Bulletin of the *Transilvania* University of Braşov • Vol. 2 (51) - 2009
Series I: Engineering Sciences

A NEW SOLUTION FOR CONSTRUCTING FINE BUBBLES GENERATORS

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Abstract: *In the paper the authors present the conditions needed for developing a fine bubbles generator that can be used for waters oxygenation. In order to manufacture holes with diameters smaller than 0.5 mm needed for the generator running, a non-conventional technology was used, the electro-erosion processing. This allows the obtaining of fine air bubbles and leads to the intensification of the oxygen transfer from the air to the water mass disposed in a tank or basin.*

Key words: *fine bubbles generator, aeration, electro-erosion processing.*

1. Introduction

Water aeration technologies have developed, through the time, from surface mechanical aerators to fine bubbles aerators; aeration technologies apply both to resting liquids and to flowing liquids with very small velocities ($w < 0.1$ m / s).

The aeration technologies follow both assurance of the oxygen necessary to the evolution of a biological process, if existent, and homogenization by mixing of the liquids containing different particles in suspension.

The mass transfer phenomenon from the oxygen in the air to the water in the purification station tanks or basins is used in the following cases:

• aeration of the residual waters from the purification stations;

• aeration of the waters from fountains, pools, piscines, basins for fish breeding;

• aeration of euthrophysed lakes.

The aeration plants work with air (21 % O_2, 79 % N2) and in the most of cases the O_2 transfer to the water is looked; as consequence, in some papers [1] they are called oxygenation plants.

2. Water aeration plants

Aeration plants were built as consequence of elaboration of aeration technologies. These plants can be classified following the two criteria:

A. According to the destination:

→ aeration plants that have as principal purpose the oxygen transfer to liquids; in this case appear problems about the transfer velocity, the surface between the gas and the liquid, etc.;

→ aeration plants that follow the impulse transfer from the gas jet to the liquid mass; here there are problems regarding the induced movement, the maintenance in suspension of the particles from the liquid etc.

B. According to the functional principle, the aeration plants are classified in:

I. pneumatic plants;

II. mechanical plants.

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I. The first category plants contain:

➝ the compressed air sources (air-blowers, low pressure compressors);

➝ air transport and distribution pipes;

➝ spreading devices, called also bubble generators;

➝ measure and control devices.

II. The second category plants contain aggregates that by mechanical ways assure the maintenance of a turbulent motion in the water mass and the driving of atmospheric air in a bubble shape.

According to the arrangement mode of the active element, the mechanical oxygenation plants are divided in:

1. surface plants (aeration brushes, surface mechanical aerators);
2. medium depth plants, for which the active element, the rotor, is placed at about 2 m under water in the basin (medium depth mechanical aerators);
3. big depth plants, for which the rotor is placed at about 4 ÷ 6 m underwater level in the basin (big depth mechanical aerators);

C. According to the air bubble dimension that intrude in the water mass from a tank or basin, the bubble generators are divided in

a. fin bubbles generators with diameter db < 1 mm;

b. medium bubbles generators with diameter db = 1 ÷ 3 mm;

c. large bubbles generators with diameter db = 3 ÷ 120 mm.

The bubble dimensions depend on the air output hole diameter, on the air flow and the air pressure from the distribution net.

The fine bubbles are obtained by an air feed injection through a porous medium (a medium that admits small holes).

To realize the air spreading into water we use:

• porous diffusers made from ceramic material;

• syntherised glass;

• rigid, porous, plastic materials;

• membrane elastomer, made from natural rubber or ethylenpropylene.

3. Conditions for developing fine bubbles generators

For an efficient oxygenation of waters, is necessary to assure a uniform spreading of the air in the whole water mass from a tank or basin; the air bubbles uniformly spread must assure the necessary of oxygen needed by the respective biological process.

This can be done with the help of the fine bubble generators (FBG), placed on the bottom of the tank or basin, guaranteeing an uniform distribution of the air.

The authors conceived and realized a FBG, presented in figure 1.

The compressed air enters in the truncated cone body 1, and reaches the drilled disk, 4; the disk has ∅ 0.3 mm or ∅ 0.5 mm holes and is fixed in the casing, 3, by the safety ring, 5, tightened by the regulating nut, 6. The casing, 3, is tightened on the truncated cone body, 1, by the nut, 2. The essential element of a FBG is the hole disk, 4, which need satisfy the following conditions:

a. to be resistant at the action of the liquid with which enters in contact (residual waters, waters with special pH);

b. to allow the air uniform distribution with small pressure losses ;

c. to be easily cut (processed);

d. to have a high mechanical resistance, sufficient to resist at the weight of a water column of 4 ÷ 5 m.

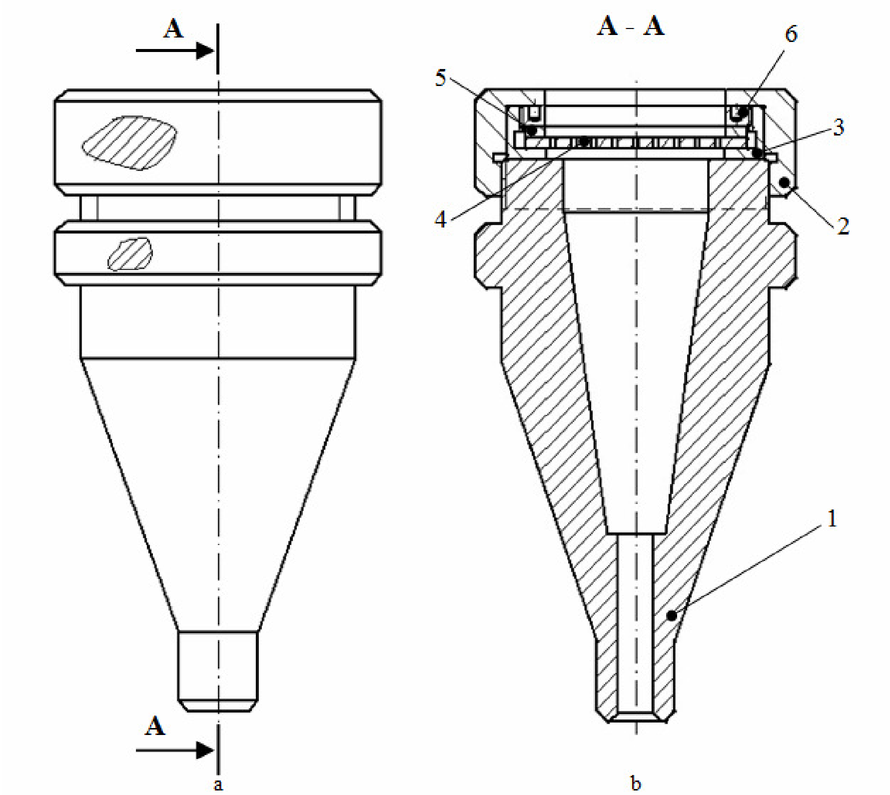

Fig. 1. *The fine bubble generator a – front view; b – cross-section*

From the specialty literature [2, 3], for FBG produced till now, two general conditions have appeared:

→ The first condition (fig. 2):

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

where: *s* is the thickness of the plane disk;
d_0 – the hole diameter

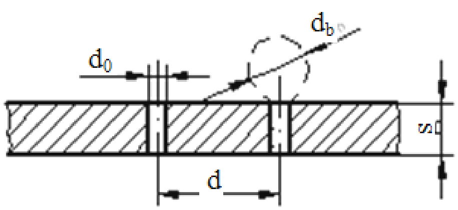

Fig. 2. *Hole spacing in the FBG disk*

The second condition:

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

in which: *d* represents the distance between the two holes.

Usually, the diameter of the formed bubble (db) is:

$$db \approx 2d_0 \quad (3)$$

Accordingly, to obtain fine or very fine bubbles, the hole diameter must be the smallest possible (d0 < 1 mm) and the holes repartition on the board must be uniform. These two conditions can be realized with the help of non-conventional technologies [4,5]:

- processing by electro/erosion;
- electrochemical processing;
- laser processing;
- processing with electron beam etc.

The experiments using a laser plant were not satisfactory so that the disk drilling was made by electro-erosion; by this process, the uniformity of the hole contour is assured, the accuracy of the cut plant can reach 0.005 mm [5].

4. Electro-erosion processing plant used in the fabrication of the FBG.

Electro/erosion processing plants are classified, according to running principles, in:

A- Processing plants with profiled electrode;

B- Processing plants with threadlike electrode.

To process the holes in the FBG disk an electro erosion-processing machine of AG 55 L type (fig. 3) was used.

This process assures an uniformity of the air injection hole diameters and, in the same time, a uniform distribution (intended by the designer) of these holes. This process controls the aeration phenomenon of a number of tanks or liquid basins:

a) ceramic porous diffusers made from crystalline aluminum oxide grains;

b) ceramic diffusers made by pure silicate glassy grains;

c) porous diffusers made from pure silicate grains in an resin type ambient.

These diffusers are able to produce the finest gas bubbles, but the bubble distribution cannot be put under control; zones in which no gas bubble get outside in the liquid can appear at the disk surface of the porous diffuser.

Fig. 3. Electro erosion processing machine AG 55 L.

Technical specifications

Data sheet	AG55L
X / Y / Z axis travel (mm)	550 x 400 x 350
Table dimension (mm)	750 x 550
Dielectric level (min - max, mm)	80 - 360
Max. workpiece weight (kg)	1.000
Max. electrode weight (kg)	50
Step resolution (mm)	0.0001
Max. positioning speed (mm/s)	5.0
Max. pulsation speed Z axis (m/min.)	36
Table - chuck distance (mm)	280 - 630
Controlled axes	4
Machine weight (kg)	6.440
C axis	
Resolution (°)	0.001
Rotational speed (min. – max. rpm, continuous)	20 - 2000

Standard features of the AG55L

- "SGF" Nano-Wear Discharge Unit

- Improved Ease of Operation
- NC operation panel
- Rise and fall work tank

Options of the AG55L
- High Precision Rotary Head, C axis
- Linear electrode changer Shuttle ATC
- Automatic tool changer (ATC)

5. Constructive variants for the drilled disk contained in the FBG

To resist to the corrosive action of water, the disks are made from an aluminum alloy, with a width of 2 mm; the holes were made by electro erosion with electrodes of diameters: d_0,1 = 0,3 mm; d_0, 2=0,5mm.

The abidance by rules (1) and (2) is presented in table 1.

Table 1

No of var.	*s*, mm	$d_{0,1}$ mm	$d_{0,2}$ mm	Condition (1) $\frac{s}{d_0} > 3$		Condition (2): $\frac{d}{d_0} > 2$				
				$\frac{s}{d_{0,1}}$	$\frac{s}{d_{0,2}}$	$d = 2d_{0,1}$ ($d = 2d_{0,2}$)	$d = 4d_{0,1}$ ($d = 4d_{0,2}$)	$d = 6d_{0,1}$ ($d = 6d_{0,2}$)	$d = 8d_{0,1}$ ($d = 8d_{0,2}$)	$d = 10d_{0,1}$ ($d = 10d_{0,2}$)
I	2	0,3	0,5	6.66	4.00	0.60	1.20	1.80	2.40	3.00
II	2			6.66	4.00	(1.00)	(2.00)	(3.00)	(4.00)	(5.00)

From the table 1, one can remark that the values are totally conform to the conditions (1) and (2).

Initially, a squared net inscribed in a ∅ 35 mm circle was projected (see fig.4), equal with the diameter of the drilled disk of the FBG.

Subsequently, by using the electro-erosion processing machine of AG 55L type, a hole net with an ∅ 0.5 mm electrode (fig. 5) was drilled in an aluminum plate of width s = 2 mm.

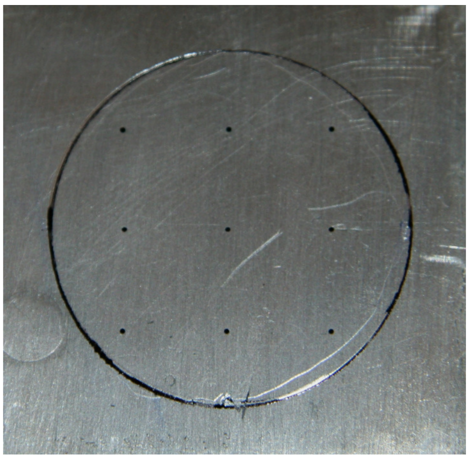

Fig. 5. *Hole network, practiced by electro-erosion*

Measurements were performed using a universal microscope „ZEISS”, taking for accuracy of linear dimensions 0.001 mm and that of angular dimensions 1′, on the 9 holes denoted 1,2, ..., 9 (see fig. 4); the results of the measurements are presented in table 2.

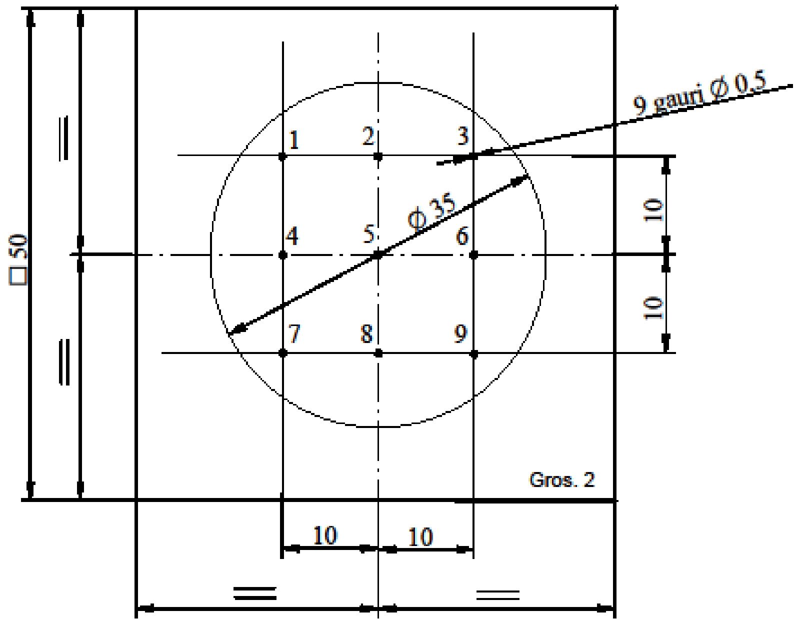

Fig. 4 Amplasarea orificiilor pe suprafata discului din G.B.F.

NOTĂ:
- Tolerante generale conform ISO 2678 - m K
- Prelucrările se vor face prin electroeroziune
- Grosimea plăcii: s = 2 mm
- Pasul retelei: d = 10 mm
- Diametrul electrodului: de = 0,5 mm

s/de = 2/0,5 = 4
s/de = 10/0,5 = 20

Ra 3,2
Ra 1,6

			Data	Format	Material	Proiectat: Ing. G. MATEESCU
	2:1	—		A 4 (210x297)	Al	Verificat: Ing. N. BĂRAN
ISO 1302	ISO 1101	√				
U.P.B. - I.M.M.			DISC PERFORAT 5-0,5 M			5
			D.B.A. - 1.4.5			

Table 2

Hole number	1	2	3	4	5	6	7	8	9	Average
d_0 mm	0,528	0,540	0,508	0,489	0,516	0,525	0,507	0,511	0,529	0,517

Table 2 proves a satisfactory accuracy of the holes manufacturing.

6. The evaluation of the pressure loss when the air passes through the drilled disk

The drilled disk holes will be assimilated to n parallel capillary tubes. The pressure loss for a hole will be calculated in the following way:

$$\Delta p = \sum \xi_i \cdot \rho_a \frac{w^2}{2} \tag{4}$$

In this equation, the sum of the local pressure loss coefficients is made from sudden section variations [6]:

- when entering the hole (s > 3d0): $\xi_i = 0.5$
- when getting out of the hole (s > 3d0): $\xi_i = 1.0$

Thus $\sum \xi_i = 1.5$

The air density (ρ_a) will be computed by considering an overpressure given by the height of the basin water (h).

$$p_m = \rho_{H2O} \cdot g \cdot h = 10^3 \cdot 9.81 \cdot 1.5 = \\ = 14{,}715 N/m^2 \tag{5}$$

The following values are chosen for the computation: the air constant R=287 J/KgK and t=20oC.

$$\rho_a = \frac{p_{atm} + p_m}{RT} = \frac{14715 + 101325}{287 \cdot 293.15} = \\ = 1.37 kg/m^3 \tag{6}$$

From [2], the critical flow rate is of $\dot{V} = 4 \div 6\,\text{cm}^3/\text{s}$ meaning:

$$\dot{V} = 4 \cdot 10^{-6} m^3/s \tag{7}$$

For a hole having d_0=0.5mm the air flow velocity obtained is equal to:

$$w = \frac{\dot{V}}{A} = \frac{\dot{V}}{\frac{\pi d_0^2}{4}} = \frac{4\dot{V}}{\pi d_0^2} = \frac{4 \cdot 4 \cdot 10^{-6}}{\pi (0.5 \cdot 10^{-3})^2} = \\ = 20.38\, m/s \tag{8}$$

$$\Delta p = 1.5 \cdot 1.37 \cdot \frac{20.38^2}{2} = 426.7\, N/m^2 \tag{9}$$

but:

$$\Delta p = \rho_{H2O} g \cdot \Delta h = 10^3 g \Delta h 10^{-3} = \\ = g \cdot \Delta h\, N/m^2 \tag{10}$$

It results that Δh expressed in mmH_2O is equal to:

$$\Delta h = \frac{\Delta p}{g} = \frac{426.7}{9.81} = 43.5\, mmH_2O\,. \tag{11}$$

This value can be set in the small and medium values range, with respect to the pressure loss in porous diffusers [2].

In the future, the experimental researches made on this new FBG type should confirm or not the above computation.

7. **Conclusions**

1. By comparison with porous diffusers made from syntherised glass or other materials, the proposed solution assures a uniform distribution of the air bubbles in the water mass;

2. The arrangement of the air injection holes in the FBG can be made in the desired way because the electro-erosion processing machine works with the help of a computational program, in XOY coordinates; the obtaining of the distance between the holes is assured with a 0.0001 mm precision ;

3. By this processing method (electro-erosion), holes can be manufactured as to produce series of plane jets, that will generate bubble screens.

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