Researches Regarding the Execution of a Flat Jet Generator Used for Water Aeration

PhD Student **Nicoleta Dorina ALBU**[1], Prof. Dr. Eng. **Nicolae BĂRAN**[1],
PhD Student **Mihaela PETROȘEL**[1], Sl. Dr. Eng. **Daniel BESNEA**[1],
Sl. Dr. Eng. **Mihaela CONSTANTIN**[1]

[1] Politehnica University of Bucharest, n_baran_fimm@yahoo.com

Abstract: *The paper presents two constructive versions for water aeration:*
- Version I: a fine bubble generator;
- Version II: a flat jet generator.
The two versions have as common elements the air flow rate and the air inlet section in the water volume. The experimental researches that will be carried out will determine which version is more favourable both in terms of increasing the dissolved oxygen concentration in the water and the energy consumption for compressing the air.

Keywords: *Water aeration, fine bubble generator, flat air jets.*

1. Introduction

By aerating water is meant the transfer of oxygen from atmospheric air into water, which is actually a phenomenon of transferring a gas into a liquid.
The most common method of removing impurities of organic nature under the action of a biomass of aerobic bacteria is the introduction of gaseous oxygen into the wastewater.
The oxygen originates most frequently from atmospheric air, in this case the process being called water aeration [1] [2].
Aeration can be accomplished by several methods, namely: by using mechanical aerators (turbine type) or pneumatic aerators (by injecting air at the basis of the volume of water), the latter being most often used. Also, the oxygen required for the aeration process.
At present, aeration is accomplished through three procedures: mechanical aerators, pneumatic aerators and mixed aerators.
Pneumatic aerators are the most commonly used. After the introduction of the activated sludge oxygenation processes, different types of air diffusion were created, tested and developed to increase the dissolved oxygen concentration in the wastewater.
These devices are either in the form of simple orifice, which generate large bubbles of air or in the form of fine bubble generators.
Due to the fact that the shape and material used to achieve the generators differ, air diffusion devices are classified according to the diameter of the produced bubbles. So there are fine bubble generators, medium bubble generators and coarse bubble generators.
Fine bubble aeration is more efficient than that achieved with coarse bubbles because the interfacial specific area between the two systems (air-water) is higher.
In order to intensify the oxygen mass transfer phenomenon from the air, it is necessary to achieve a maximum interphase contact surface, therefore a minimum diameter of the bubble.
The gaseous mixture which may be introduced into water to increase the oxygen concentration may be:
1. Atmospheric air (21% O_2 + 79% N_2);
2. Atmospheric air + oxygen taken from a cylinder in certain proportions;
3. Low-nitrogen air supplied by oxygen concentrators.
In case 1 it can be said that there is an aeration process that aims to oxygenate the waters.
In cases 2 and 3, as the oxygen content of the gaseous mixture changes, the notion of water oxygenation is introduced, i.e. a distinction should be made as follows:
• Water aeration by the introduction of atmospheric air into the water (1);
• Water oxygenation by the introduction of oxygen-enriched air (2) + (3).

Aeration and oxygenation of water is a two-phase mass transfer process, the gaseous phase passes into the liquid phase (water).
The applications of this process are used in the following areas:
- Wastewater treatment;
- For biological wastewater treatment;
- When collecting and separating emulsified fats from wastewater;
- In water treatment processes taken from a source to make it drinkable.

2. The formulation of the studied problem

For the water aeration, a certain atmospheric air flow rate (21% O_2 + 79% N_2) $\dot{V} = 600\, dm^3 / h$ is considered to be injected into a water tank in two versions:
Version I: The air is introduced into the water by means of a fine bubble generator (FBG),
Version II: The air is introduced into the water through a flat jet generator (FJG).
The common element is the air flow rate, air pressure and the air outlet section in the water.

2.1 Presentation of the fine bubble generator

It is proposed a new generation of FBG to which the air dispersion orifices in the water are processed by micro-drilling. There were 152 orifices with Ø 0.1 mm in the plate. [1] [2]
Figure 1 show the orifices plate.

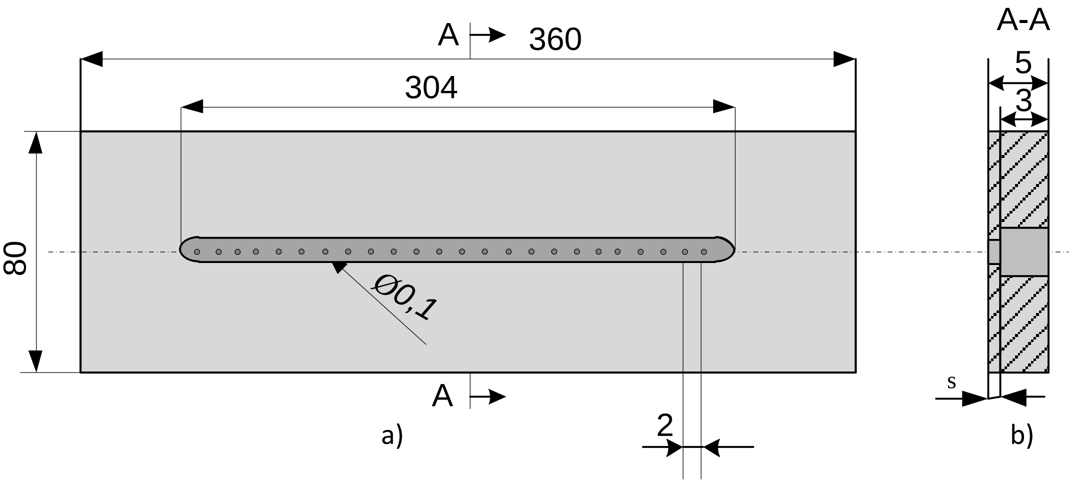

Fig. 1. FBG orifice plate
a) plan view; b) cross section

To process the orifices in the plate, a 3 mm deep and 304 mm long alveolar channel was created; the outlet through which the air exits has a thickness of 2 mm.
Subsequently, using a CNC (Numerical Computerized Control) which has a special machine for microprocessing type KERN Micro, there were made 152 orifices with Ø 0.1 mm in the channel.
This machine has an accuracy of ± 0.5 µm, which has ensured the creation of a FBG which is an original constructive solution.
Figure 2 shows the constructive solution of the FBG.

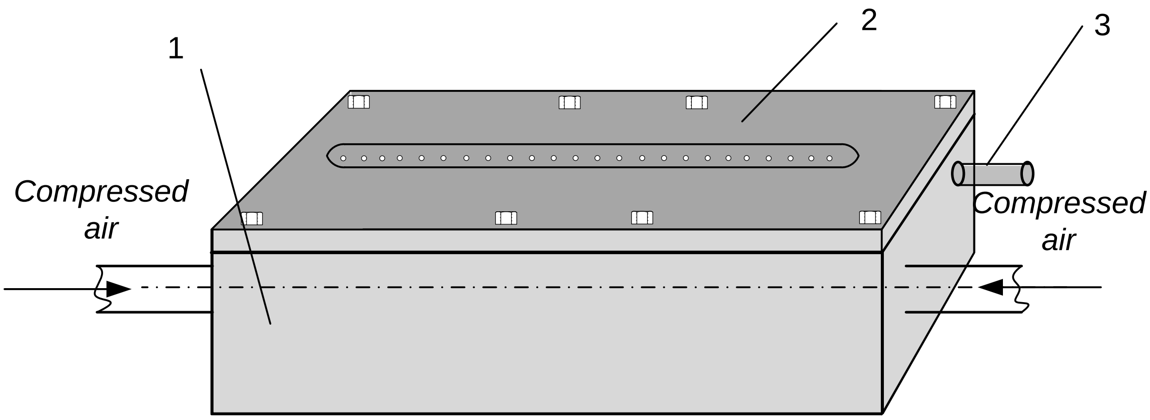

Fig. 2. Fine air bubble generator
1 - compressed air tank; 2 - orifice plate; 3 - connection for measuring the pressure of the compressed air

The FBG instaled in the aeration system is shown in Figure 5.

2.2 Computation elements for the flat jet

When introducing a stream of air into the water, the following considerations must be considered [3] [4] [5]:
- The kinetic energy of the gas stream is consumed by entraining the water particles generating the so-called "reverse flow";
- The outlet of the jet may have a circular or rectangular shape (square, rectangle);
- After leaving the initial section the jet tends to preserve the shape of the initial section [3] [6].

So:
- If the outlet is circular (round) a symmetrical axial jet will be obtained;
- If the outlet section is a rectangle (a slot), a plan jet is obtained.

The air outlet section in the water will have a rectangular shape that will generate a jet air plane.
The shape of the section is determined as follows [3]: a FBG which has 152 orifices Ø 0.1 mm diameter is chosen.
The area of airflow section in water will be:

$$A = n \cdot \frac{\pi d^2}{4} = 152 \cdot \frac{\pi}{4}\left(0.1 \cdot 10^{-3}\right)^2 = 1.1932 \cdot 10^{-6} m^2 \tag{1}$$

This area turns into a rectangle with the following dimensions: L - length; l - width.
Therefore, choosing the width l = 0.01 $\cdot 10^{-6}$ m, it results:

$$A = L \cdot l \tag{2}$$

$$\begin{gathered} 1.1932 \cdot 10^{-6} = L \cdot 0.01 \cdot 10^{-6} \\ L = 119.32\,mm \end{gathered} \tag{3}$$

So the dimensions of the rectangular slot will be:

$$L \cdot l = 119.32 \times 0.01 mm \tag{4}$$

The length of the slot will be constant, and its width will be adjusted with a digital indication micro meter [7]. The digital micro meter measures in the range 0-25 mm with a precision of 0.001mm.

2.3 The constructive solution of the flat jet generator

The air flat jet generator (FJG) is shown in Figures 3, 4.
Generating the rectangular slot emitting a jet of air plane is determined by the micro meter (4) by moving the movable plate (3) to the fixed plate (1).

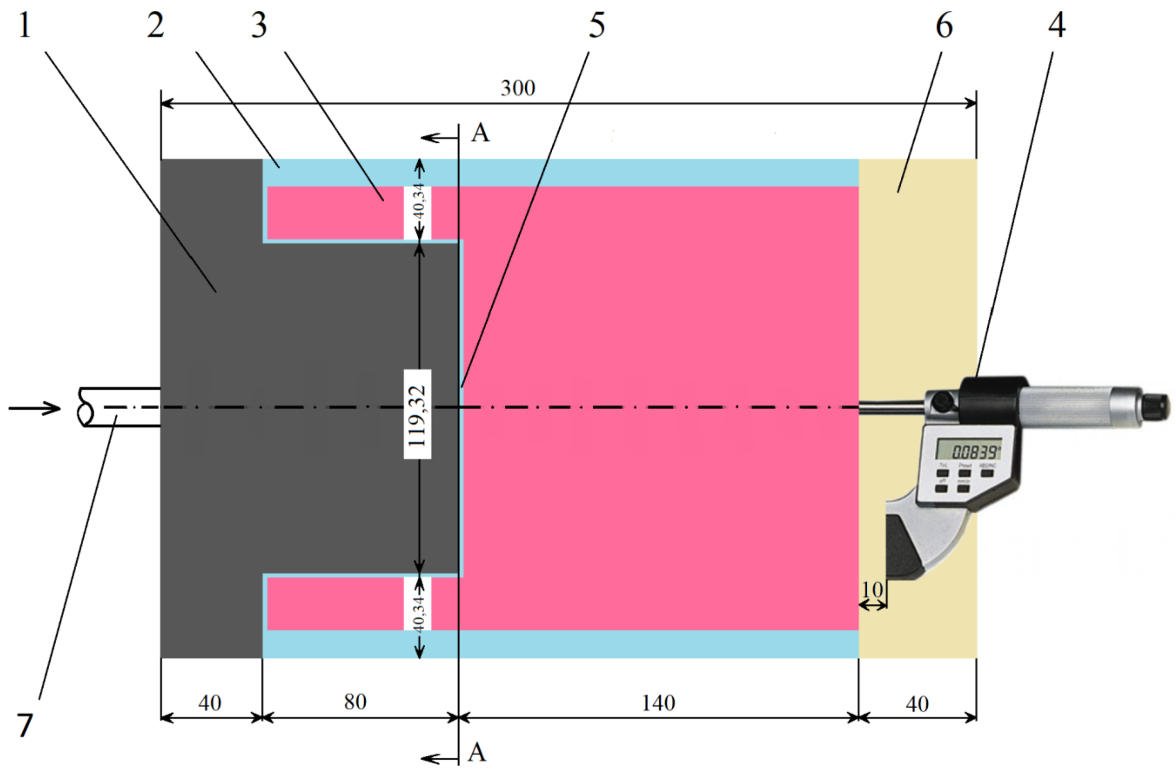

Fig. 3. Rectangular slot adjustment device (119.32 x 0.01)
1 - fixed plate; 2 - linear guide with paten; 3 - movable plate; 4 – micro meter with digital display;
5 - rectangular slot; 6 - base plate; 7 - compressed air inlet connection

For a more accurate execution of the plates 1, 3, 6 from Figure 3, a modern processing technology, namely laser technology, was used [8].

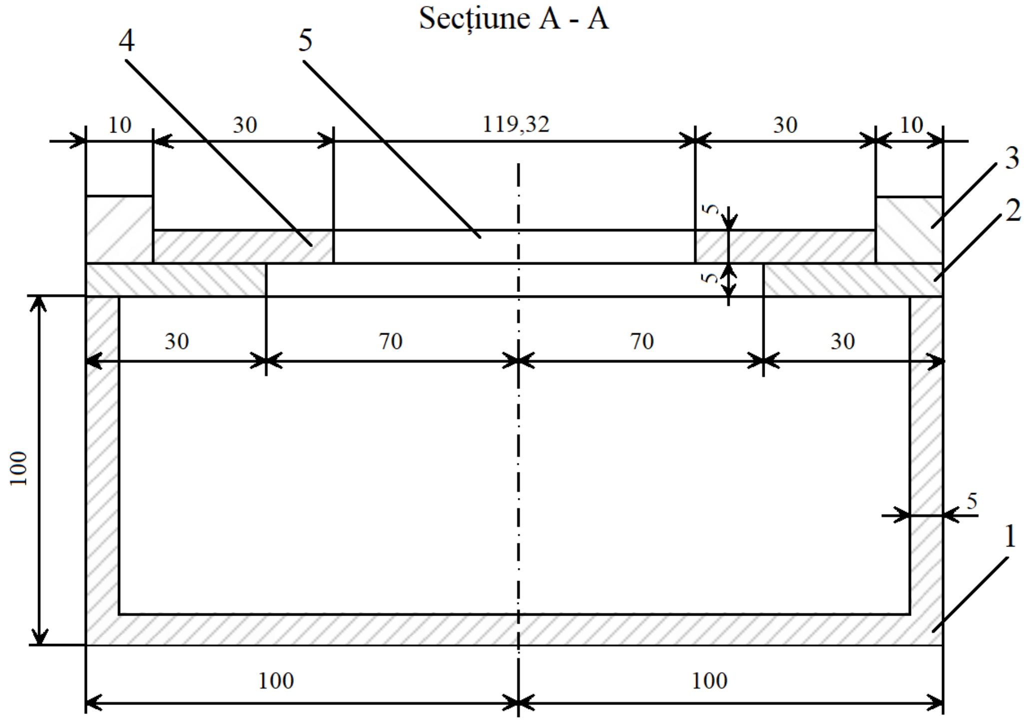

Fig. 4. Section through slot
1 - paralelipipedic vessel; 2 - base plate; 3 - linear guide; 4 - movable plate; 5 - fixed plate

After setting the width (l) of the rectangular slot, the movable plate (4) is fixed to the base plate; the electronic micro meter is then removed and FJG is inserted in the water.
By building a plurality of parallel rectangular slots in the movable plate, a "curtain" of flat, parallel jets can be made.
The distance between these jets is calculated to avoid the coalescence of the air bubbles [9] [10].

3. The experimental installation

The same experimental installation will be used for researches on the operation of FBG and FJG (Figure 5), with the distinction that position 13 will be changed from FBG to FJG.

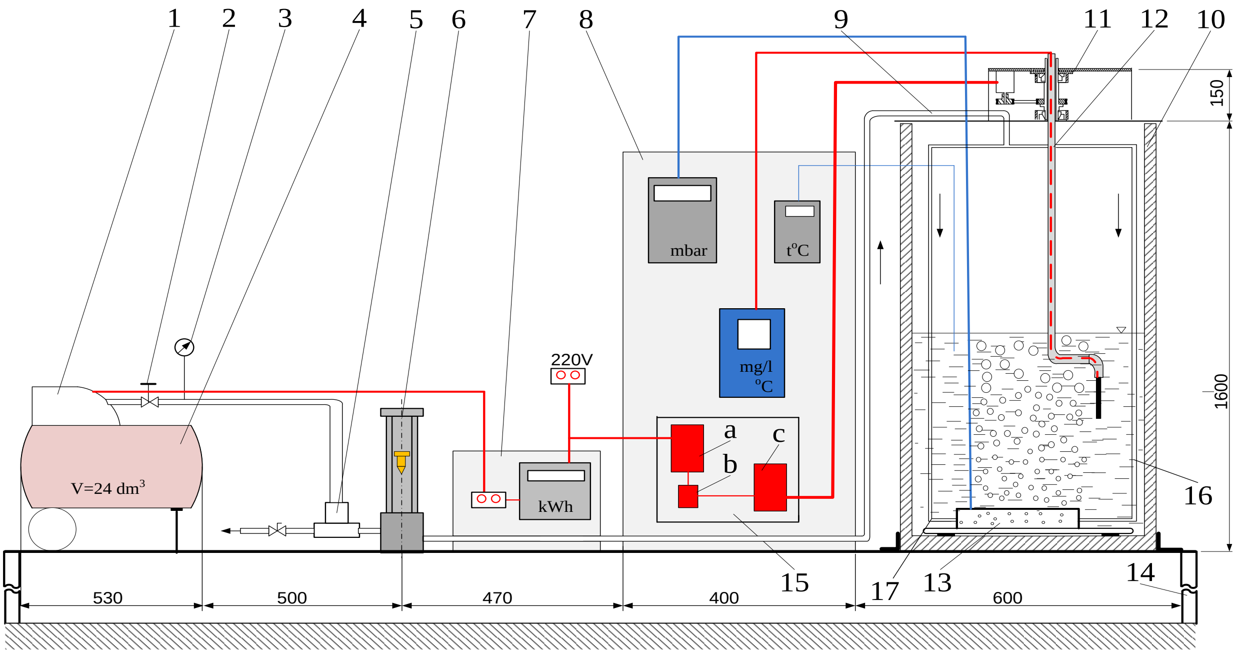

Fig. 5. Outline of the experimental installation for researches on water oxygenation
1 - air reservoir electro compressor; 2 - pressure reducer; 3 - manometer; 4 - compressed air tank V = 24 dm³; 5 - T-bend; 6 - rotameter; 7 - electric panel; 8 - instrument panel; 9 - pipe for conveying compressed air to the generator; 10 - water tank; 11 - probe actuation mechanism; 12 - oxygen probe; 13 - FBG + FJG.; 14 - support for the installation; 15 - control electronics: a - power supply, b - switch, c - control element; 16, 17 - compressed air supply pipes

In version I when the FBG works, the height of the water layer will be 500 mmH_2O, and the air flow rate introduced into the water will be 0.6 m^3 / h; these data are also kept constant in the case of FJG.
In a future paper, the methodology of the experimental researches and the obtained results will be presented.

4. Conclusions

a. This paper is of interest to a number of research engineers, doctoral students, etc. who study in the field of water aeration.
b. The novelty consists in the fact that two versions are analyzed:
Version I: FBG in a water tank;
Version II: FJG in the same operating mode as the FBG.
During the experimental researches, the change in dissolved oxygen concentration in the water and the time elapsed until the value of the saturation concentration is reached will be pursued.
The researches will continue to determine the power consumption of the air compressor that supplies compressed air for the two FBG and FJG versions.

References

[1] Tănase, E. B. "Influența compoziției gazului insuflat în apă asupra conținutului de oxigen dizolvat." Doctoral thesis. Politehnica University of Bucharest. Faculty of Mechanical Engineering and Mechatronics, 2017.
[2] Constantin, M., N. Băran, and B. Tănase. "A New Solution for Water Oxygenation." *International Journal of Innovative Research in Advanced Engineering (IJIRAE)* 2, no. 7 (2015): 49-52.
[3] Dobrovicescu, Al., N. Băran, and Al. Chisacof. *The basics of technical thermodynamics. Elements of technical thermodynamics*/*Bazele termodinamicii tehnice. Elemente de termodinamică tehnică*. Bucharest, Politehnica Press, 2009.
[4] White, F. M. *Fluid Mechanics*. New York, McGraw Hill Inc., 2011.
[5] Isbășoiu. E.C. Gh. *Fluid Mechanics Handbook*/*Tratat de mecanica fluidelor*. Bucharest, AGIR Publishing House, 2011.
[6] Cengel, Y.A., and J.M. Cimbala. *Fluid Mechanics in SI Units*. Third edition. New York, McGraw Hill Education, 2014.
[7] www.emag.ro/micromanometrudigital.
[8] www.LASERcutBucuresti@gmail.com.
[9] Mlisan-Cusma, Rasha. "Influenţa arhitecturii generatoarelor de bule fine asupra concentraţiei de oxigen dizolvat în apă." Doctoral thesis. Politehnica University of Bucharest. Faculty of Mechanical Engineering and Mechatronics, 2017.
[10] Oprina, G., I. Pincovschi, and Gh. Băran. *Hydro-Gas-Dynamics of aeration systems equipped with bubble generators*/*Hidro-Gazo-Dinamica sistemelor de aerare echipate cu generatoare de bule*. Bucharest, Politehnica Press, 2009.