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Experimental researches concerning the stability of the bubbles columns generated by porous diffusers

by

Gabriela OPRINA[*], B.D. OLTEANU[**], R.S. LIS[***]

[*] Phd. Student, Eng., Politehnica University of Bucharest, Hydraulics and Hydraulic Machinery Department
****** Student, Politehnica University of Bucharest, Hydraulics and Hydraulic Machinery Department
******* Student, Politehnica University of Bucharest, Hydraulics and Hydraulic Machinery Department

Abstract

Was experimentally determined that, from certain gas flow rates, the bubble column emitted by porous diffusers begins to describe a helical movement is breaking up having the appearance of a fir. The gas flow rates corresponding to this phenomenon are determined.

Introduction

To intensify the mass transfer between free air and liquids is utilized the injection of the air through porous diffusers. The diffusers are made from porous ceramic materials, small orifices plastics and have different shapes [1]. Theirs utilization in biological treatment tanks is made either paving the bottom of tanks, either arranging in rows, at determinate distances. This fact and the different shapes of diffusers shows that hydro-gas-dynamic problems associated to diffusers production and operation were not totally solved. During the laboratory researches established that, beginning with a determinate air flow Q_s, the bubble column emitted by porous diffusers do not conserve its shape [2]:

- for $Q > Q_s$ the axis of column describes an helicoidally movement;
- for Q □ Q_s the column divides into fragments, having the appearance of a fir.

1. Generation regimes of the bubbles

The generation regimes of the bubbles differentiate through a stability air flow rate Q_s which is calculated with the relation (1), established for water/air operating fluids and an $r = 0.1 \div 2$ mm radius capillary tubes [3]

$$Q_s = \pi \left(\frac{16}{3g^2} \right)^{1/6} \left(\frac{\sigma r}{\rho_g} \right)^{5/6}, \qquad (1)$$

where s is the factor of gas-liquid surface tension, ?$_g$ – air density, g – gravity.
For water/air with ? = 1000 kg/m^3, s = $8\cdot10^{-3}$ N/m, it obtains

$$Q_s = 0,2364 \cdot 10^{-5} r^{5/6} \text{ m}^3/\text{s} = 8,511 r^{5/6} \text{ l/h}.$$

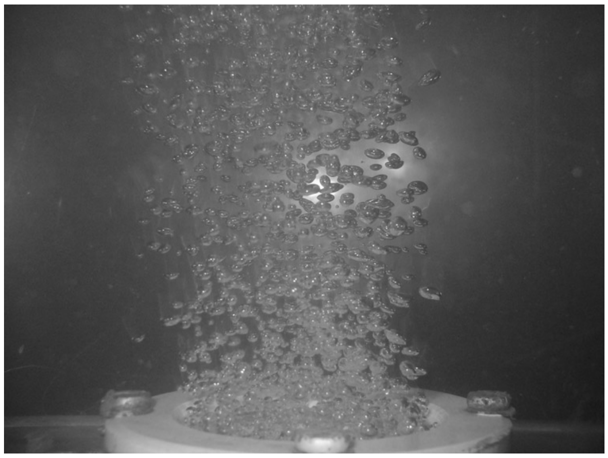
Quasi-static regime

This regime is obtained for $Q < Q_s$ air flow rates and the formed bubbles are isolated and have a uniform size (fig. 1).

Fig.1, *Bubbles emission aspect in quasi-static regime for a ceramic porous diffuser F = 50 mm*

(Q = 60 l/h < Q_s)

Dynamic regime ($Q = Q_s$)

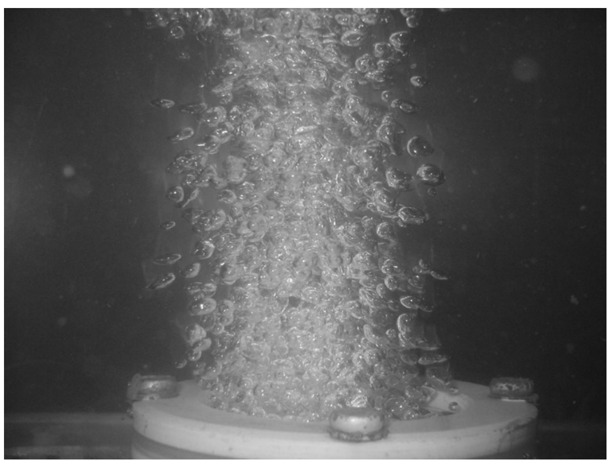


In this regime also intervenes the inertia of mass force; it forms cluster of bubbles (bubbles coalescence take place).

Fig.2, *Bubbles emission aspect in dynamic regime for a ceramic porous diffuser F = 50 mm*

(Q = 180 l/h ˜ Q_s)

Turbulent regime ($Q >> Q_s$)



This regime is characterized by a great bubble density in the column section which does not favour the bubbles coalescence. The force of friction and dynamic head force are considered; at the increase of the air flow rate, the bubbles volume increase significantly towards the others regimes (fig.3).

Fig.3, *Bubbles emission aspect in turbulent regime for a ceramic porous diffuser F = 50 mm*

(Q = 350 l/h Q_{cr})

The stability of the bubbles column

The experimental researches pursued the stability of the bubbles column for three dimensions of ceramic disc diffusers, term of the gas flow rate. The gas flow rate for operating in optimum conditions is given by the specific flow rate q which is obtained by the ratio of the air flow rate Q to the emission area of the diffusers, generally expressed in cm^2. The specific flow rate is recommended to be between 1 and 7 l/h·cm^2.

In the experimental researches were tested porous diffusers having the following emission diameters: F 50, F 100 and F 150. It established the stability air flow rate as follows:

- Q_s = 160 ÷ 180 l/h for ceramic diffusers F 50 mm;
- Q_s = 500 ÷ 680 l/h for ceramic diffusers F 100 mm;
- Q_s = 400 ÷ 500 l/h for ceramic diffusers F 150 mm.

Table 1, The specific air flow rate for diffusers operation

Diffuser type	Diameter [mm]	Area [cm^2]	q [l/h·cm^2]
ceramic	50	19.625	8.15 ÷ 9.17
	100	78.5	6.36 ÷ 8.66
	150	176.625	2.26 ÷ 2.83

The tested diffusers operate in a normal regime, with a stable bubbles column, even for specific air flow rate values greater than the ones recommended by literature.
The stability specific air flow rate q_s is obtained by the ratio of the stability air flow rate Q_s to the emission area of the diffusers. The diagram below shows the dependence $q_s - Q$.

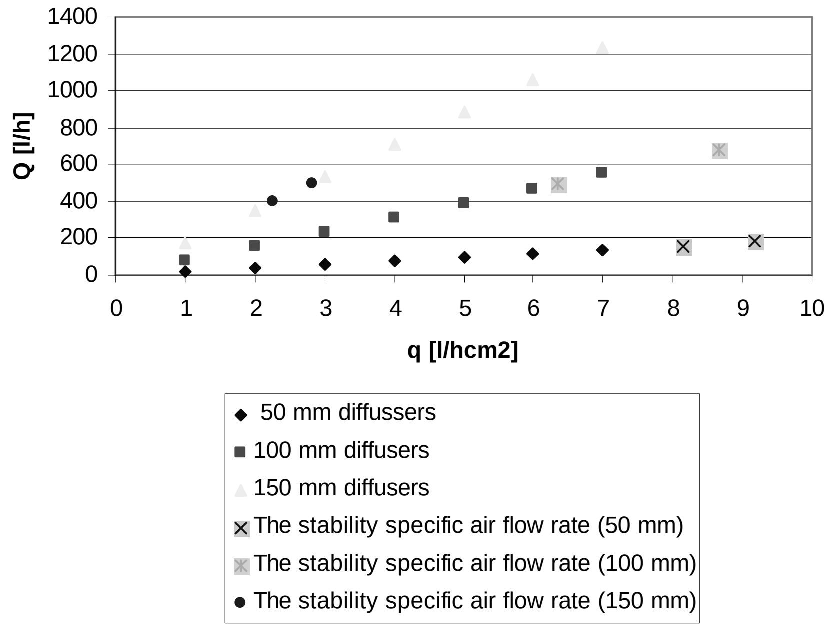
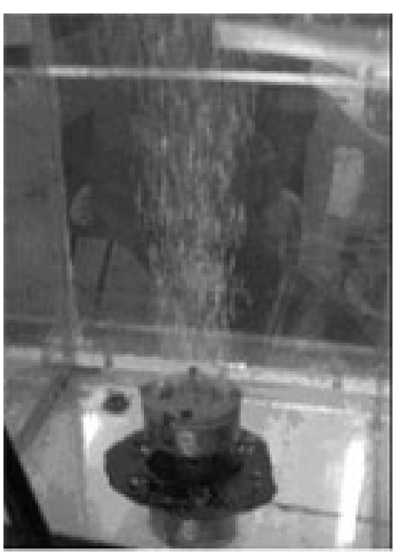


Fig. 4, *The stability specific air flow rates for the tested porous diffusers*

The measurements were realized in a rectangular plexi basin with H = 1 m – the immergence depth. The stability of the bubbles column was analyzed beginning with small air flow rates. It was determined the evolution of the gas bubbles column function of the injection air flow rate.



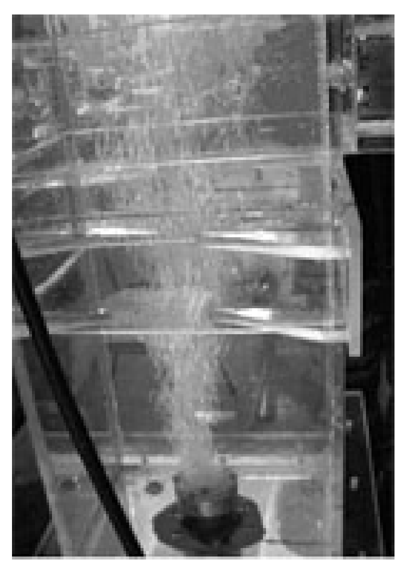
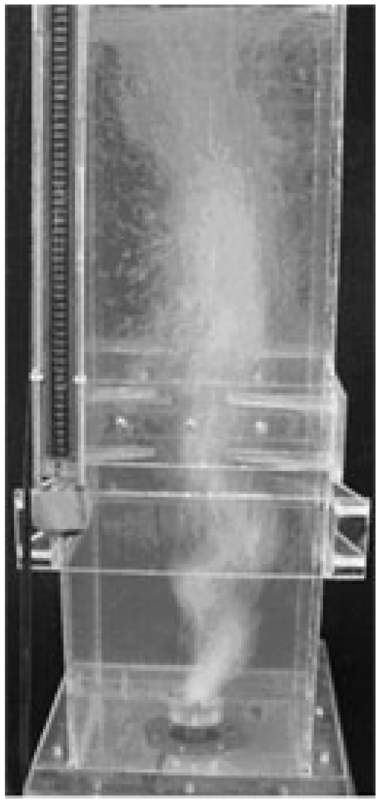


Fig. 5, *The bubbles column aspect at Q* = 60 l/h   Fig. 6, *The bubbles column aspect at Q* = 200 l/h

In figure 5 can be observed that the bubbles column is stable.
When the gas flow rate reaches about 180 l/h, the transient regime installs. In this regime, from time to time, the bubbles column has determinate deviations (non-periodical), in random directions and heights (fig. 6). From gas flow rates which exceeds 250 l/h, the bubbles column gets a strong helicoidally movement (fig. 7). At grater gas flow rates, often produces detachments (breaking) of the bubbles column, similar to a fir aspect (fig. 8). At gas flow rates which exceed 400 l/h, the bubbles column bows, touching alternatively the basin’s walls.



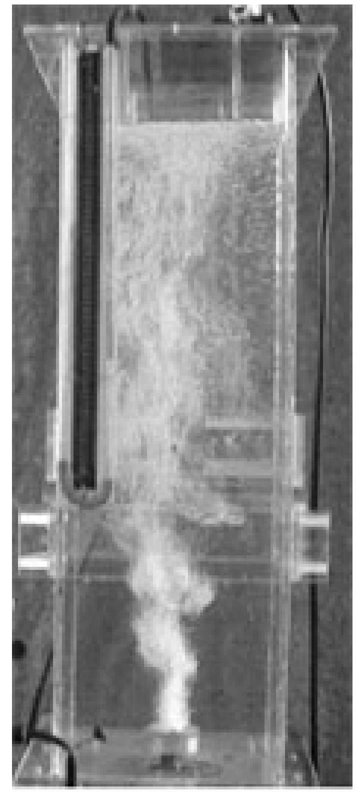


Fig. 7, *The bubbles column aspect at Q*=400 l/h   Fig. 8, *The bubbles column aspect at Q*=450 l/h

Conclusions

The efficient operation of the porous diffusers is limited by the maximum stability gas flow rate [4]. The maximum stability gas flow rate determines the diffusers assembling in industrial plants, eliminating the interaction between adjacent columns [5]; through the inducted gas lift effect it assures the liquid recirculation.

The maximum stability gas flow rate is in a direct connection with the oxygenation process efficiency. The laboratory tests made on a ceramic diffuser F 50 mm showed the aeration efficiency is maxim for values of approximately 150 l/h; for $Q > Q_s$ the process efficiency decreases. The aeration systems using porous diffusers minimize the energy costs obtaining a maxim oxygenation with small air flow rates.

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