

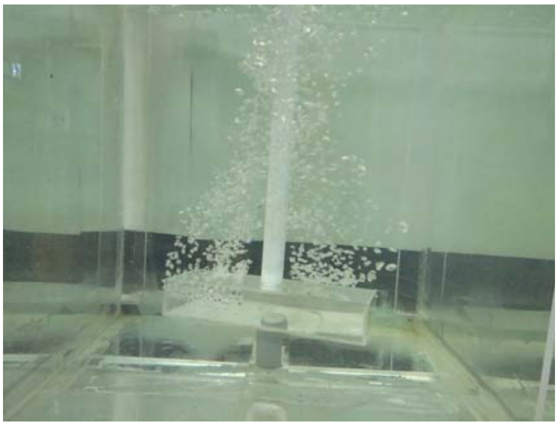

Fig. 7. FBG in rotational motion.

4. CONCLUSIONS

● The use of the FBG equipped with nozzle plates manufactured by electroerosion assure an uniform distribution of the air bubbles that enter the water mass.

● As the nozzles have the same diameter, the air bubbles have the same diameter at the water input.

● There is no clogging danger for the nozzles.

● For FBG that have the perforated plate in rotational motion, the water oxygenation time is shortened two times compared with the FBG that have a fixed perforated plate**.**

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