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A New Type of Fine Bubble Generator Used to Water Aeration

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Abstract: *The paper presents a fine air bubble generator made by micro-drilling with a special KERN Micro machine. The perforated plate of the generator has 152 orifices with a diameter of 0.1 mm. The scheme of the installation, the researches methodology and the experimentally obtained results are presented.*

Keywords: *Fine bubble generator, water aeration, oxygen transfer*

1. Introduction

Aeration of water by means of pneumatic installations (or diffusion aeration) is defined by the process of insufflating atmospheric air or oxygen-enriched atmospheric air, under pressure, under the surface of a liquid. Oxygen transfer takes place through the contact surface between the air bubble and the surrounding liquid.
Air is introduced under pressure into the aeration system and is released by it in the form of columns of air bubbles. Thus, pneumatic water aeration systems can be classified according to the size of the bubble they produce [1] [2]:
• Aeration installations that produce large and coarse bubbles (with a bubble diameter> 3 mm);
• Aeration installations that produce medium bubbles (with a bubble diameter between 1-3 mm);
• Aeration installations that produce fine bubbles (with a bubble diameter between 0.1 mm and 1 mm);
According to the size of the diameter of the air bubbles, the bubbles can be classified as follows (figure 1):

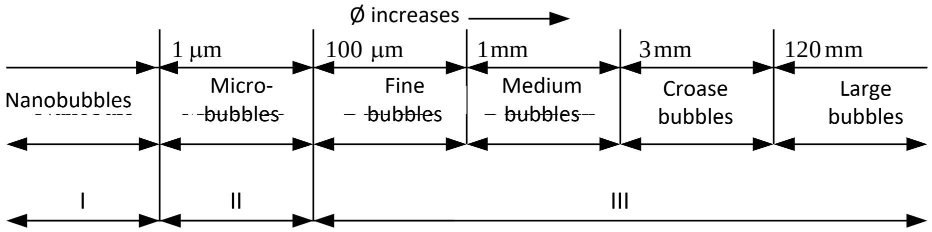

Fig. 1. Classification of gas bubbles according to their diameter [3]

According to the way the bubbles are obtained, the aeration installations fall into three categories [3] [4] [5]:
a) Aeration installations with drilled pipes;
b) Aeration installations provided with porous diffusers;
c) Aeration installations with fine bubble generators.
In recent years, researches on water aeration have focused on obtaining fine bubble generators in which the air supply orifices to the water have a diameter Φ <1 mm. Fine bubble generators have been built, the perforated plate being made by an unconventional technological process (spark-erosion); this process ensures a uniform distribution of the holes on the plate surface and an equal diameter of the holes [3] [4].
Fine bubble generators have applicability in several fields due to the efficiency of the aeration process and the low consumption of electricity, such as environmental protection (wastewater treatment), agriculture (rehabilitation of aquatic systems), health, food industry, chemical industry, etc. [6].

2. Installation scheme for introducing atmospheric air into water

The experimental installation is composed of (figure 2):
- Electro compressor with air tank (1), for the production of compressed air with the following functional parameters: maximum discharge pressure p = 8 bar, suction flow rate $\dot{V} = 600\ dm^3/h$, operating temperature t = (- 10 ÷ 100) °C, electric motor power P = 1,1 kW, speed n = 2850 rpm, tank volume V = 24 dm^3. The electric compressor is equipped with a differential pressure manometer in the range 1 ÷ 16 bar to display the air pressure in the compressor tank and a pressure reducer (2), to determine the pressure in the system pipes.
- Plastic compressed air pipes, with inside diameter Ø 15 mm and a wall thickness of 2 mm; it supplies the microbubble generator with air and ensure the evacuation of the surplus air delivered by the compressor to the atmosphere.
- Aeration tank made of plexiglass plates with a thickness of 5 mm, measuring 0.5 x 0.5 x 1.6.
- The microbubble generator (MBG). This type of MBG was subjected to tests in an experimental installation built in the laboratories of the University POLITEHNICA of Bucharest. The orifices in the plate with d_0 = 0.1 mm were made using a C.N.C. (Computer Numerical Control) which has a special micro processing machine KERN Micro type.
- Oxygenometer probe actuation mechanism.

The scheme of the installation used to carry out the experimental researches is presented in figure 2.

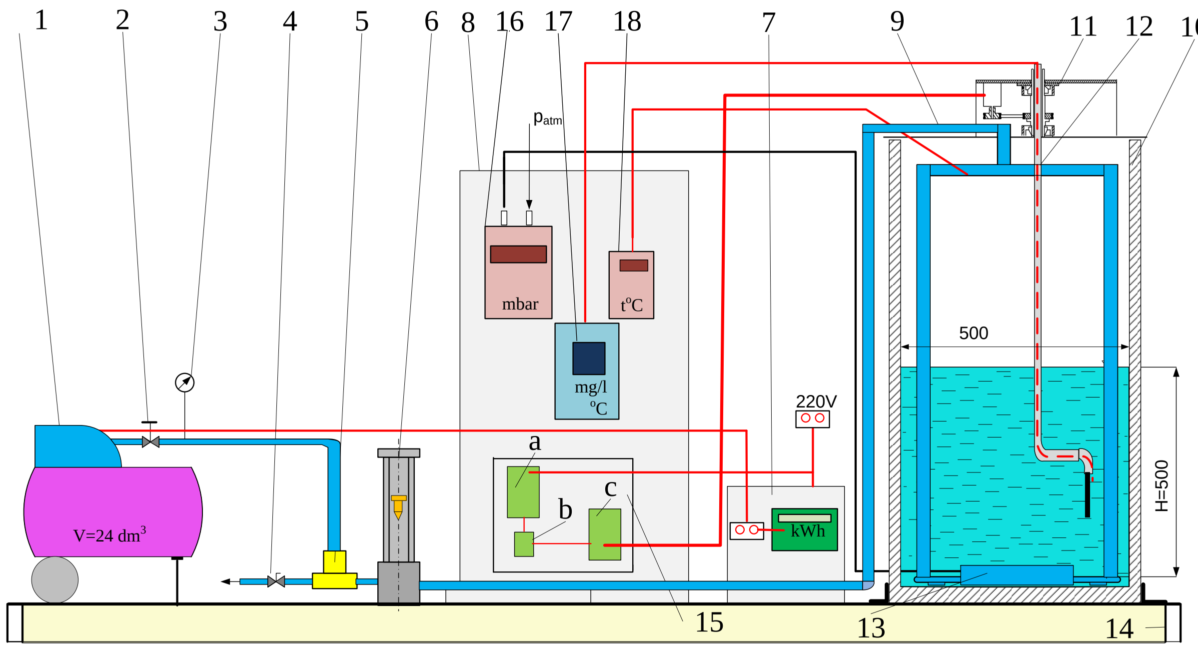

Fig. 2. Scheme of the experimental installation for research on water oxygenation
1 - electro compressor with air tank; 2 - pressure reducer; 3 - manometer; 4 - connection for evacuating air into the atmosphere; 5 – T-joint; 6 - rotameter; 7 - electrical panel; 8 - panel with measuring devices; 9 - pipe for transporting compressed air to the microbubble generator; 10 - water tank; 11 - mechanism of actuation of the probe; 12 - oxygenometer probe; 13 - microbubble generator; 14 - support for installation; 15 - control electronics: a - power supply, b - switch, c - control element, 16 - digital manometer; 17 - oxygenometer; 18 - digital thermometer

Figure 2 shows that, after compressing the air, the air temperature, pressure and flow rate are measured; subsequently it is introduced in MBG with the parameters: $\dot{V} = 600\ dm^3/h$, p = 573 mm H_2O.
The duration of the experiments is 2 hours, during which time the dissolved oxygen concentration in the water increases from C_0 to C_s.
Taking into account the volume flow of the gas, an air velocity results through the MBG supply line [7].

$$\dot{V} = A \cdot w \tag{1}$$

$$w = \frac{\dot{V}}{A} = \frac{\dot{V}}{\frac{\pi \cdot d_i^2}{4}} = \frac{600 \cdot 10^{-3}}{3600} \cdot \frac{1}{0.785 \cdot (0.012)^2} \tag{2}$$

$$w = 1.474 \ m/s \tag{3}$$

As a result, the Reynolds number is $Re = \frac{w \cdot d_i}{\upsilon} = \frac{1.474 \cdot 0.012}{16 \cdot 10^{-6}} = 1105.5$, so the theoretical flow regime is laminar.

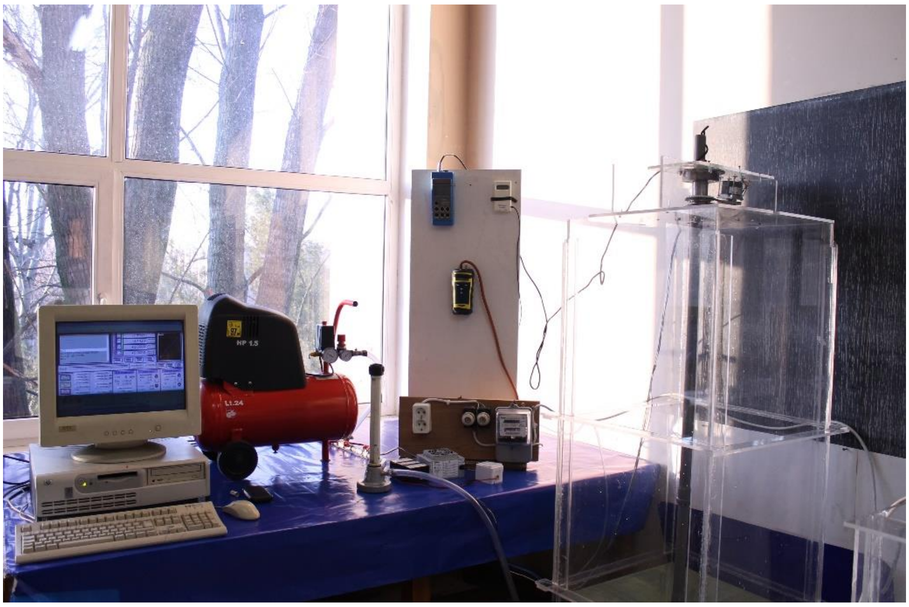

Fig. 3. Overview of the experimental installation for the introduction of atmospheric air

The installation for the introduction of atmospheric air into water is shown in figure 3.

3. Experimental researches

The experimental researches carried out in the laboratory of the Department of Thermotechnics, Engines, Thermal and Refrigeration Equipment's aimed the experimentally determination of the variation of the dissolved oxygen concentration in water as a function of time.
For each measurement stage, the following phases follow one another:
-The pressure test of the fine bubble generator is performed;
-Fill the tank with water up to H = 0.5 m;
-Measure the initial concentration of dissolved oxygen in water C_0 (mg / dm^3);
-Measure the water temperature in the tank and the air temperature;
-Introduce the fine bubble generator into the water and note the time of beginning the experiment;
-The flow rate and the pressure of the compressed air are measured and kept constant with the help of the control valves;
-After 15 minutes, the oxygenation of the water is stopped and the oxygenometer probe is inserted in the water;
- The electro-mechanism of actuating the probe is started, which ensures a speed of 0.3 m / s; when the value of the oxygen concentration on the oxygenometer screen stabilizes, it means that the measurement has been completed;
-The oxygen meter probe is lifted from the tank;
-Restart the oxygenation system and note the time.
From previous researches [8][9][10][11][12] it was found that by blowing an air flow $\dot{V} = 600 \ dm^3/h$ in the water tank with hydrostatic load of H = 0.5 m with a volume of water (0.5 x 0.5 x 0.5 =

0.125m^3), the dissolved oxygen concentration in water approaches the value of the saturation concentration after a time τ = 2 h.
The dissolved oxygen concentration in water was measured at equal time intervals: τ = 0 min; τ = 15 min; τ = 30 min; τ = 45 min; τ = 60 min; τ = 75 min; τ = 90 min; τ = 105 min; τ = 120 min.

4. Experimental obtained results

The operation of the MBG of rectangular shape with 152 orifices with a diameter of Ø 0.1 mm is shown in figure 4.

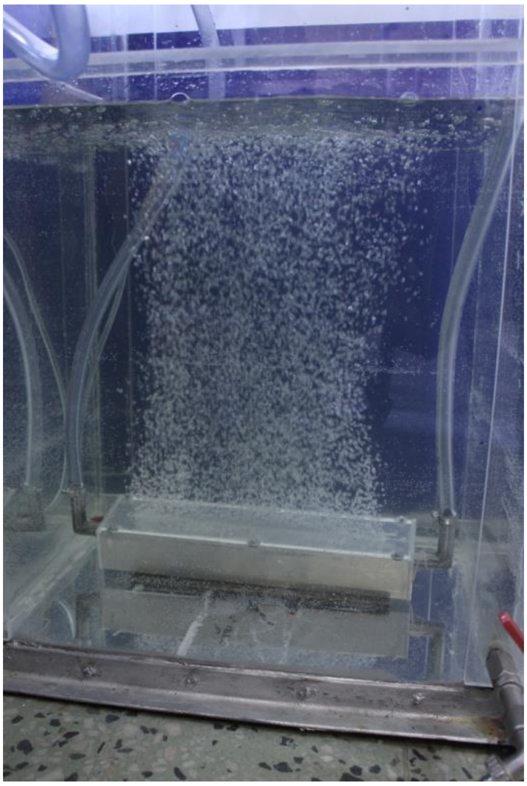

Fig. 4. Microbubble generator with 152 orifices Ø 0.1 mm in operation

Following the performed measurements, the data in Table 1 were obtained.

Table 1: Values of the concentration as a function of time

τ [min]	0	15	30	45	60	75	90	105	120
$\dot{V}_{air}$ $[dm^3/h]$	600	600	600	600	600	600	600	600	600
$\dot{V}_{IO_2} = 0.21 \cdot 600 = 126\ [dm^3/h]$	126	126	126	126	126	126	126	126	126
$\dot{V}_{O_2}$ from other sources	0	0	0	0	0	0	0	0	0
t_{H2O} [°C]	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7
t_{air} [°C]	24.1	24.1	24.1	24.1	24.1	24.1	24.1	24.1	24.1
C_0 [mg/dm^3]	5.84	5.84	5.84	5.84	5.84	5.84	5.84	5.84	5.84
C_s [mg/dm^3]	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
C [mg/dm^3]	5.84	6.89	7.65	8.01	8.10	8.26	8.31	8.35	8.39

Based on the data in table 1, the graph in figure 5 was drawn.

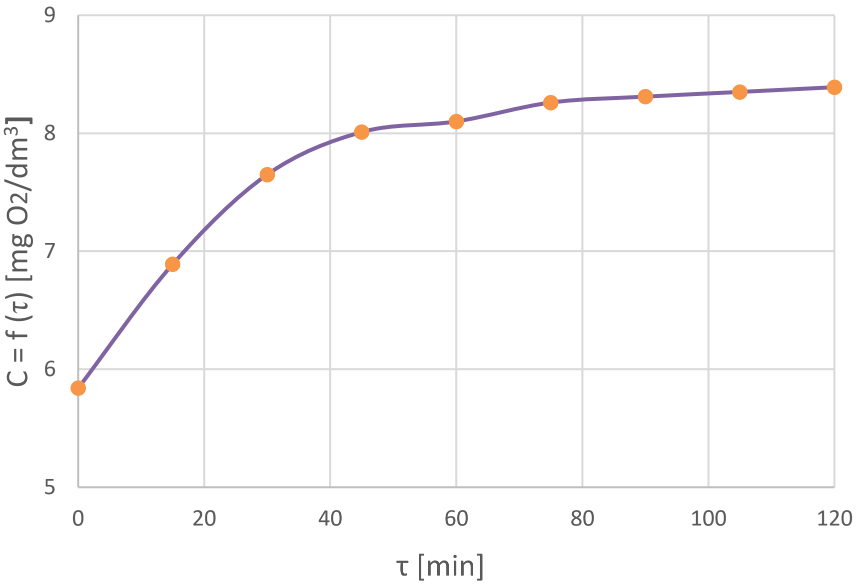

Fig. 5. Variation in the dissolved oxygen concentration in water

These results are in good agreement with those obtained theoretically, contained in similar papers [13] [14].

5. Conclusions

For the aforementioned researches, a microbubble generator (MBG) was used which is provided with a perforated plate with 152 orifices of Ø 0.1 mm made by micro-drilling.
During the experimental researches, the following values are kept constant: gas pressure at the entrance to the MBG, the gas flow rate and the hydrostatic load.
At an interval of 15 minutes the air supply to the MBG is stopped and the oxygenometer probe is inserted; the signal taken from the probe is processed in the microcomputer and digitally displayed on the microcomputer screen. There is a good correspondence between the theoretical data and the data experimentally obtained.

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