RESEARCHES ON THE GENERATION OF FINE AIR BUBBLES REQUIRED FOR WATER AERATION PROCESSES

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Abstract. The paper presents the constructive solutions of the fine bubble generators at which the dispersion element of the air in the water consists of: a ceramic or plastic plate; a perforated metal plate; a perforated elastic membrane. There are other constructive solutions that will be analyzed in the papers that will be published later on. The pressure loss at air passage is indicated for each presented constructive solution, their advantages and disadvantages are highlighted.

Keywords: water aeration, fine air bubble generators.

1. INTRODUCTION

Given the multitude of aeration systems and their efficient operation, there is a need for theoretical and experimental research to treat the water aeration system unitarily. Mass transfer between water and air depends on the contact surface and the time length it takes place.

In order to achieve the best possible aeration, it is necessary to generate fine air bubbles and a longer contact time between the gaseous phase (air) and the liquid phase (water).

It is proposed to make a distinction between water aeration and water oxygenation in the following sense: in studies conducted in the laboratory of the Department of Thermotechnics, Engines, Heat and Refrigeration Equipment's on increasing the dissolved oxygen concentration in water the following experiments were carried out [1]. The following gases were successively introduced into the water:

A) Atmospheric air (21% O_2 and 79% N_2);

B) Atmospheric air + oxygen form a cylinder at certain volumetric volumes;

C) Low nitrogen air supplied by oxygen concentrators (95% O_2 + 5% N_2).

As a result, a distinction has to be made between the two processes: aeration ↔ oxygenation:

I. The aeration is the term used for the introduction of atmospheric air into water;

II. The term "water oxygenation" implies an additional source of oxygen, compared to the atmospheric air introduced into the water.

The oxygen present in water is known as dissolved oxygen (DO) and is measured conventionally in [mg/dm^3], the oxygen content dissolved in water is an important indicator of the utility of a water source.

The water oxygenation process is based on the transfer of oxygen from the gaseous phase to the liquid phase; there is an interphase process that can be stationary or non-stationary.

The gas phase can be air, ozone air, pure oxygen, and the liquid phase is clean water or wastewater. The oxygenation processes occur in the following areas:

- In sewage treatment and treatment plants;
- In the disinfection (ozonation) stations of raw water taken from a source in order to make it drinkable;
- In the chemical industry;
- Food industry, fishing industry etc.

In water treatment and treatment processes, aeration is a basic process in ensuring water quality.

2. THE GENERATION OF FINE AIR BUBBLES BY POROUS DIFFUSERS BUILT OF CERAMIC OR PLASTIC MATERIALS

2.1. Fine bubble generators with porous ceramic plates

Ceramic materials are the oldest materials used to construct fine bubble generators. The ceramic plates are made up of irregular or spherical mineral particles, which are classified according to size and mixed with binding materials, compressed in various shapes and processed at high temperatures to form ceramic bonds between the particles.

The results are a series of orifices through which the compressed air passes. The air comes out of the ceramic plate orifices and is modeled due to superficial tensions and the air flow rate in form of bubble, characteristics that define the size of the bubble.

The ceramic plates are made of alumina, aluminum, silicate or silicon. The bubble generators of ceramic materials have been in operation for a long time, it is well known and both the advantages and the problems that arise in operation are known.

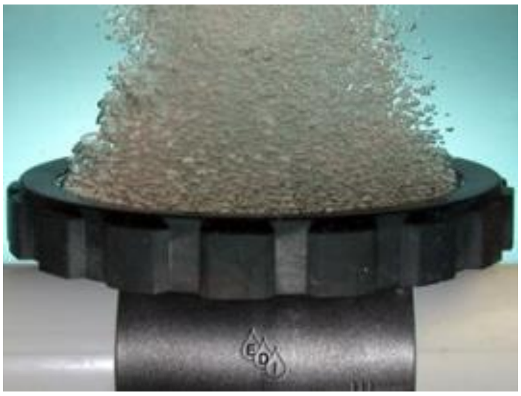

Fig. 1. Porous diffuser of ceramic material.

Ceramic diffusers (Figure 1) uses aluminum oxide, silicate aluminum, while the elastic ones can be made of synthetic rubber [2] [3] [4].

2.2. Fine bubble generators with porous plastic plates

Recently, fine bubble generators are made of plastics because it has more techno-economic properties than ceramic materials.

In the process of constructing fine bubble generators, due to the properties of plastic materials, the size of the gas outlets can be controlled. Among the superior properties of these materials are: low weight, durability, high shock resistance, etc.

Plastic materials can be rigid or non-rigid; the non-rigid ones require an internal support structure. A disadvantage of these types of generators is that it does not always ensure a uniform distribution of air in the mass of the aerated liquid.

Depending on the material used in the plate construction and on the characteristics of the waste water, after a certain period of operation, it get clogged and requires cleaning.

Fig. 2. Bubble generators made of porous plastic materials.

2.3. Fine bubble generators with perforated plates made of metal

These function as perforated membranes, but the construction materials are metallic materials or rigid plastic in which individual orifices through the material from one face to another are made and allow air to disperse in the water.

Fig. 3. Perforated metal plate for fine bubble generators.

The perforated plates have orifices that can be obtained by spark-erosion or micro-drilling [5] [6].

3. PRESSURE LOSSES AT POROUS CERAMIC GENERATORS

Porous diffusers can be made of ceramic (PDc) or glass (PDg).

For fine bubble generators containing porous diffusers, experimental researches was carried out to determine the pressure loss occurring at the air passage. Thus, pressure losses were determined for a ceramic porous diffuser of Ø150 mm with different porosity (Figure 4) [2].

It can be noticed from figure 4 that a pressure loss of 1.1 ÷ 1.2 mH_2O occurs for $\dot{V} = 600\ dm^3/h$. For fine bubble generators (F.B.G.) with porous diffusers made of glass, the loss of pressure is lower (Figure 5).

Apart from the fact that the porous diffusers exhibit a relatively high pressure loss, it has the disadvantage that it does not ensure a uniform distribution of the air bubbles in the water mass; also, the size of the air bubbles emitted by porous diffusers is not the same.

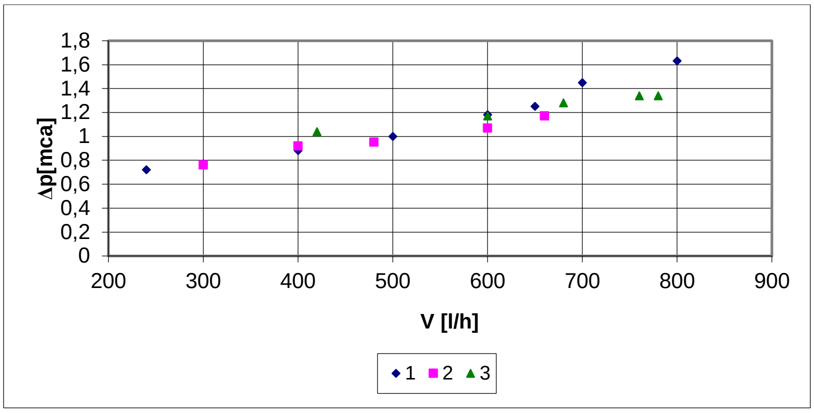

Fig. 4. Variation of pressure loss in function of the air flow rate for CPD Ø150 mm.

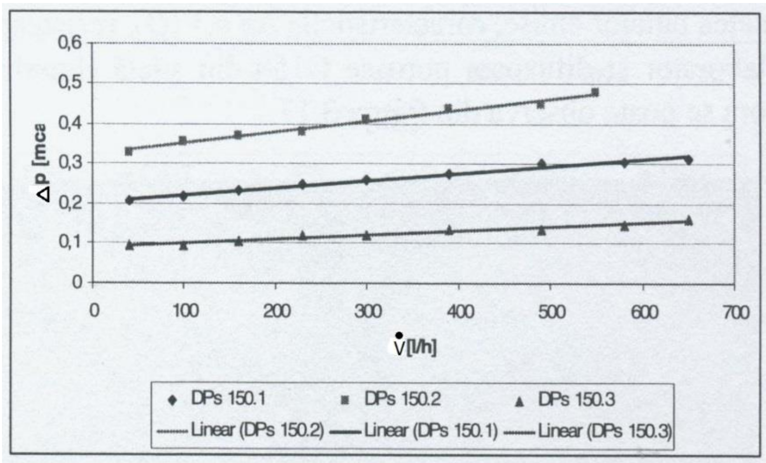

Fig. 5. The variation of the pressure drop funtion of the flowrate for PDg with Ø 150 mm.

4. GENERATION OF FINE AIR BUBBLES BY POROUS DIFFUSERS CONSTRUCTED FROM A PERFORATED ELASTIC MEMBRANE

The SANITARE company [7] builds porous difussers with perforated elastic membranes. It differ from the above (ceramic and plastic) in that it does not have a network of interconnected orifices through which the air circulates. Individual orifices are executed across the surface of the membrane through which the air circulates (Figure 6).

The materials from which it is made are materials with very high elastic properties (rubber, latex, silicone materials, EPDM membrane: Etilen - Propilen - Dien - Monomer).

Elastic and tubular fine bubble generators have the long-lasting ozone-resistant EPDM rubber functional part, and the diffuser body is made of shock-resistant plastics.

On this equipment, the orifices closes when the air is shut off and do not require frequent maintenance because during operation the membrane vibrations lead to self-cleaning of the active surface.

Fig. 6. Fine bubble generators with perforated membranes.

In Figure 6, F.B.G. is equipped with an EPDM resistant ozone and UV radiation membrane, has good chemical resistance and can operate at -45 °C to 130 °C. Figure 7 presents an outline of the F.B.G. with EPDF membrane.

On the surface of the circular disc, when air is introduced through the connection 3, the elastic membrane is deformed and through the orifices therein the air exits in water (Figure 7 b).

To determine the order of the bubbles emitted by this membrane, the following dimensions in millimeters were measured with the optical microscope:

The area of an orifice will be:

$$A_1 = 0.08 \cdot 0.79 = 0.0632 \text{ mm}^2 \quad (1)$$

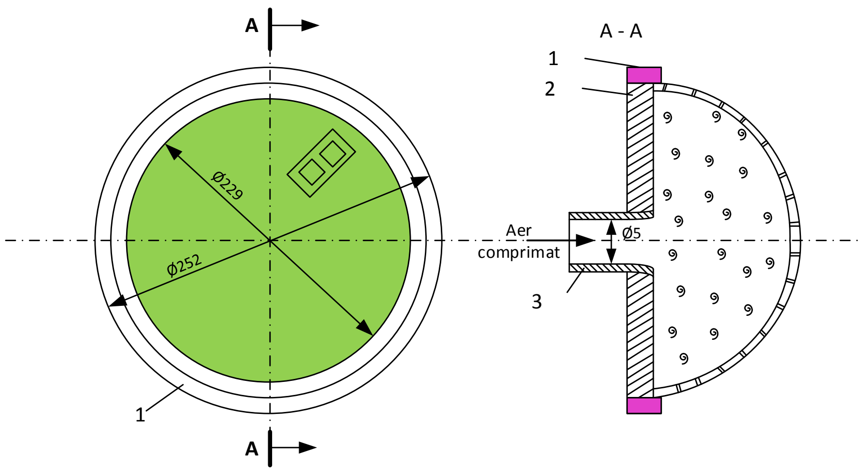

Fig. 7. F.B.G. built with perforated elastic membranes:
a) front view; b) cross section
1 - rubber disc fixing nut; 2 - difuser body; 3 - compressed air inlet connection; 4 – membrane.

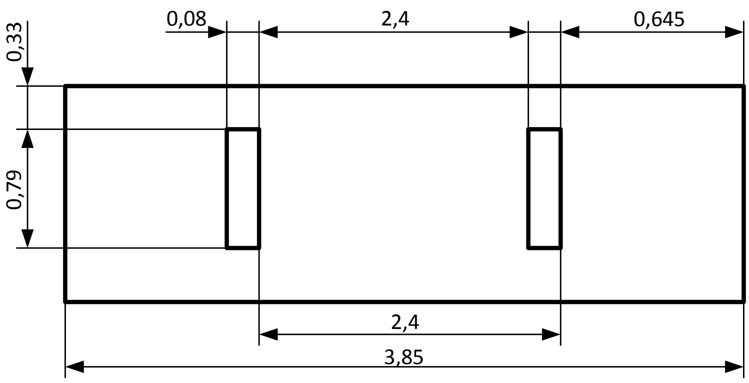

Fig. 8. The architecture of two orifices in the perforated elastic membrane.

If it is desired to determine the equivalent diameter of the orifice, the following formula [8] is applied:

$$d_e = \frac{4A}{P} \text{ [m]} \quad (2)$$

where:

A - is the area of the air passage;

P – the perimeter watered by air

The orifices being rectangular, the following is obtained:

$$d_e = \frac{4 \cdot 0.0632}{2(0.08 + 0.79)} = 0.145 \text{mm} \quad (3)$$

This diameter is the same order of magnitude as the one made at a F.B.G. in the Department of Thermotechnics, Engines, Heat and Refrigeration Equipment's, which was 0.1 mm.

Regarding the pressure drop (Δp) on these F.B.G., the company SANITAIRE does not present data; other companies as TRAILGAZ, FLYGT indicates Δp = 300 ÷ 400 mmH_2O [2].

5. CONCLUSIONS

The use of porous diffusers in ceramics has the following disadvantages [9] [10]:

- The emission of air bubbles takes place through air bubbles of unequal diameters;
- Air bubbles appear irregularly only on certain portions of the porous diffuser area;
- Porous diffusers exhibit high pressure losses; for a porous ceramic diffuser of Ø150 for a flow rate of 600 dm^3/h, the Δp value is 1.2 mH_2O;
- The damage to ceramic diffusers is due to the clogging of pores and deposits on the surface of the diffusers;
- Cleaning them after a possible clogging is difficult.

REFERENCES

[1] B. Tănase, *„Influența compoziției gazului insuflat în apă asupra conținutului de oxigen dizolvat”,* Teză de doctorat Universitatea POLITEHNICA din București, Facultatea de Inginerie Mecanică și Mecatronică, București, 2017.

[2] G. Oprina, I. Pincovschi, Ghe. Băran, *„Hidro-Gazo-Dinamica Sistemelor de aerare echipate cu generatoare de bule”,* Ed. POLITEHNICA PRES, București, 2009.

[3] H. Chansonn, *„Air – Water Interface Area in Self – Aerated Flows”*, Water Res, IAWPRC, Vol. 28, No. 4, pp. 923 – 929 (ISSN 0043 – 1354).

[4] G. Mateescu, *„Hidro-gazodinamica generatoarelor de bule fine”*, Teză de doctorat Facultatea de Inginerie Mecanică şi Mecatronică, Universitatea POLITEHNICA din Bucureşti, 2011.

[5] I. Gavrilaş, N. I. Marinescu, *„Prelucrări neconvenţionale în construcţia de maşini”*, Editura Tehnică, Bucureşti, 1991.

[6] A. Nanu, *„Tehnologia materialelor”*, Editura Didactica şi Pedagogică Bucureşti 1977.

[7] *** www.cefain.ro/difuzoare_cu_membrana-epdm.ro

[8] Al. Dobrovicescu, N.Băran, şi col., Colecţia „Bazele Termodinamicii tehnice”, vol. I *Elemente de termo-dinamică tehnică*, Editura POLITEHNICA PRESS, Bucureşti, 2009.

[9] Al. S. Pătulea, *„Influenţa parametrilor funcţionali şi a arhitecturii generatoarelor de bule fine asupra eficienţei instalaţiilor de aerare”,* Teză de doctorat, Universitatea Politehnica din Bucureşti, 2012.

[10] G. Oprina, *„Contribuţii la hidro-gazodinamica difuzoa-relor poroase”*, Teză de doctorat Universitatea POLITEHNICA din Bucureşti, Facultatea de Energetică, Bucureşti, 2007.