IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 8 Issue 2, February 2021
ISSN (Online) 2348 – 7968 | Impact Factor (2020) – 6.72
www.ijiset.com

Electro-mechanical system for actuating the probe of an oxygenometer

Mihaela Petroșel[1], Nicolae Băran[2] and Mihaela Constantin[3]

[1] Faculty of Mechanical and Mechatronics Engineering, Politehnica University of Bucharest, Bucharest, 060042, Romania

[2] Faculty of Mechanical and Mechatronics Engineering, Politehnica University of Bucharest, Bucharest, 060042, Romania

[3] Faculty of Mechanical and Mechatronics Engineering, Politehnica University of Bucharest, Bucharest, 060042, Romania

Abstract
The paper presents the electrical method for measuring the concentration of dissolved oxygen in water and the experimental installation built for this purpose. The constructive solution of the fine air bubble generator and the results obtained after its operation for two hours are described. The oxygenometer used in the measurements is described and the electromechanical system that moves the oxygenometer probe into the water tank.
Keywords: *Dissolved oxygen in water, Oxygenometer, Displacement of the oxygenometer probe.*

1. Introduction

Taking into account that, in some papers, the aeration processes are confused with the oxygenation processes, a delimitation must be made between them.
Theoretical and experimental researches papers aim to increase the concentration of dissolved oxygen in water; this can be done in two ways:
I. By introducing atmospheric air into water, a process called aeration [1];
II. By introducing a gaseous mixture consisting of [2]:
- atmospheric air + O_2 from a cylinder;
- atmospheric air + O_2 delivered by oxygen concentrators (95% O_2; 5% N_2);
- atmospheric air + ozone (O_3) delivered by ozone generators.

Dissolved oxygen is an important parameter in assessing water quality due to its influence on living organisms in a volume of water. In Limnology (the study of lakes), dissolved oxygen is an essential factor. Dissolved oxygen levels that are too high or too low can affect aquatic life and affect water quality [2] [3].
Non-compound oxygen, or free oxygen, is oxygen that is not bound to any other element (Figure 1). Dissolved oxygen is the presence of those oxygen molecules free from water. The water-bound oxygen molecule (H_2O) is a compound and is not considered in determining the level of dissolved oxygen [2].

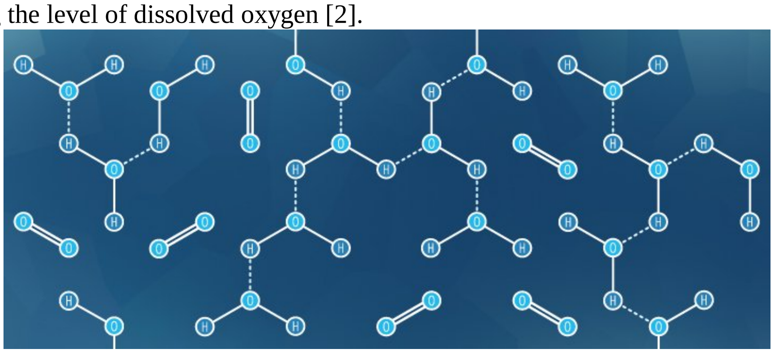

Fig. 1 Free oxygen molecules in water [2].

Dissolved oxygen is needed for many life forms, including fish, invertebrates, bacteria and plants. These organisms use oxygen in their breath. Fish and crustaceans obtain oxygen for respiration through their gills, while plants and phytoplankton need dissolved oxygen for respiration when there is no light for photosynthesis.
The amount of dissolved oxygen required varies from one life form to another. Crabs, oysters and worms need minimal amounts of oxygen (1 ÷ 6 mg / dm^3), while fish in shallow water need a higher level (4 ÷ 15 mg / dm^3) [2].
In water treatment and purification processes, oxygenation is the basic operation in ensuring a proper water quality.
Oxygenation is applied in the following areas [4] [5] [6]:
- In water treatment processes, when removing dissolved inorganic substances or chemical elements such as iron, manganese, etc., by oxidation and formation of sedimentable compounds or which can be retained by boiling;
- In the biological treatment of wastewater, either by the process with activated sludge or with biofilters;
- In disinfection processes, by ozonation of raw water captured from a source for the purpose of drinking it;
- In the separation and collection of emulsified fats from wastewater.

Water oxygenation is a mass transfer process with wide applications in the technique of water treatment and purification. Oxygenation equipment is based on the dispersion of one phase in the other, for example gas in liquid, energy consuming process.
Dissolved oxygen enters in water from the air or as a by-product of plants. From the air, oxygen can slowly diffuse to the surface water of the surrounding atmosphere, or it can be mixed rapidly by aeration, either natural or man-made. Aeration of water can be caused by wind (creating waves), waterfalls or other forms of running water.
Dissolved oxygen is also a residual product of photosynthesis of phytoplankton, algae and other aquatic plants [2].

2. Methods of measuring the dissolved oxygen concentration in water

There are three methods for measuring the concentration of dissolved oxygen in water [7]:
- chemical method;
- electric method;
- optical method.

Each method has different embodiments.
The paper will study the electrical method with the detail of some conditions for performing the measurements.
The electrical methods named in some papers electrochemical methods are based on two techniques for measuring the concentration of dissolved oxygen in water [8] [9] [10]:
a) the technique of the galvanic process, in which there is a very low electric voltage between the electrodes;
b) the technique of the polarographic process, in which an electric voltage (direct current) is applied between the two electrodes (cathode and anode).
In the following, only the polarographic procedure is analyzed.
The devices used to measure DO in water are called oxygen meters.
As a whole, an oxygenometer consists (figure 2) of a microprocessor (1) connected to a probe (3) which is introduced into the water whose OD content is to be measured.
In the laboratory of the Department of Thermotechnics, Engines, Thermal and Refrigeration Equipment's there is such an oxygenometer which is used in experimental research on water oxygenation (figure 2).

Fig. 2 Oxygenometer used in measurements
1 - microprocessor; 2 - connecting cable; 3 - probe body; 4 - small cylinder containing an electrolyte solution; 5 - oxygen permeable Teflon membrane.

The oxygen passing through the oxygen-permeable Teflon membrane (5) causes a change in the electric current between the cathode and the anode, in a small cylinder containing an electrolyte solution (4); this change is proportional to the amount of oxygen that has penetrated the membrane and is displayed on the microprocessor screen in [mg / dm3].
Advantages of electrical methods:
1. The device is portable, measurements can be performed in the laboratory, swimming pools, lakes, ponds;
2. The device instantly or continuously monitors the DO concentration;
3. No equipment for sampling, etc. is required.

3. Framing of the electromechanical system for actuating the oxygenometer probe in the scheme of the experimental installation

Figure 3 shows the sketch of the experimental installation for introducing atmospheric air into water.
During the experimental researches the following values are kept constant:
-Air flow: $\dot{V}$ = 0.6 m^3 / h;
-Inlet air pressure in FBG: p = 573 mmH_2O;
-Hydrostatic load: H = 500 mmH_2O;
-The air temperature = 24 ^{0}C which corresponds to C_s = 8.4 mg / dm^3, C_0 = 5.84 mg / dm^3.
Measurement time: τ = 120 min.

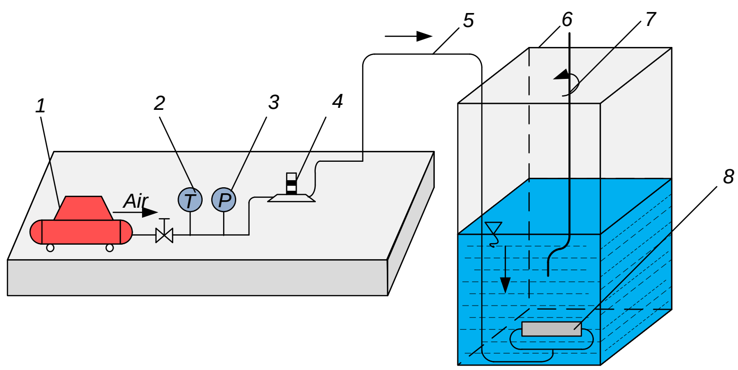

Fig. 3 Sketch of the experimental installation for introducing atmospheric air into water
1 - air compressor; 2 - thermometer; 3 - manometer; 4 - rotameter; 5 - compressed air supply pipe of the microbubble generator (MBG.); 6 - parallelepiped tank with water; 7 - oxygenometer probe; 8 - fine bubble generator

After 15 minutes, cut off the air supply to the MBG and insert the oxygenometer probe (7); the signal taken from the probe is processed in the microcomputer and digitally displayed on the microcomputer screen.
Figure 4 shows the constructive solution of FBG which has created in the plate 152 orifices with a diameter of 0.1 mm.

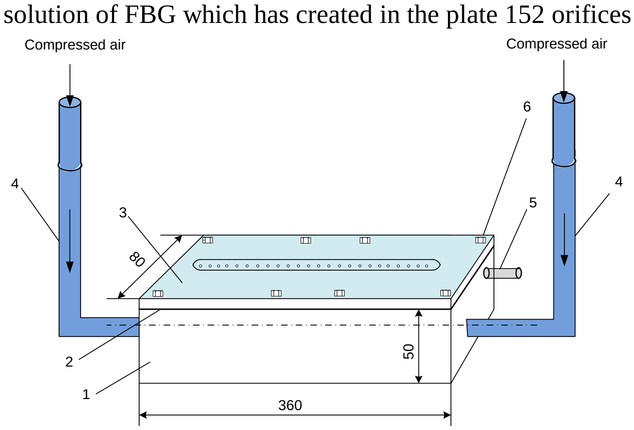

Fig. 4 Fine air bubble generator

1- compressed air tank; 2- sealing gasket; 3- plate with holes; 4- FBG Ø 18mm compressed air supply pipe; 5-connection for measuring compressed air pressure; 6- screws for fixing the plate with orifices in the tank frame

Figure 5 shows the FBG mounted in the water tank.

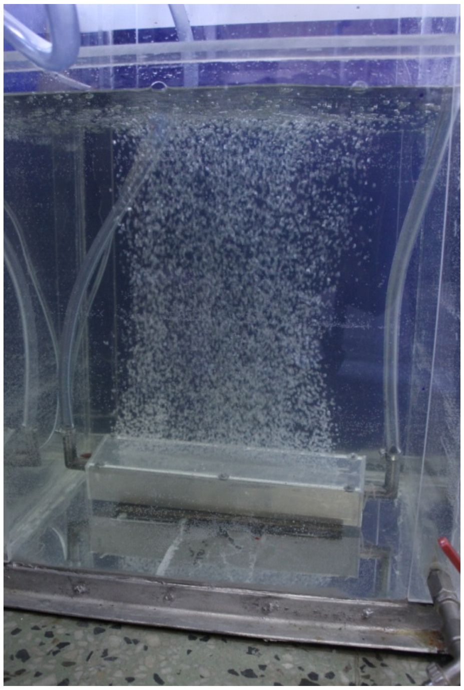

Fig. 5 Microbubble generator with 152 orifices Ø 0.1 mm in operation

Following the experimental measurements, the curve C = f (τ) presented in figure 6 was build.

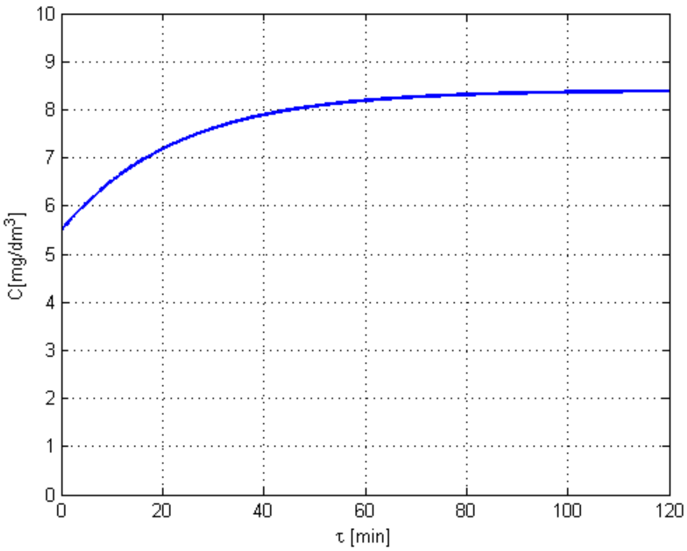

Fig. 6 Variation of the dissolved O_2 concentration in water as a function of time for FBG with 152 orifices Ø 0.1 mm

The dissolved oxygen concentration in the water was measured with the operating oxygenometer based on the electrical method [2]; the results of the measurements are similar to those in the literature [11] [12].

The oxygenometer probe (figure 7) is equipped with an actuating mechanism that rotates the probe in the water tank during the measurements; the dissolved oxygen concentration in the water being measured every 15 minutes. In order not to disturb the accuracy of the measurement during the measurement the FBG it is removed from the water tank.

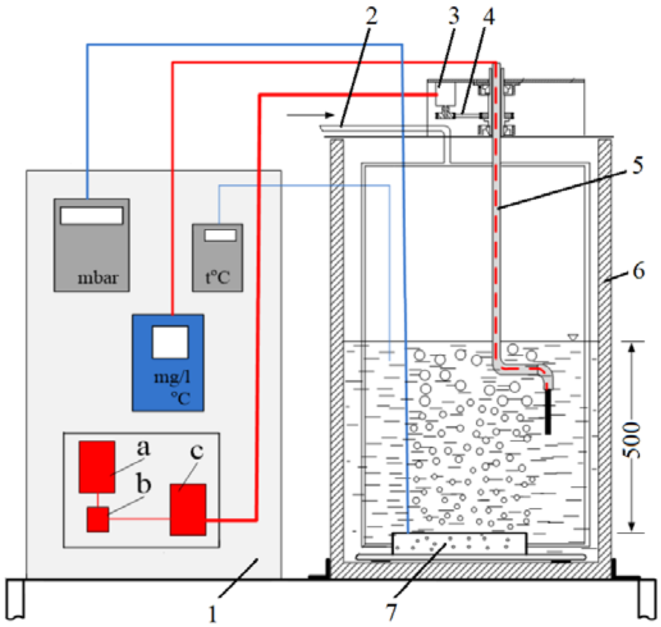

Fig. 7 Experimental installation for actuating the oxygenometer probe
1 - panel with measuring devices (a - power supply; b - switch; c - control element); 2 - compressed air pipe; 3 - electric motor; 4 - toothed belt; 5 - oxygenometer probe; 6 - water tank; 7 - FBG

The oxygenometer leaflet states that the oxygenometer probe must be moved in water at a speed of w = 0.3 m / s.
The probe performs a rotational movement with radius r = 0.125 m, and its speed is given by the relation (4):

$$w = \omega / r \; [m / s] \quad (1)$$

$$\omega = w / r = 0.3 / 0.125 = 2.4 \; [rad / s] \quad (2)$$

$$\omega = (2\pi n) / 60 \quad (3)$$

$$n = (60 \cdot \omega) / 2\pi = (60 \cdot 2.4) / 2\pi = 22.92 \; [rot / min] \quad (4)$$

The change in the concentration of dissolved oxygen in the water is transmitted through the probe to the oxygenometer (figure 7).

4. Conclusions

The method of electrical measurement of the dissolved oxygen concentration in water presented in the paper has the following advantages:
- It is not necessary to take the water sample under analysis;
- The oxygenometer instantly indicates the change of the dissolved oxygen content in the water with a high precision;
- The measuring scheme includes modern devices with digital indication;
- The electromechanical system for actuating the oxygenometer probe is monitored by an electronic computer.

References

[1] G. Oprina, I. Pincovschi, Ghe. Băran, Hidro-Gazo-Dinamica Sistemelor de aerare echipate cu generatoare de bule, Ed. POLITEHNICA PRES, București 2009.
[2] E. B. Tănase, Influența compoziției gazului insuflat în apă asupra conținutului de oxigen dizolvat, Teză de doctorat, Universitatea POLITEHNICA din București, Facultatea de Mecanică și Mecatronică, București, 2017.

[3] Al. S. Pătulea, Influența parametrilor funcționali și a arhitecturii generatoarelor de bule fine asupra eficienței instalațiilor de aerare, Teză de doctorat, Universitatea Politehnica din București, 2012.
[4] L. R. Droste, Theory and Practice of Water and Wastewater Treatment, 1996.ISBN 978-0-471-12444-3 - John Wiley & Sons inc.
[5] A. G. Roza, Cercetări privind utilizarea ozonului la oxigenarea apelor, Teză de doctorat, Universitatea Politehnica din București, Facultatea de Mecanică și Mecatronică, București, 2019.
[6] Roza Giovani Albertino, Albu Nicoleta Dorina, Donțu Octavian, Moga Corina, Băran Nicolae, Constantin Mihaela, "Researches on the use of ozone generators for wastewater treatment", Proceedings of the International Conference of Mechatronics and Cyber-Mix Mechatronics – 2019, pp. 11-21.
[7] I. M. Călușaru Constantin, E. B. Tănase, N. Băran, R. Mlisan (Cusma), Researches Regarding the Modification of Dissolved Oxygen Concentration in Water, IJISET – International Journal of Innovative Science, Engineering & Technology, Vol. 1, Issue 6, 2014, pp. 228-231.
[8] Al. Pătulea, I. M. Călușaru, N. Băran, Researches regarding the measurements of the dissolved concentration in water, Advanced Materials Research, Trans Tech Publications, Switzerland, vols. 550-553, 2012, pp. 3388-3394.
[9] I. M. Călușaru, A. Costache, N. Băran, G. L. Ionescu, O. Donțu, The determination of dissolved oxygen concentration in stationary water, Applied Mechanics and Materials, Trans Tech Publications, Switzerland, vols. 436, 2012, pp. 233-237.
[10] A. Pătulea, N. Băran, I. Călușaru, Measurements of Dissolved Oxygen Concentration in Stationary Water, World Environment, vol. 2(4), 2012, pp. 106-109.
[11] E. B. Tănase, N. Băran, R. Mlisan, An Efficient Solution for Water Oxygenation, Asian Engineering Review Vol 1, No.3, 36-40, 2014.
[12] E. P. Hassel, "Technical Thermodynamics", University Rostock, Germany, Inst. Technical Thermodynamics, 2011.

Mihaela Petroșel graduated from University Politehnica of Bucharest. She is today a PhD student in the Faculty of Mechanical and Mechatronics of Politehnica University – Bucharest.

Nicolae Băran was born in Cujmir, Romania, on October 23, 1944. He studied at the Politehnica University of Bucharest and received PhD. Degree from the same university. Since 1976 he worked as a Professor in the Faculty of Mechanical and Mechatronics Engineering.

Mihaela Constantin was born in Turnu Măgurele, Romania, on January 26, 1985. She graduated from the Politehnica University - Bucharest, and received a PhD degree from the same university. She is today Lector in the Faculty of Mechanical and Mechatronics and Mechatronics Engineering of the Politehnica University – Bucharest.