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A New Solution for Water Oxygenation

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***Abstract*—The paper presents a fine bubble generator with orifice achieved based on micro-drilling technologies. The equation that determines the variation speed of dissolved oxygen concentration in the water is integrated using implicit Runge-Kutta method. The study presents the theoretical and experimental results conducted on a laboratory installation equipped with modern measurement devices.**

***Keywords*—Water oxygenation, fine bubble generator, micro-drilling technologies, dissolved oxygen, spark erosion**

I. INTRODUCTION

The water oxygenation consumes from 50% to 90% of the total energy of a secondary wastewater treatment plants [1]. Systems development of immersed fine bubble oxygenation has accelerated; it has a higher efficiency of oxygen transfer towards many other oxygenation systems [2].

Studies in the literature [3] showed that fine bubble oxygenation devices could save 20% to 50% of energy compared with coarser bubble diffusers.

The size of formed bubbles depends on the flow and pressure in the distribution pipe and on the orifice of their release [4] [5]. The general problem of the equipment based on the dispersion of a gas in water is to produce small air bubbles, in economically way. Introducing air into a volume of water can be achieved mechanical or pneumatically [6].

Fine bubble generators (FBG) must ensure a uniform dispersion of gas throughout the liquid mass in order to be mixed and at the same time to provide, the necessary oxygen for carrying out chemical or biological processes that takes place in the respective basin.

For achieving plates with orifices of FBG, recent studies [7] lead to the use of advanced nonconventional technologies, namely, spark erosion processing.

II. THE EQUATION THAT DETERMINES THE SPEED OF DISSOLVED OXYGEN CONCENTRATION IN WATER

The differential equation of first order, which defines the transfer speed of the O_2 from air in stationary water, is [8]:

$$\frac{dC}{d\tau} = aK_L\left(C_s - C\right) \quad \left[\frac{kg}{m^3}\cdot\frac{1}{s}\right] \tag{1}$$

where $dC/d\tau$ – the transfer speed of dissolved oxygen in water; ak_L – volumetric mass transfer coefficient [s^{-1}]; C_s – mass concentration of oxygen in water at saturation [kg/m^3]; C – current mass concentration of oxygen in water [kg/m^3].

To solve this equation (1), the implicit scheme of Runge-Kutta numerical method is applied [9].
For the initial data:
- Temperature of the tap water t_1= 24°C.
- Initial (C_0) and saturation (C_s) concentration of dissolved O_2 concentration in water: C_0=3.12 mg/dm^3; C_s= 8.3 mg/dm^3 the software was run and the curve in Figure 1 resulted.

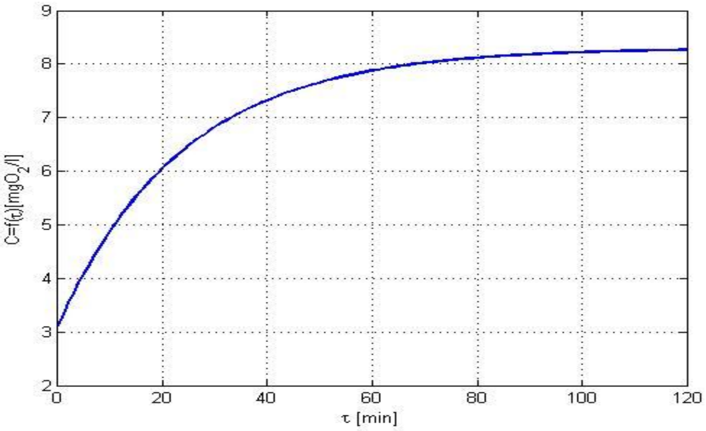

Fig. 1 The variation of dissolved O_2 concentration in water function of time for tap water at the temperature t= 24 °C

Figure 1 shows the variation curve of dissolved O_2 concentration in water function of time for tap water at the temperature of 24 °C. To validate these theoretical researches it was conceived, designed and built an experimental stand.

III. THE DESCRIPTION OF THE EXPERIMENTAL STAND

The experimental stand is composed of [10]:

- Compressor, to produce compressed air with the following operating parameters: maximum discharge pressure p = 8 bar, aspirated flow rate = 200 dm^3/min, operating temperature t = -10^0C ÷ 100 ^{0}C, electric motor power P = 1.1 kW at rpm n = 2850 rpm/min, tank volume (V = 24 dm^3).

The compressor is equipped with a manometer 0-16 bar to show the pressure in the tank compressor and a pressure reducing valve for the establishment of the pressure in the piping system.

- Air pipes for the delivery of the compressed air, made of plastic, with the inner diameter of Ø15mm and a wall thickness of 2 mm; these supplies the fine bubble generator with air and ensures the evacuation of the excess air supplied by the compressor to the atmosphere.

- The aeration tank constructed of Plexiglas plates with thickness of 5 mm, having the dimension, 0.5×0.5×1.5 (W×L×h).

- Fine bubble generator which consists of elements to connect to the compressed air pipe, the generator body and an element to dispersion of air into the water mass.

The sketch of the stand used for performance of experimental researches is presented in Figure 2.

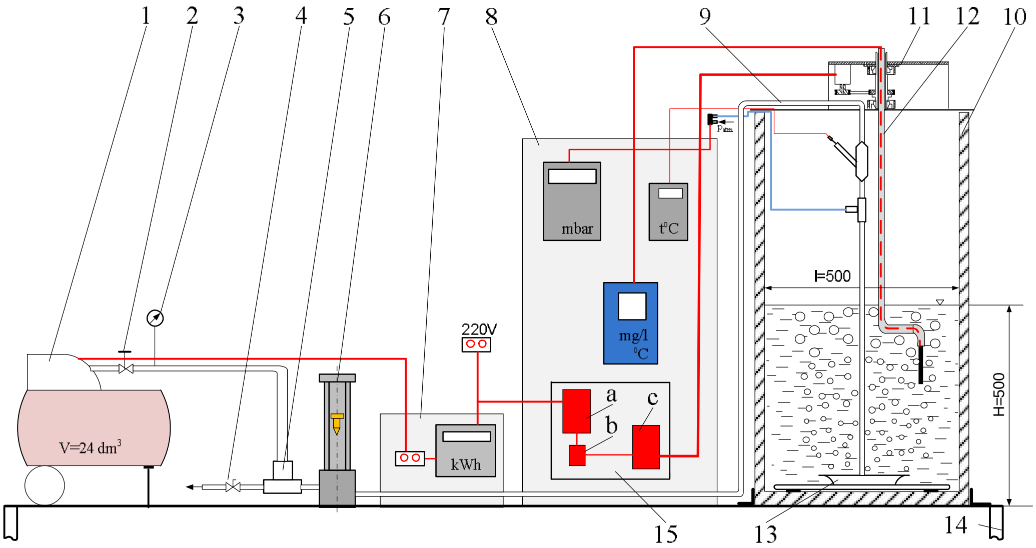

Fig. 1 Sketch of the experimental setup for researches regarding water oxygenation
1– electro compressor with air tank; 2– pressure reducer; 3–manometer; 4–union for air exhaustion in the atmosphere; 5– T-joint; 6– rotameter; 7– electrical board; 8– measurement device panel; 9– pipe for the transport of the compressed air to the FBG; 10– water tank; 11– mechanism for the actuation of the probe; 12– oxygen meter probe; 13– FBG; 14– plant holder; 15–control electronics: a– supply unit, b- switch, c- control element

During the measurement, the pressure of the compressed air and the air flow were measured, these values were kept constant in time. The hydrostatic load was H= 500 mH_2O.

In Figure 3 is observed the perforated plate with 6 orifices of Ø 0.5 mm, and Figure 4 shows the FBG model. As a constructive form, a rectangular shape for the orifice plate was selected. A sketch of this plate is shown in Figure 3:

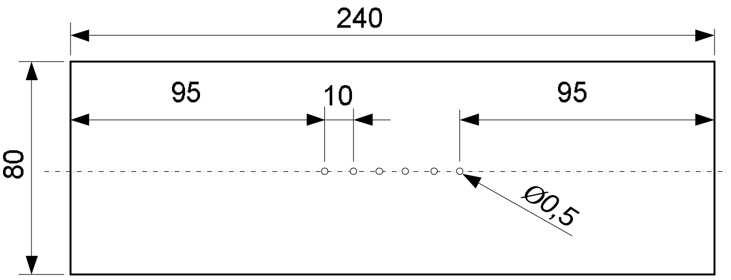

Fig. 3 Perforated plate with orifices of Ø 0.5 mm

For this plate, a rectangular fine bubble generator body was designed. Figure 4 shows the three-dimensional image of it:

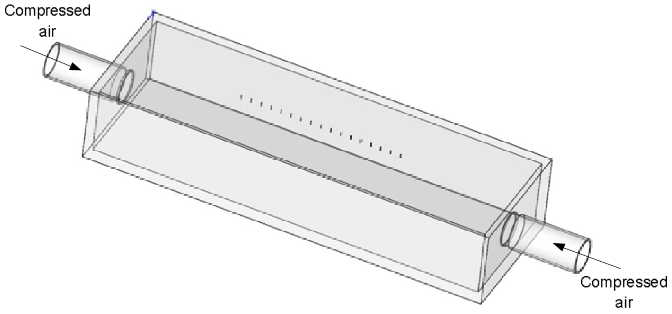

Fig. 4 Fine air bubble generator

IV. EXPERIMENTAL RESEARCH REGARDING THE VARIATION OF DISSOLVED O_2 CONCENTRATION IN WATER

The experimental measurements for the determination of dissolved O_2 concentration in water were performed in a rectangular Plexiglas tank having a height of 1.6 m and a width of 0.5 m shown in Fig. 2. The tank was filled with water having a temperature of 24 °C. Table 1 presents the results of experimental researches conducted on tap water having a temperature of 24 ºC.

In the table, on columns, was noted: 1- the number of measurement, 2- oxygenation time [min], 3- dissolved oxygen concentration in water at FBG testing [mg/dm^3], 4- air pressure entering the FBG [mbar], 5- intake air pressure in the FBG [mmH$_2$O], 6- supply air volumetric flow rate in the FBG [dm^3/h], 7-pressure drop on FBG [mmH$_2$O].

TABLE I

THE VALUES OF THE MEASURED VARIABLES FOR T_{H2O}= 24 °C

1	2	3	4	5	6	7
No.	τ[min]	C[mg/dm^3]	p[mbar]	p[mmH$_2$O]	$\dot{V}$ [dm^3/h]	Δp[mmH$_2$O]
0	0	3.12	57.2	583.44	600	20.44
1	15	4.85	57.2	583.44	600	20.44
2	15	5.95	57.2	583.44	600	20.44
3	15	6.92	57.2	583.44	600	20.44
4	15	7.45	57.2	583.44	600	20.44
5	15	7.77	57.2	583.44	600	20.44
6	15	7.89	57.2	583.44	600	20.44
7	15	8.12	57.2	583.44	600	20.44
8	15	8.23	57.2	583.44	600	20.44

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Based on the data from Table 1, the curve (2) of Figure 5 is plotted.

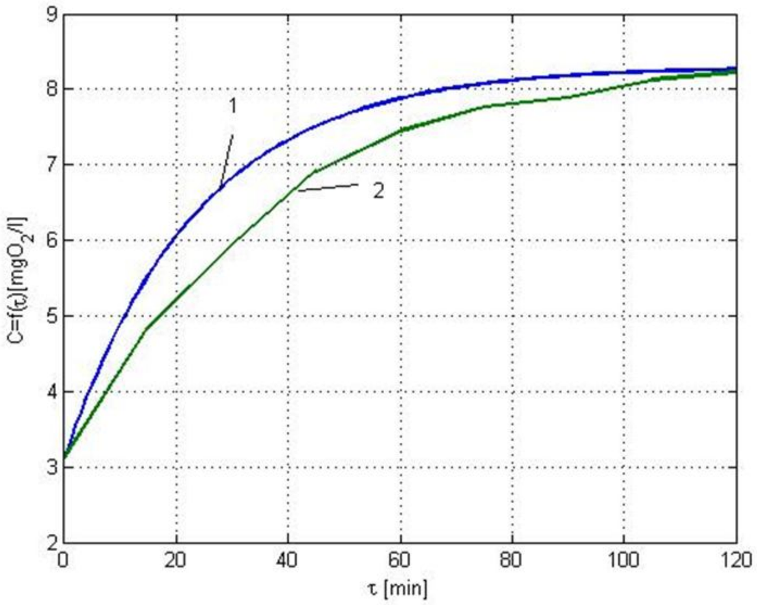

Fig. 5 The variation of dissolved O_2 concentration in tap water: C=f (τ)
1 - theoretical results for tap water at t= 24°C,
2 -experimentally determined values for tap water at t=24°C

V. CONCLUSIONS

1. Fine bubble generators manufactured by spark erosion represent an original solution; this type of FBG provide a controlled and uniform spreading of air in water.
2. From Figure 5 one can notice a good coincidence between the theoretical and the experimental results, which confirms the accuracy of the computing program.
3. The experimental researches indicates the equalizing of dissolved oxygen concentration values, both theoretically and experimentally after 120 minutes.
4. Pressure losses that appeared when air passed through FBGs were less that in the case of porous diffusers manufactured from ceramic materials or glass.

REFERENCES

[1] G. M. Wesner, L. J. Ewing, Lineck, T. S. Jr., Hinrichs, D. J., *Energy Conservation in Municipal Wastewater Treatment*, EPA-430/9-77-01 1, NTIS No. PB81-165391, U.S. EPA Report, Washington, DC, 1977.
[2] U.S. EPA, EPA Summary Report, *Fine Pore (Fine Bubble) Aeration Systems*, EPA/625/8-85/010, Water Engineering Research Laboratory, Cincinnati, Ohio, 1985.
[3] U.S. EPA, EPA Report, *Design Manual Fine Pore Aeration Systems*, EPA/625/1-89/023, Water Engineering Research Laboratory, Cincinnati, Ohio, 1989.
[4] I. Pincovschi, *Hydrodynamics of gas-liquid disperse systems*, (in Romanian), PhD Thesis, POLITEHNICA University of Bucharest, 1999.
[5] S.G. Georgescu, *Evolution D'une bulle de gase*, These, Institut National Polytehnique De Grenoble, Avril, 1999.
[6] D. Robescu, D. L. Robescu, Processes, water treatment plant and equipment, (in Romanian), UPB, Bucharest, 1996.
[7] G. M. Mateescu, *Hydro-gas-dynamics of fine bubble generators* (in Romanian), PhD Thesis, Faculty of Mechanical Engineering and Mechatronics, POLITEHNICA University of Bucharest, 2011.
[8] I. M. Căluşaru, A. Costache, N. Băran, G. L. Ionescu, O. Donţu, *A new solution to increase the performance of the water oxygenation process*, Journal of Chemistry, vol. 64, no. 10 /2013, pp. 1143 – 1145.
[9] J. Printems, *Notes on Numerical Methods for Partial Differential Equations in Finance*, Universite de Paris12, 2007.
[10] Al. S. Pătulea, *Influence of functional parameters and of fine bubble generators architecture on the efficiency of aeration plants* (in Romanian), PhD Thesis, Faculty of Mechanical Engineering and Mechatronics, POLITEHNICA University of Bucharest, 2012.