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Reduction of energy consumption in water aeration plants

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Abstract

The paper presents two constructive solutions for fine bubbles generators (FBG).
Version I: FBG equipped with porous diffusers
Version II: FBG with plates that have nozzle processed by electro erosion. For both versions, the pressure losses and the energy consumption that occurs in waters aeration process (oxygenation) are specified. The advantages of tanks aeration with fine bubble generators, in version II, are highlighted.

Keywords: *Water aeration, Fine bubble generators, Energy consumption, Pressure losses.*

1. Introduction

The oxygen transfer towards water that occurs in aquariums and fish farms, as well as in used waters, represents an important problem in the implementation of aeration technologies. If fine bubble aeration [1] is used, important energy savings are obtained, of 20 ÷ 50 % of the energy needed for aeration [2]. The energy consumption can be decreased by using fine bubble generators (FBG) with small pressure losses; in the same time, the efficiency of the oxygen transfer towards water has to be high and the compressed air consumption has to be reduced.

Air pressure at the fine bubble generator input is a very important parameter used in the selection and monitoring of fine bubble generators, independently of their shape or material from which they are manufactured. Its monitoring is needed during the functioning of the aeration plant because it indicates if the fine bubble generator is working correctly by the fact that each choking of the FBG nozzles automatically leads to an increase of the air pressure at the input.

The nozzle dimensions are highly important parameters that characterize a FBG, because they directly influence its working pressure. The working pressure of a FBG is in fact the air pressure found under the nozzle plate.

The first part of the paper presents the results of the experimental research on porous diffusers.

Subsequently the design and the construction of a new type of fine air bubble generator are exposed; to this FBG the air nozzles are made by electro erosion. This fine bubble generator creates a very low pressure loss; generates an energy saving in air compressing stations, necessary to tanks aeration.

In the end of the paper the results of the experimental research on this new type of fine bubble generator are presented.

2. Fine bubble generators where the porous plate is manufactured from ceramic materials

The shape of porous diffusers can be circular, rectangular etc.; the diameter of circular diffusers can be of Ø50, Ø100 or Ø150 [2]. The manufacturing process can lead to various porosity values, the pore diameter being in the range of 4 ÷ 500μm. Figure 1 presents a photograph of an Ø150 mm porous diffuser.

Fig. 1 Aspect of Ø150 ceramic porous diffusers.

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For this type of FBG, the pressure losses remain high enough compared to the values specified in the technical documentation provided by renowned manufacturers DIFFUSER EXPRESS [4], TRAILLGAZ [5].
Figure 2 presents the variation of the pressure loss (Δp) in the case of an Ø150 FBG in function of the flow rate of the air that passes through the FBG.
Three different lots of ceramic porous diffusers with different volumetric porosity were tested [2] – fig. 2.

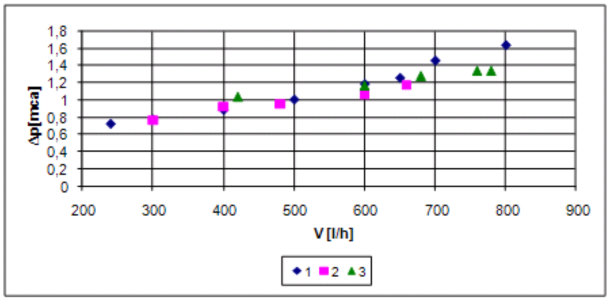

Fig. 2 Variation of pressure loss in function of the air flow

It can be noticed from figure 2 that a pressure loss of $1.0 \div 1.2$ mH_2O occurs for $\dot{V} = 600\ \ dm^3/h$.
The medium value of the pressure loss is of $\Delta p_I = 1.1\ mH_2O = 1100\ mmH_2O = 11213\ N/m^2$. This pressure loss refers specifically to the FBG and does not include the losses in the compressed air supply network.

3. Fine bubble generators where the porous plate is built from metal plates perforated by electro erosion

A high performance FBG must have a pressure loss as reduced as possible and to emit bubbles uniformly on its whole surface [6] [7].
Figure 3 presents a new type of FBG where the porous plate is built from an aluminum plate with Ø0.5 mm nozzles manufactured by spark erosion. The nozzles size establishes the size of the gas bubble [8].

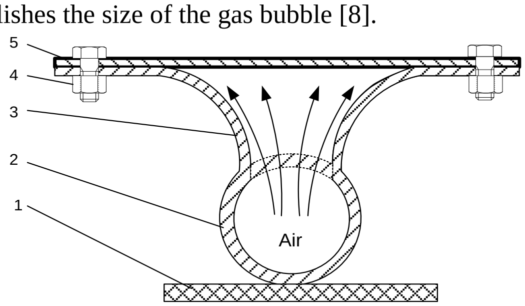

Fig. 3 Section through a rectangular shape FBG
1- holder; 2- compressed air supply pipe; 3 – FBG body; 4 – screw for fastening the plate to the body; 5- nozzle plate

This type of FBG was put to tests using an experimental plant built in the laboratories of POLITEHNICA University of Bucharest. Other types of FBG with nozzles manufactured by electro erosion are presented in [9] [10].
Figure 4 presents the principle scheme of the plant used for water oxygenation.

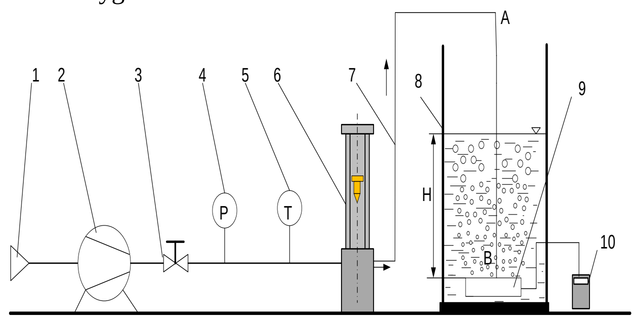

Fig. 4 The scheme of the experimental plant
1-air filter; 2-electrocompressor with compressed air tank; 3-pressure reducer; 4-manometer; 5-thermometer; 6-rotameter; 7-pipe for supplying the FBG with compressed air; 8-water tank; 9-FBG; 10- numeric display manometer.

During dynamic conditions, air flows through the A-B pipe (fig.4), inflows the FBG body and enters through the nozzles in the water from the tank. The air pressure (p_1) at the input of the FBG body has to surmount hydrostatic load, surface tension and pressure losses (Δp_{II}):

$$p_1 = \rho_{H_2O} \cdot g \cdot H + \frac{2\sigma}{r_0} + \Delta p_{II}\ \ [N/m^2] \qquad (1)$$

If p_1 is known, using this relation one can find the value of Δp_{II}:

$$\Delta p_{II} = p_1 - \rho_{H_2O} \cdot g \cdot H + \frac{2\sigma}{r_0}\ [N/m^2] \qquad (2)$$

Experimental measurements led to the following data:

$$p_1 = 583.44\ \ mmH_2O = 5723.5\ \ N/m^2$$

H-height of the water layer above the FBG; H=0.5 m.
r_o –inner radius of a nozzle; $r_o = 0.25 \cdot 10^{-3}$m;
σ-surface tension coefficient of water; $\sigma = 73 \cdot 10^{-3}$ N/m
By replacing in (1), one obtains:

$$\Delta p_{II} = 5723.5 - 1000 \cdot 9.81 \cdot 0.5 - \frac{2 \cdot 73 \cdot 10^{-3}}{0.25 \cdot 10^{-3}} = 244.35\ \ N/m^2 \qquad (3)$$

This value is lower than the one from the version I ($\Delta p_I > \Delta p_{II}$).
Between the two versions there is a difference:

$$\Delta p = \Delta p_I - \Delta p_{II} = 11213 - 244.35 = 10968.65\ N/m^2 \qquad (4)$$

The energy consumed in an aeration process (E) is computed using the following relation [2]:

$$E = \dot{V} \cdot \Delta p \cdot \tau\ \ [J] \qquad (5)$$

where:
$\dot{V}$ - volumetric air flow rate [m^3/s];
Δp - pressure loss [N/m^2];
τ- working time of the plant [s].

$$\Delta E = 600 \cdot 10^{-3} \cdot 10968.65 \cdot 1 = 6581.19 \ J$$

During one year, with the functioning of a single GBF is obtained annual energy savings:

$$\Delta E = \frac{6581.19 \cdot 24 \cdot 365}{3.6 \cdot 10^{6}} = 16.114 \ kWh / year$$

Obviously in wastewater treatment plants, the number of F.B.G. is in the range of thousands, so there is a significant energy saving.

4. Conclusions

1. The use of porous diffusers has the following disadvantages:
- Emitted air bubbles have uneven diameters;
- Air bubbles appear irregularly, only on certain parts of porous diffusers surface;
- The porous diffusers have significant pressure losses.

2. The use of FBG with plates perforated by spark erosion has the following advantages:
- A uniform distribution of the nozzles on the plate surface, according to the designer's specifications, is assured;
- Nozzle diameters being equal, air bubbles with the same shape and diameter are emitted; it is possible to control the air flow;
- There is no risk of choking the perforated plate;
- Due to small pressure losses, a significant economy of energy $\Delta E = 16.114 \ kWh / an$ for each functioning FBG appears.

3. The constructive solution of fine bubble generator presented in this paper provides both the formation of fine air bubbles (diameter 0.5 mm) and their uniform dispersion in water.

4. Fine bubble generators with nozzles performed through electro erosion has a much lower pressure loss compared with porous diffusers.

5. A low pressure loss leads to an electricity economy for operating the air compressors.

6. The energy consumption needed for aeration represents about 67% from the total consumption of a cleaning plant. This high percentage explains the scientific researches regarding the obtaining of FBGs with reduced pressure losses.

7. The development of water oxygenation using FBGs with plates perforated by spark erosion helps energy saving and efficient protection of environment.

8. Considering the above, the Romanian researchers propose to replace the porous diffusers in water aeration tanks with fine bubbles generators to which, the nozzles plate is obtained by electro erosion.

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