FINE BUBBLES GENERATOR

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In this paper the authors present a new type of fine bubbles generator whose dispersion element of the air into the water mass is a metallic board of rectangular shape in which a number of holes is practiced.

The holes were positioned in xOy coordinates and manufactured by electro-erosion using an electrode of 0.5 mm diameter.

The fine bubbles generator was introduced in a water basin and included in the structure of an experimental stand; the results obtained from the experimental researches performed are exposed.

Keywords: fine bubbles generator, water aeration, electro-erosion processing.

1. Introduction

The aeration plants have as principal aim the transfer of the oxygen from the air to resting or moving water mass; this can be done by injecting an air current into the water mass. The injection of the air is made through a series of very small holes existent in porous materials, or created in boards made from plastic, metal etc. After exiting the holes, the air bubbles, from the water mass, form a bubble column that can be assimilated to a planar jet.

Taking account of this similarity, some useful elements of the jet theory are exposed in the following.

From the jet theory [1] it is known that the exit hole of the gas jet can have a circular or rectangular form (square, rectangle). After exiting the initial section (the exit section of the hole) the gas jet tends to keep the form of the initial section. If the exit section is a circle, a round or axially symmetric jet is obtained; if the exit section is a rectangle a planar jet is obtained.

By assimilating a fine air bubble column to a gas jet it can be asserted that fine bubbles generators (FBG) can be divided in two classes, considering the form of the initial section:

I – FBG of circular form, when the gas bubble emitting equipment has a round form, for example, a disk endowed with holes.

II – FBG of rectangular form, when the gas bubbles are ejected from holes realized in a board of rectangular shape.

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It is specified that the term „circular shape” or „rectangular shape” is related to the form of the hole board, meaning the exit section of the totality of the bubble gas columns. The constructive solution and functioning of a FBG for which the dispersion of the air into the water is done through a drilled disk was studied in [2]; the FBG has a circular form, the bubble column will accordingly admit a round section.

In the present paper the dispersion of the air into the water is achieved through a board endowed with holes of rectangular shape; the bubble columns appearing in the water form a planar jet, and the FBG in its totality is of rectangular shape.

2. Presentation of the constructive solution of the fine bubbles generator

In order to provide an efficient oxygenation of the waters, it is necessary to provide a uniform dispersion of the air into the whole water mass from a tank or basin; the air bubbles uniformly diffused must assure the necessary of oxygen demanded by the concerned biological process. This can be obtained using fine bubbles generators, located on the base of the tank or basin, assuring a uniform distribution of the air. The authors have conceived and realized a FBG composed of a drilled board (the hole board) and the FBG body.

Fig. 1. Fine bubbles generator in function.

Between the hole board and the body of the FBG a sealing up waterproof system is mounted. A FBG of rectangular shape results by screwing the drilled board to the body of the FBG (Fig.1). Figure 1 presents the FBG in function, connected to the compressed air pipe and dived in a water basin.

3. Description of the experimental stand developed in order to test the FBG

To avoid the transmissions of vibrations from the compressor to the FBG the stand is composed by two independent units (Fig. 2). The stand contains:

- a compressor (1) having the following parameters: maximal pressure at overflow p = 8bar; intake air flow rate $\dot{V}$ = 200dm^3/min; working temperature t = 10^{0}C – 100^{0}C; power of the electric motor P = 1.1kW; number of turns n = 2850rpm; volume of the tank V = 24dm^3. The compressor is endowed with a manometer (3) and a pressure reducer (4) that assures the needed working pressure;
- a plexiglass tank containing water, having the following dimensions: 0.5×0.5×1.5m^3.

Two compressed air pipes were made in order to supply the needed feed for the FBG:

- a pipe through the valves (15) feeds the FBG;
- a pipe through the valves (16) and (17) allows the discharge of the air excess delivered by the compressor.

The air flow rate introduced in the FBG is measured with the rotameter (5) that will be changed depending of the value range of the air flow rates. When entering the FBG the air temperature is measured with a digital thermometer (6) and the pressure is measured using a digital manometer (7).

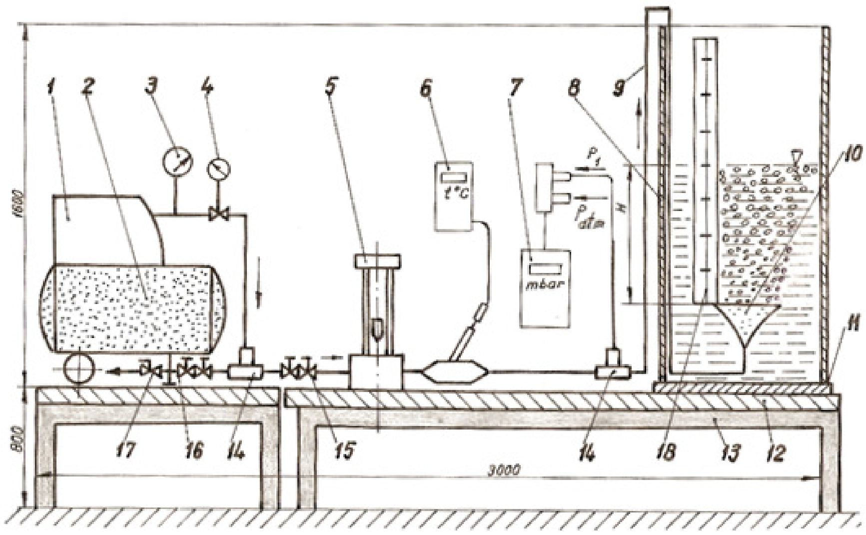

Fig. 2. Sketch for the experimental stand of the FBG: 1- air compressor; 2- compressed air tank; 3- manometer; 4- pressure reducer; 5- rotameter; 6- digital thermometer; 7- digital manometer; 8- water tank; 9- compressed air pipe; 10- FBG; 11- base plate of the tank; 12- base plate of the stand; 13- metallic bearings; 14- tee; 15- valves for the regulation of the air feed to the FBG; 16- valves for the air feed discharged to the exterior; 17- shutting-off valve; 18- graded scale.

4. Experimental researches on the functioning of the new type of fine bubbles generator

4.1. Establishing the working system of the fine bubbles generator

Depending on the gas feed introduced in the GBF three bubble formation systems can be distinguished [1], [5], [6], [7]: the quasi-static system; the dynamic system; and the turbulent system. Every system corresponds to a certain range of frequencies of formation of the gas bubbles; the transition between these systems depends on the gas flow rate, on the physical properties of the liquid, on the dimension of the holes.

For the quasi-static system the injected air flow rate is very small, inferior to the value of $1cm^3/s$ [3]. The frequency of formation of the bubbles is under 100 bubbles per minute and it is proportional to the gas flow rate.

The quasi-static system is separated from the dynamic system by the critical gas flow rate given by the relation [3]:

$$\dot{V}_{cr} = \pi \left(\frac{16}{3g^2} \right)^{\frac{1}{6}} \left(\frac{\sigma \cdot r_0}{\rho_{H_2O}} \right)^{\frac{5}{6}}, \tag{1}$$

where g is the gravity and σ is the superficial tension coefficient.

The FBG contains a rectangular board on which a row of 19 holes with diameters of d_0 = 0.5mm; $r_0 = d_0/2$ was drilled. The following values are considered: $\rho_{H2O} = 10^3 kg/m^3$, $g = 9.81 m/s^2$; $\sigma_{H2O} = 8 \cdot 10^{-2} N/m$. The critical air flow rate for a single hole is equal to:

$$\dot{V}_{cr} = \pi \left(\frac{16}{3 \cdot 9.81^2} \right)^{\frac{1}{6}} \left(\frac{8 \cdot 10^{-2} \cdot 0.25 \cdot 10^{-3}}{10^3} \right)^{\frac{5}{6}} \tag{2}$$

$$\dot{V}_{cr} = 0.744 \cdot 10^{-6} \text{m}^3/\text{s} = 2.681 \text{dm}^3/\text{h}.$$

The total critical flow rate for the entire drilled board will be of:

$$\dot{V}_{cr,t} = 19 \dot{V}_{cr} = 19 \cdot 2.681 = 50.964 \text{dm}^3/\text{h}.$$

On the experimental plant, the drilled board supports a water bed of height $H = 500mmH_2O$; the pressure given by the superficial tension [3] is of:

$$p_{ts} = \frac{2\sigma}{r_0} = \frac{2 \cdot 8 \cdot 10^{-2}}{0.25 \cdot 10^{-3}} = 620 \text{N/m}^2. \tag{3}$$

$$\Delta h_{ts} = \frac{p_{ts}}{\rho_{H_2O} \cdot g} = \frac{620}{10^3 \cdot 9.81} = 0.063 \text{mH}_2\text{O}.$$

Therefore the first gas bubbles will appear if the digital manometer displays:

$$\Delta h_1 > H + \Delta h_{ts}; \; \Delta h_1 > 563 \text{mmH}_2\text{O}. \quad (4)$$

Due to the fact that the passing through a hole generates a pressure loss (Δh_{GBF}), it results that:

$$\Delta h_{GBF} = \Delta h_1 - H - \Delta h_{ts} \text{mmH}_2\text{O}. \quad (5)$$

To provide a pressure of the injected air greater than 563mmH_2O, the injected air flow rate need to be greater than $\dot{V}_{cr,t}$ thus the generating bubbles conditions will be dynamic.

4.2. The experimental establishment of the pressure losses at the air flowing through the fine bubble generator

Firstly the FBG was subjected to a number of air tests, namely the FBG was extracted from the water basin; the following tests were accomplished:

- the air flow rate $\dot{V}$ [dm^3/h] entering the FBG was measured with the rotameter (5) (Fig. 2);
- the static overpressure Δh_1 [mbar] of the air at the entrance in the FBG was measured with the digital manometer (7).

The air flow rate passing through a hole $\dot{V}_1$ [dm^3/h] and Δh_1 were calculated in mmH_2O (Table 1).

Table 1

The values of the measured quantities obtained during air tests

$\dot{V}$ [dm^3/h]	400	800	1200	1600	2000
$\dot{V}_1$ [dm^3/h]	21.50	42.10	84.20	168.40	336.80
Δh_1 [mbar]	4.20	15.00	31.50	60.00	102.30
Δh_1 [mmH_2O]	42.81	152.90	321.10	611.62	1042.81

The graphs shown in Figure 3 were traced based on the data presented in Table 1. Figure 3 shows that for air flow rates smaller than 1200 dm^3/h, the pressure drop on the FBG is smaller than 321mmH_2O.

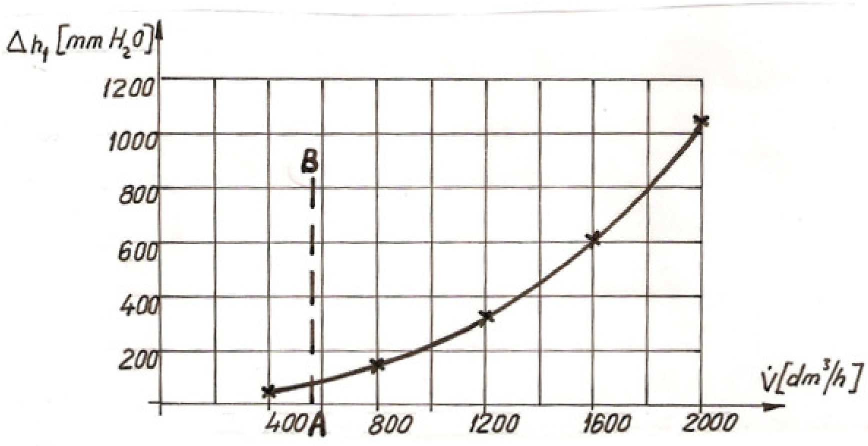

Fig. 3. Graphical representation of function $\Delta h_1 = f(\dot{V})$ for FBG during the compressed air test.

4.3. Results of the tests regarding the functioning of the FBG in water

The FBG was introduced in the water basin, having over the hole board a water bed of height H = 500mm; if the pressure due to the superficial tension is also considered, Δh_{ts} = 63mmH_2O; this means that the first air bubbles will appear if Δh_1 > 563mmH_2O (line MN from Figure 4).

Corresponding to this value, there is a minimal flow rate for which the first air bubbles appear, namely $\dot{V}$ > 554dm^3/h (line AB from Figure 4). Thus for a flow rate of 400dm^3/h and $\Delta h_1 < 563\text{mmH}_2\text{O}$ air bubbles do not appear, therefore the value (Δh_1 - H - Δh_{ts}) from the first column of Table 2 does not bear a physical sense.

The values of the measured quantities: the air flow rate $\dot{V}$ [dm^3/h] introduced in the GBF; static overpressure at the entrance in the FBG Δh_1 [mbar], are presented in Table 2.

Table 2

The values of the quantities measured during the FBG functioning

$\dot{V}$ [dm^3/h]	400	800	1200	1600	2000
Δh_1 [mbar]	52.00	61.60	82.00	116.00	167.00
Δh_1 [mmH_2O]	529.80	627.70	835.50	1187.10	1704.20
(Δh_1 - H) [mmH_2O]	29.80	127.70	335.50	687.10	1204.20
(Δh_1 - H - Δh_{ts}) [mmH_2O]	-	64.70	272.50	624.10	1141.20

In Table 2 were also calculated:

- $(\Delta h_1 - H)$ in $[mmH_2O]$ - quantity that represents the static pressure of the air at the entrance in the FBG, in the absence of the hydrostatic load *H*;
- $(\Delta h_1 - H - \Delta h_{ts})$ in $[mmH_2O]$ - quantity that represents the pressure loss for the air passing through the FBG.

Graphs presented in Figure 4 were traced using data presented in Table 2. From the study of the graphs traced in Figure 4, it can be seen that for air flow rates of 600-1200dm^3/h ($12\dot{V}_{cr,t} \div 24\dot{V}_{cr,t}$), the pressure drop on the FBG belongs to the range of 100-300mmH_2O; at greater flow rates the conditions become turbulent, the phenomenon of coalescence of the bubbles appears, the bubble column is distorted.

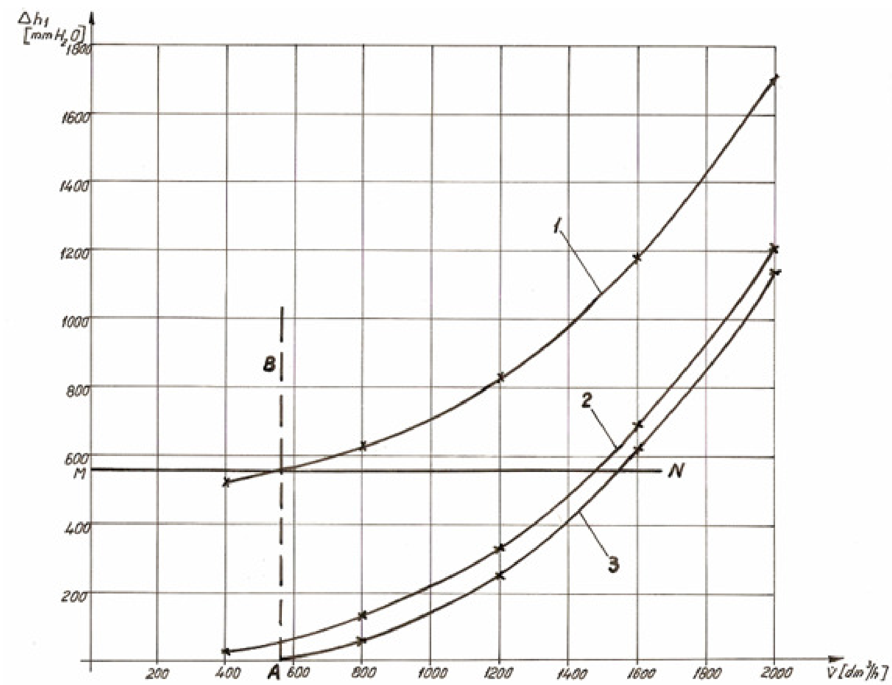

Fig. 4. Graphical representation of the functions: (1) $\dot{V} = f(\Delta h_1)$; (2) $\dot{V} = f(\Delta h_1 - H)$; (3) $\dot{V} = f(\Delta h_1 - H - \Delta h_{ts})$

5. Conclusions

The new type of FBG proposed by the authors, compared to existent data in the thematic literature [3], [4], [5], [6] has the following advantages:

- the pressure loss of the presented FBG is lower than for the porous diffusers, fact that leads to the saving of the energy spent for the compression of the air;
- using this type of FBG, a precise and uniform distribution of the injected air in the water mass from a tank or basin is ensured;
- due to the fact that the electro-erosion processing machine works in *xOy* coordinates, the holes on the board can be located on a line, on a square net, on a chess-like form etc;
- the FBG emits air bubbles with diameter smaller than 1mm, fact that intensifies the oxygen transfer to the water;
- the construction of FBG is solid, resistant to water action;
- by placing in a chess-like form two rows of holes, a bubble curtain is created, which can aerate a water mass that moves with reduced velocity.

R E F E R E N C E S

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