Researches on the Development of a Nanobubbles Generator Used to Waters Aeration

PhD. Student **Marilena Monica BOLTINESCU (ROZA)**[1], Prof. Dr. Eng. **Nicolae BĂRAN**[1], ŞL. Dr. Eng. **Mihaela CONSTANTIN**[1*]

[1] Politehnica University of Bucharest

* i.mihaelaconstantin@gmail.com

Abstract: *The paper presents a new type of air bubble generator that uses a plate with 900 nm orifices. Previous research has worked with fine bubble generators with orifices of 0.1 mm order. It is known that the smaller the orifices diameter, the smaller the bubbles immersed in water, so the water aeration will be more efficient.*
Obviously, the constructive solution of the nanobubbles generator presented in the paper is clearly superior to the other bubble generators built in the laboratories of POLITEHNICA University of Bucharest.
At the end of the paper, the framing of the nanobubbles generator within an experimental installation is presented.

Keywords: *Nanobubbles generator, nanotechnologies, water aeration.*

1. Introduction

By water aeration is meant the transfer of oxygen from atmospheric air to water; this phenomenon is a process of mass transfer of a gas to a liquid.
In the paper [1], the authors propose to make a distinction between water aeration and water oxygenation of in the following sense:
- In aeration processes, atmospheric air has a content of 21% O_2;
- In the processes of oxygenation, oxygen is added to the atmospheric air and later this mixture is introduced in the water; as a result, the volume of oxygen in the mixture is higher than 21%;

The supplemental oxygen introduced can be obtained by one of the following methods:
a) From a cylinder containing liquid oxygen;
b) From devices called oxygen concentrators that deliver a gas with a concentration of 95% O_2 and 5% N_2;
c) With the help of ozone generators by mixing atmospheric air with ozone;
All three solutions (a, b, c) lead to a faster increase in the concentration of dissolved oxygen in the water.
Figure 1 shows the following:
- Each water molecule consists of an oxygen atom bonded to two hydrogen atoms (H_2O);
- Oxygen dissolved in water can be found, among water molecules, in the form of two oxygen atoms (O_2);

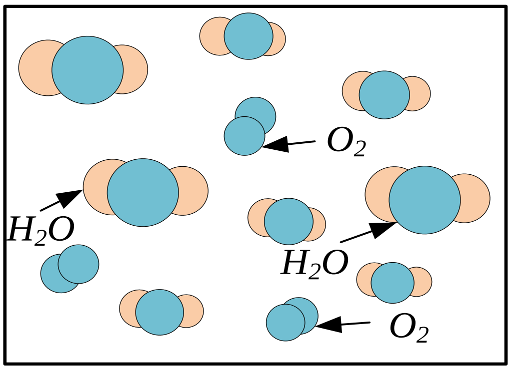

Fig. 1. The presence of dissolved oxygen in water; water molecules (H_2O) and dissolved oxygen molecules (O_2)

Both water aeration and water oxygenation increase the concentration of dissolved oxygen in the water.
This ensures good water quality, avoids the occurrence of a dissolved oxygen deficiency that would endanger living things in the water. For example, fish need about 5 mg / dm^3 of dissolved oxygen in water to survive [2].
By introducing gaseous oxygen into wastewater, organic impurities are removed under the action of aerobic bacteria.

2. Characteristics of fine bubble generators

Pneumatic aeration systems that generate fine bubbles (ø <1 mm) are the most efficient.
Fine bubble generators (FBG) are divided into five classes according to their construction, namely [3][4]:
I. FBG constructed of perforated membranes;
II. FBG made of porous plastics;
III. FBG constructed of ceramic (ceramic FBG);
IV. FBG constructed by micro-drilling or spark-erosion;
V. FBG built using nanotechnologies;
The parameters that influence the performance of a water aeration process are [5]:
a) The constructive characteristics of the fine bubble generators which mainly refer to:
- the orifices diameter in the perforated plate of the FBG;
- the orifices distribution in the perforated plate to avoid bubbles coalescence;
- the shape of the orifices plate and the construction of the fine bubble generator;
b) The characteristics regarding the architecture of the fine bubble generators that are mounted in the aeration tanks.
These characteristics refer to the distribution of FBG in the aeration tank, to the constructive solution of compressed air supply.
- The following conditions must be observed when constructing an FBG:

$$\frac{s}{d_0} > 3 \quad (1)$$

$$\frac{d}{d_0} > 8 \quad (2)$$

where: s - thickness of the perforated plate [m];
d_0 - the orifices diameter [m];
d - the distance between two successive orifices [m];
- At the location of the FBG in the aeration tank depending on the water layer height, a distance between two side by side FBG is calculated so as to avoid of the bubble columns coalescence formed by the two fine bubble generators.

3. Presentation of the nanobubbles generator

The main element of the nanobubbles generator (figure 2) is the plate (3) which ensures the uniform dispersion of the compressed air in a certain volume of stationary water.
In the plate (3), 290 orifices with diameter ø = 900 nm are performed with a step between them equal to 5 mm.

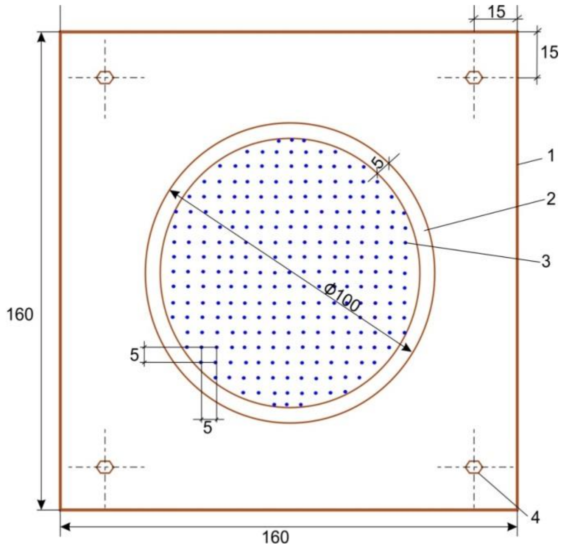

Fig. 2. Plan view of the nanobubbles generator.
1 - support plate 160 x 160 x 8; 2 - fixing ring of the orifices plate;
3 - plate with 290 orifices ø = 900 nm; 4 - plate fixing screws.

The plate (3) is made of silicon and has the following characteristics:
Diameter: 100 ± 0.3 mm
Resistivity: 1 ÷ 5 ohm cm
Thickness: 525 ± 20 µm
The orifices were made by anisotropic corrosion of silicon, applying the BOSCH process.
The plate is manufactured in Germany by SIEGERT WAFER GmbH. The plate was processed by the collaboration between the University POLITEHNICA of Bucharest and the National Institute for Research and Development in Micro technology Bucharest.
Figure 3 shows a view of the nanobubbles generator (NBG) in a vertical position. The plate with the 290 orifices (6) is fixed to the cylinder body (4) by the annular angle (5).

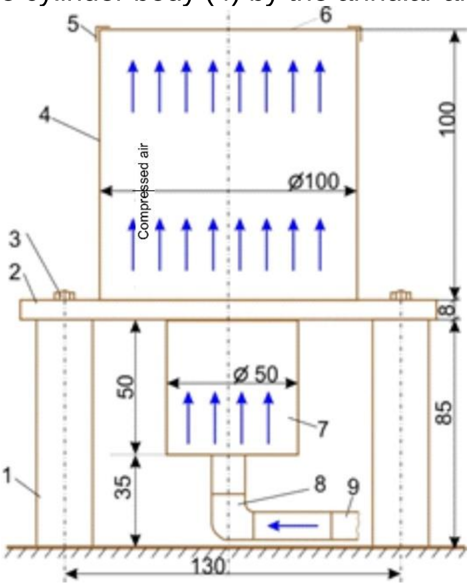

Fig. 3. Side view of the nanobubbles generator.
1 –support ø20 x 2; 2 - support plate 160 x 160 x 8; 3 - fixing screw;
4 - cylindrical body ø100 x 4; 5 - fixing ring; 6 - orifices plate; 7 - pipe ø50 x 2;
8 – bend at 90^0, ½ ''; 9 - pipe Dn 15 for compressed air supply.

The compressed air delivered by a compressor through the pipe (9) expands first in the tube (7) and then in the cylinder (4); in this way, a uniformity of the air flow rate through the orifice plate (6) is achieved.

4. Scheme of the experimental installation

Figure 4 shows the scheme of the experimental installation designed to test a set of four nanobubbles generators. The compressed air delivered by the electro compressor (2) is accumulated in the tank (3) and subsequently passes through the pressure reducer (4) to the assembly of four NBG (7); the compressed air pressure must overcome the hydrostatic load (H) i.e. the water layer height in the tank (8) and the loss of air pressure when passing through the orifices [6][7].

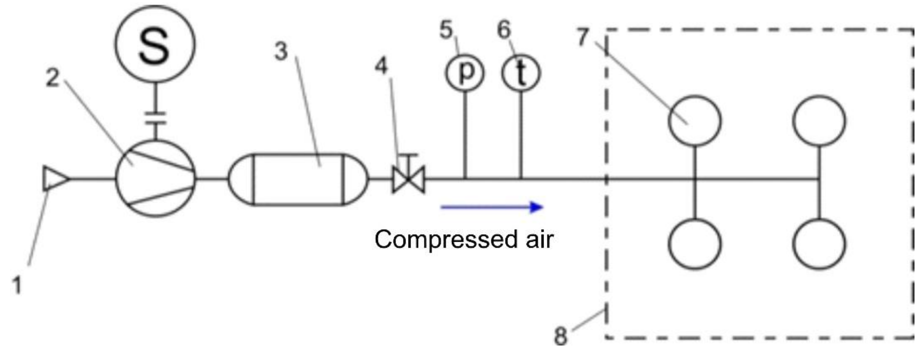

Fig. 4. Scheme of the experimental installation for water aeration with nanobubbles generators.
1 - air filter; 2 - electro compressor; 3 - compressed air tank;
4 - pressure reducer; 5 - pressure measuring device; 6 - temperature measuring device;
7 - set of four nanobubbles generators; 8 - the contour of the water tank.

The air flow rate passing through a NBG will be [8][9]:

$$\dot{V} = A \cdot w \; = \; n \cdot \frac{\pi d^2}{4} \cdot w \; [m^3 / s] \tag{3}$$

where:
A - the area of the air inlet water section;
n - the orifices number;
d - the orifices diameter;
w - air speed when passing through the orifices;.

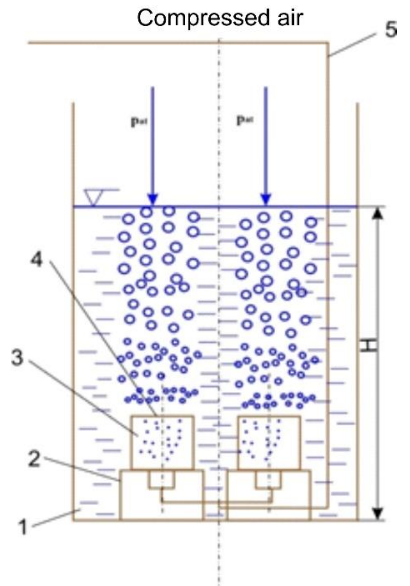

Fig. 5. Placing the NBG inside the water tank.
1 - water tank; 2 - NBG support skeleton; 3 - cylindrical body with compressed air;
4 - silicon plate with orifices ø = 900 nm; 5 - NBG compressed air supply pipe.

The total flow rate of compressed air entering all four NBGs will be:

$$\dot{V}_t = 4 \cdot \dot{V} \ [m^3/s] \quad (4)$$

The air flow speed (w) depends on the pressure drop that occurs when air passes through an orifice and is to be experimentally determined.

5. Conclusions

* Nanotechnology is a technology whose practical result is of the magnitude order of nanometres; creating a NBG is an original and much better solution for the FBG class.
** Advantages of using FBG when aerating the waters are:
- a low pressure drop compared to other aeration systems;
- a high efficiency;
- ensures a uniform distribution of the air bubble columns in the volume of water subjected to aeration;
- simple from a constructive point of view;
- quick and easy to assemble and disassemble;
- a long service life and do not require permanent supervision;
*** Experimental researches will aim to increase the concentration of dissolved oxygen in water as a function of time C_{O_2} = f (τ); it will be compared with similar data existing in the literature.

**** The results of the experimental researches will be published in a future paper that will appear in this journal.

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