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Researches on increasing the oxygen transfer speed to water in the process of water aeration

George Marin[1], Mădălina Zamfir[1], Rareş Păun[1], Daniel Besnea[1], Tănase Beatrice[1], Mihaela Constantin[1]

[1] Department of Thermotechnics, Engines, Thermic and Refrigeration Plants, University Politehnica of Bucharest, Bucharest, 060042, Romania

Abstract

The first part of the paper presents the parameters that influence the oxygen transfer speed to water; it is then shown that this speed is increased if the diameter of the air intake orifices in water decreases.
The constructive solution of the air bubble generator and its operation is revealed.
Keywords: *Water aeration, Fine air bubble generator.*

1. Introduction

In the operation of water treatment plants, which are equipped with bubble generators, the water is aerated using compressed air; for compressing it electric power is used, therefore it should be considered:
• An efficient use of the compressed air;
• The choice of air dispersing devices in the water, devices that have a loss of pressure as low as possible;
Equipment's used for water aeration are based on the gas dispersion in a water mass in order to increase the dissolved oxygen concentration in water.
Figure 1 shows that oxygen occurs in two forms [1]:
• O_2 linked to H_2
• free O_2 called dissolved oxygen in water

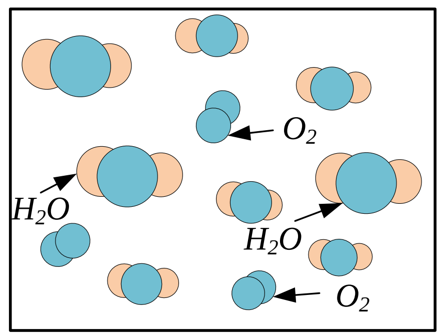

Fig. 1 Oxygen dissolved in water.

The solubility of oxygen in water is dependent on the temperature, the atmospheric pressure, the size of the air - water contact surface and its turbulence.
The gas introduced into the water can come from the following sources [2]:
• Atmospheric air (21% O_2 + 79% N_2);
• A mixture of atmospheric air and pure oxygen taken from an oxygen bottle;
• Low nitrogen air supplied by oxygen concentrators.
By their size, the gas bubbles introduced into the water can be classified as follows (Figure 2):

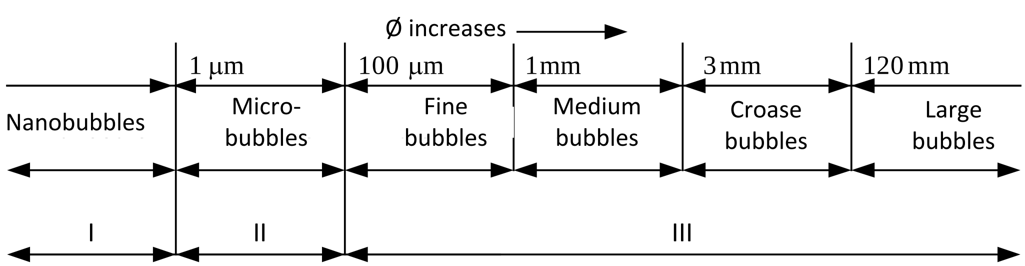

Fig. 2 Classification of gas bubbles according to their diameter (Ø)
I - the area where the gas bubbles can be observed under the microscope;
II - the area where gas bubbles can be observed with difficulty;
III - the area where gas bubbles can be observed with the naked eye.

The paper presents a fine bubbles air generator, in which the plate has 152 orifices with d_0 = 10 μm. As a result of the research in the field of micro technologies, air bubbles can be called "micro bubbles".

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2. The speed of oxygen transfer to water

The equation which defines the transfer speed of the O_2 from air in water, is [3][4]:

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

where:
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].
Equation (1) indicates the modification of oxygen concentration in time, as a result of molecular diffusion of O_2 from the area with high concentration to the area with low O_2 concentration.
From equation (1) it is noted that to increase the transfer speed O_2 to water, the following are required:
I. the increase of k_L and C_s
II. the decrease of C_0
The conditions I and II are given in Table 1.

Table 1: Solutions for increasing $dC/d\tau$

No.	The purpose	Theoretical solution	Practical solution
1	The increase of a	The decrease of the gas bubble diameter	The decrease of the F.B.G. orifices diameter
2	The increase of k_L	The turbulence enhancement	-
3	The increase of C_S	The increase of the O_2 concentration into the water	-
4	The increase of C_0	Minimum C_0 values depending the existing microorganisms nature into water	Introducing air, oxygen and O_3 into water

3. Influence of the specific interphase contact surface area on the increase of water oxygenation transfer speed

The value of the specific interphase contact surface area can be expressed in several ways:
• As ratio between the gas particle area A [m^2] and the volume of the biphasic system (air + water) V [m^3]:

$$a = \frac{A}{V} \left[\frac{m^2}{m^3}\right] \qquad (2)$$

• For a gas-liquid system, the value of "a" is expressed by the relation [2]:

$$a = \frac{6\varepsilon}{d_s} \qquad (3)$$

in which:
ε – void fraction, global mean;
d_s - Sauter diameter of the dispersed system.
If the relation (1) for a spherical gas bubble is resumed it is obtained:

$$a = \frac{4 \cdot \pi \cdot \left(\frac{d_b}{2}\right)^2}{\frac{4}{3} \cdot \pi \cdot \left(\frac{d_b}{2}\right)^3} = \frac{6}{d_b} \qquad (4)$$

As a result, for increasing the mass transfer of oxygen from air to water the gas bubble must have a diameter as small as is possible.
The bubble diameter value exiting the orifice is given by relation [2]:

$$d_b = 2R_0 = 2 \cdot \left(\frac{3}{2} \cdot \frac{r_0}{\rho} \cdot \frac{\sigma}{g}\right)^{\frac{1}{3}} \qquad (5)$$

where:
σ- surface tension coefficient: σ =73x10-3 N/m
ρ- water density; ρ=1000 kg/m^3.
• From the relation (1) one can observe that the oxygen transfer speed to the water increases if "a" increases;
• From the relation (4) one can observe that "a" increases if the bubble diameter (d_b) is smaller;
• From the relation (5) one can observe that "d_b" is smaller as the orifice radius of the bubble outlet in the plate is smaller.
So, to increase the speed of water oxygenation, the diameter of the orifice in the perforated plate must be as small as possible.

4. Presentation of the constructive solution of the air microbubbles generator

The microbubbles generator is provided with a plate having orifices through which the compressed air enters a certain volume of free surface water.
The orifices in the plate were made using unconventional technologies, namely through the Bosch process [5] [6].
Figure 3 shows an overall view of the microbubbles generator; the silicon plate is fastened to the generator body so that, on the outlet surface of the compressed air in the water, the orifices have Ø 10 μm.

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Fig. 3 General view of the fine bubble generator
1 - support plate; 2 - generator body; 3 - compressed air supply pipes.

5. Presentation of the experimental installation

The experimental stand is composed of (Figure 4):

* Air compressor (1) for compressed air production with the following functional parameters: maximum discharge pressure, p = 8 bar, suction flow, $\dot{V} = 600\,dm^3/h$, working temperature t = -10°C ÷ 100°C, electric motor power P = 1.1 kW, speed n = 2850 rpm, tank volume V = 24 dm^3. The compressor is equipped with a differential pressure manometer in the range of 0-16 bar to display the air pressure in the compressor tank and a pressure reducer (2) to determine the pressure in the piping system.

* * Compressed air pipes for delivering compressed air, with internal diameter Ø15 mm and a wall thickness of 2 mm; they feed the microbubbles generator with air and ensure that the excess air delivered by the compressor to the atmosphere is evacuated.

* * * Aeration basin made of 5 mm thick plexiglass plates, size 0.5x0.5x1.6 m.

* * * * The microbubbles generator. This type of M.B.G. was tested in an experimental installation built in the laboratories of University POLITEHNICA of Bucharest [5] [6].

The scheme of the installation used for experimental researches is shown in Figure 4.

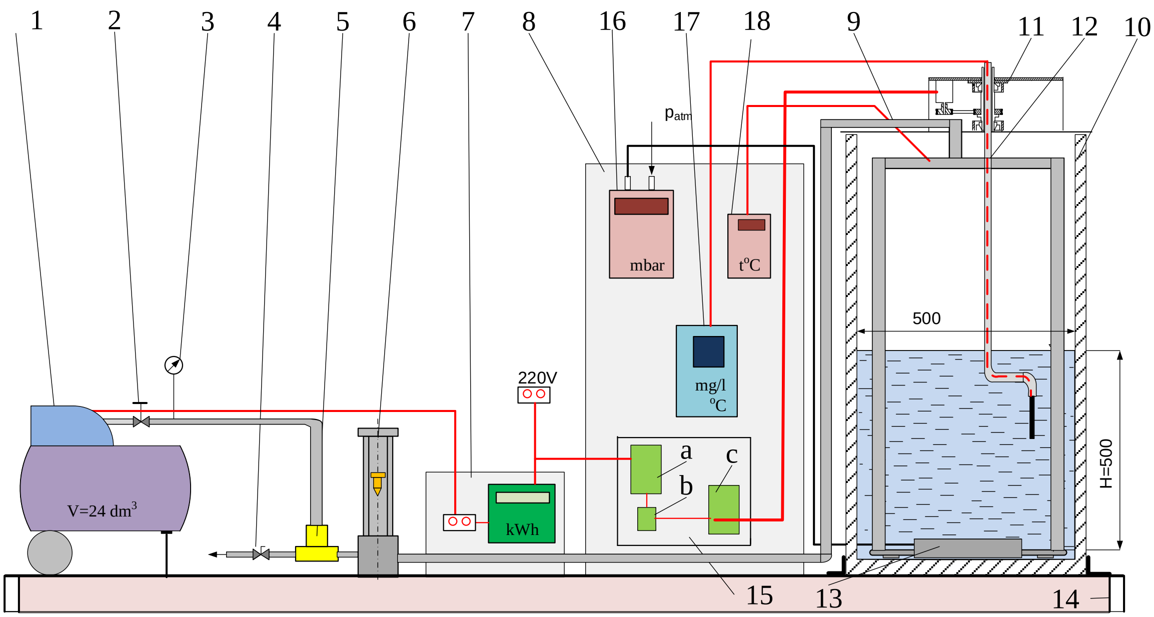

Fig. 4 Sketch of the experimental plant for researches regarding water oxygenation
1-electro compressor with air tank; 2– pressure reducer; 3–manometer; 4– connector for air exhaustion in the atmosphere; 5– T-joint; 6– rotameter; 7–electrical panel; 8- panel with measuring devices;9- pipe for the transport of the compressed air to the FBG; 10– water tank; 11- mechanism for the probe actuation; 12– oxygen meter probe; 13– FBG; 14- installation holder; 15–electronics control: a– supply unit, b- switch, c- control element; 16–digital manometer; 17– oxygen meter; 18–digital thermometer.

6. Experimental researches

Figure 5 shows the operation of the air microbubbles generator.

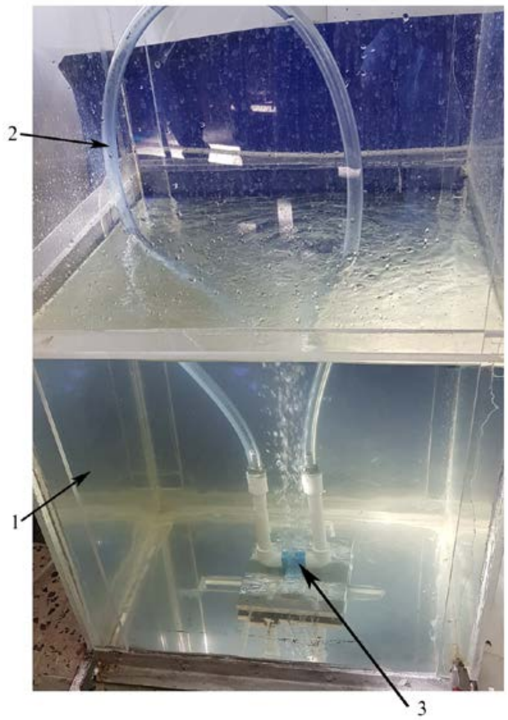

Fig. 3 Microbubbles generator
1 - water tank; 2 - compressed air duct; 3 - air microbubbles generator.

From the measurements made it has been shown that the oxygen transfer speed to water has increased compared to previous researches [7] [8] [9].

7. Conclusions

• To increase the water oxygenation speed, the value of the interfacial area "a" should be increased;
• The value of "a" increases if the diameter of the air intake in the water (d_0) is reduced;
Compared with other experimental results [10] [11] [12], the results confirm that the water oxygenation speed increases by reducing the diameter of the air intake orifice.

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George Marin He studied at the Politehnica University of Bucharest and is today a PhD student in the Faculty of Mechanical and Mechatronics of Politehnica University – Bucharest..

Mădălina Zamfir She studied at the Politehnica University of Bucharest and is today a PhD student in the Faculty of Mechanical and Mechatronics of Politehnica University – Bucharest.

Rareș Păun He studied at the Politehnica University of Bucharest and is today a PhD student in the Faculty of Mechanical and Mechatronics of Politehnica University – Bucharest..

Daniel Besnea was born in Buzău, Romania on July 19, 1967. He studied at the Politehnica University of Bucharest and received PhD. Degree from the same university. Since 2006 he worked as a Lector in the Faculty of Mechanical and Mechatronics Engineering.

Tănase Beatrice was born in Romania, Câmpina, on April 6, 1990. She graduated from Politehnica University – Bucharest. She is today a professor assistant in the Faculty of Mechanical and Mechatronics of Politehnica University – Bucharest.

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.