ISSN 1454 - 8003
Proceedings of 2019 International Conference on Hydraulics and Pneumatics - HERVEX
November 13-15, Băile Govora, Romania

RESEARCHES REGARDING THE DESIGN AND CONSTRUCTION OF AIR DISPERSION DEVICES IN THE TRANSPORTED WATER THROUGH PIPES

Octavian DONȚU[1], Rasha CUSMA[1], Constantin Remus VOICU[1], Iulian Alexandru GRIGORE[1], Francesca ȘELEA[1], Nicolae BĂRAN[1], Mihaela PETROȘEL[1], Titu-Cătălin CIOIENARU[1]

[1] University Politehnica of Bucharest, Faculty of Mechanical and Mechatronic Engineering, remus.voicu@yahoo.com

Abstract: *The research paper presents three devices for the dispersion of the air into the water:*
1) Device realized with the help of a 3D printer;
2) Device based on the construction of „ARHIMEDE's" spiral, which has 18 holes for the dispersion of the air in the transversal section of the tube;
3) Device which places a number of 17 holes generated by syringe needles into the transversal section. Each device (needle) that disperses the air into the wastewater transported inside of the tube, has the purpose to increase the concentration of the dissolved oxygen into the water.

Keywords: *Wastewater treatment, dissolved oxygen into the water.*

1. Introduction

Water aeration represents a process of mass transfer of the oxygen from the atmospheric air to a volume of water; resulting in an increase of the concentration of the dissolved oxygen into the water.
The water aeration systems constitute a certain energy consumption; which through the usage of modern technology construction of these systems it can obtain a reduction of energy consumption.
In the research papers [1], [2], [3] it shows the fact that pneumatic aeration is far more superior to the mechanical aeration systems.
The most developed aeration systems are the ones that produce fine air bubbles [4], [5] in which the aeration of the wastewaters is done through the introduction of compressed air into the water pipes used to transport the wastewaters.
Through this constructive solution, the aeration tanks filled with hundreds of m^3 are eliminated, thus the investment is reduced and a cost saving is made from the operating costs of the wastewaters treatment.
In stagnant systems, the transfer of one molecular species in the interior of the system is realized through a process of mass transfer which is called molecular diffusion.
In the case where we have a displacement of the fluid which contains a certain component the result is a convective diffusion.
The component is transferred due to the difference in concentration; the flow rate of the fluid is determined by the intensity of the mass transfer [6].
In table 1, mass transfer in specialty technic is presented.

Table 1: Classification of the diffusion processes

The environment in which the process takes place	The nature of the flow	Flow regime	Nature of the diffusion phenomenon
A-Stagnant Fluid ($w = 0$)	-	-	Molecular diffusion
B-Fluid in motion ($w > 0$)	B1-free movement	-	Natural convective diffusion (Natural mass convection)
	B2-forced movement	Laminar flow	Forced convective diffusion (Forced mass convection)
		Turbulent flow regime	Forced convective diffusion (Forced mass convection)

2. Flow spectrum and the establishment of the flow regime of the biphasic fluid (air + water)

The structure of the biphasic flow regime, respectively how the geometric form and the phases are arranged is important for the thermodynamic interplay between the two phases

- Liquid phase: water;
- Gaseous phase: air.

The biphasic flow can take place in horizontal and vertical pipes.
In horizontal pipes case, a stratified flow can occur due to the difference in density $\rho_{apă} > \rho_{aer}$ (figure 1.a).
In vertical pipes case, the air bubbles are dispersed in the liquid mass (figure 1.b).

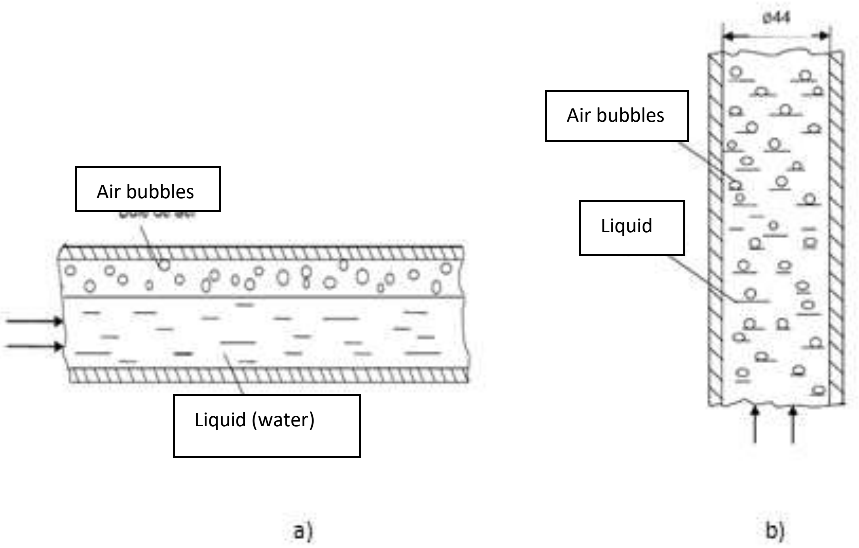

Fig. 1. Biphasic flow spectrum in horizontal (a) and vertical (b) pipes

Establishment of the flow regime of the biphasic mixture (water + air) is done as follows: the water volume that needs to be aerated in half is $0.125\ m^3$.

This volume will be pumped through a pipe of $\emptyset 50 \times 3$, as a result, the water flow (V) and the speed of the water (w) in the pipe will be [7], [8]:

$$\dot{V} = \frac{V}{\tau} = \frac{0,125}{2 \cdot 3600} = 0.01736 \cdot 10^{-3}\ m^3/s \tag{1}$$

$$\dot{V} = A \cdot w = \pi \cdot \frac{d^2}{4} \cdot w = 0.01736 \cdot 10^{-3}\ m^3/s \tag{2}$$

$$w = \frac{\dot{V}}{0.785 \cdot d^2} = \frac{0.01736 \cdot 10^{-3}}{0.785 \cdot (0.044)^2} = 0.0114\ m^3/s \tag{3}$$

For water at 20℃ cinematic viscosity:

$$\nu = 1 \cdot 10^{-6}\, m^2/s \tag{4}$$

$$R_e = \frac{w \cdot d}{\nu} = \frac{0.0114 \cdot 0.044}{1 \cdot 10^{-6}} = 501.6 \tag{5}$$

The flow regime for the water is ($R_e < 2320$), a laminar flow.
The air flow introduced into the water [9], [10]:

$$\dot{V} = \frac{0,6}{3600} = 0.0001666\ m^3/s \tag{6}$$

The low result value does not modify the flow regime established before.

3. Construction of the air dispersion device into the water with the help of a 3D printer

The pipe $\emptyset 50 \times 3$ has an inner diameter of 44mm; three circles with the diameters of 11mm, 22mm and 33mm are chosen, so that the holes created on the circles will assure an equal distribution of the air in the pipe.

The length of the circles will be:

$$\begin{aligned} L_1 &= \pi \cdot d_1 = \pi \cdot 11 = 34.56\, mm \\ L_2 &= \pi \cdot d_2 = \pi \cdot 22 = 69.12\, mm \\ L_3 &= \pi \cdot d_3 = \pi \cdot 33 = 103.67\, mm \end{aligned} \tag{7}$$

Total length $L_t = 207.35\, mm$.

A number of 17 holes will be placed at a distance of l equal to:

$$l = \frac{L_t}{n} = \frac{207.35}{17} = 12.19\, mm \tag{8}$$

On the first circle (figure 2) a number of holes will be determined:

$$n_1 = \frac{34.56}{12.19} = 2.8 \cong 3\ holes \tag{9}$$

The number of holes is determined for the second and third circle:

$$n_2 = \frac{69.12}{12.19} = 5.6 \cong 6\ holes \tag{10}$$

$$n_3 = \frac{103.67}{12.19} = 8.5 \cong 8\ holes \tag{11}$$

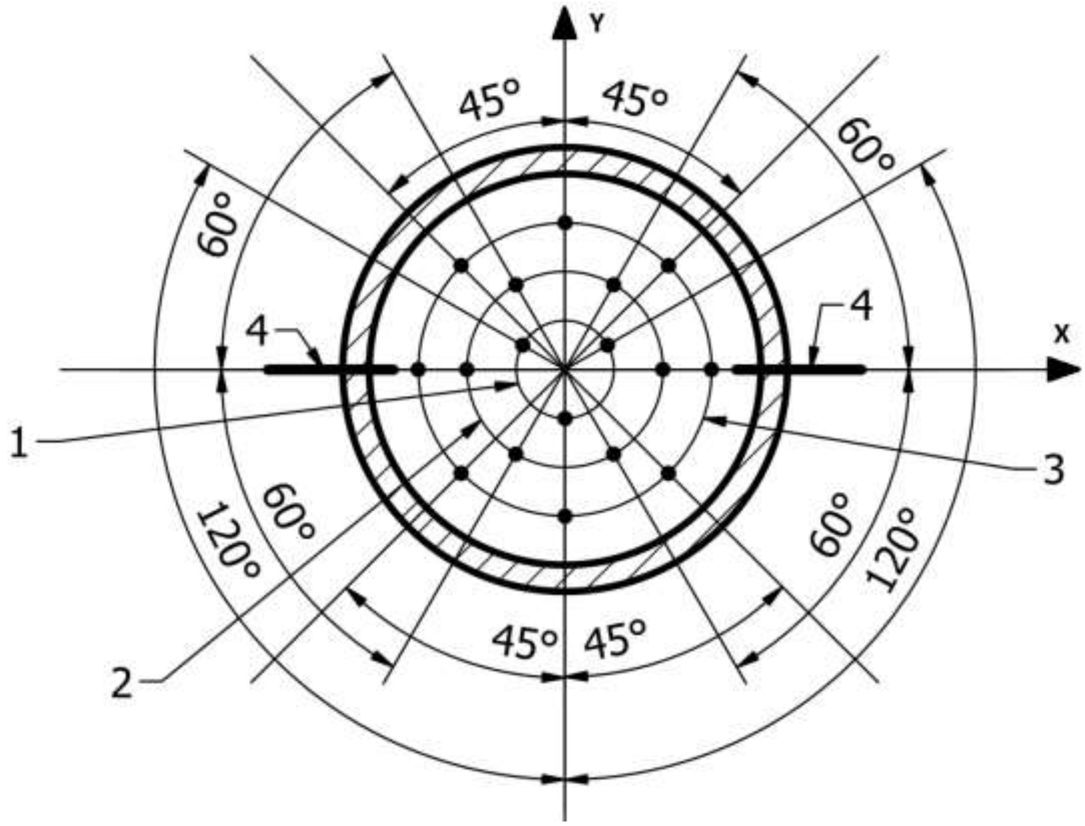

Fig. 2. The location of the three circles inside the pipe with $\emptyset 50 \times 3\ mm$
1-circle with Ø $11\ mm$;2-circle with Ø 22 mm;3-circle with Ø 33 mm;4-coupling for compressed air.

On the first circle (1) 3 holes of Ø $0.3\ mm$ are located at 120°; on the second cirle (2) 6 holes of Ø $0.3\ mm$ are located at 60°; on the third circle (3) 8 holes of Ø $0.3\ mm$ are located at 45°.
An uniform distribution of the air in the transversal section of the pipe is acquired by having an equal distance between the circles equal to 5mm. [11], [12].
The compressed air is introduced in through the air coupling 4 in the circle 3 and then in the circle 2 and 1 (figure 3).

Fig. 3. Compressed air dispersion device build on the 3D printer

The circles were materialized through Ø $3\ mm$ pipes build on a 3D printer.

4. Construction of a device based on the construction of Spiral of Archimedes

The spiral is provided with 17 holes of $\emptyset\, 0.3\, mm$ located at an equal distance along the spiral (figure 4).

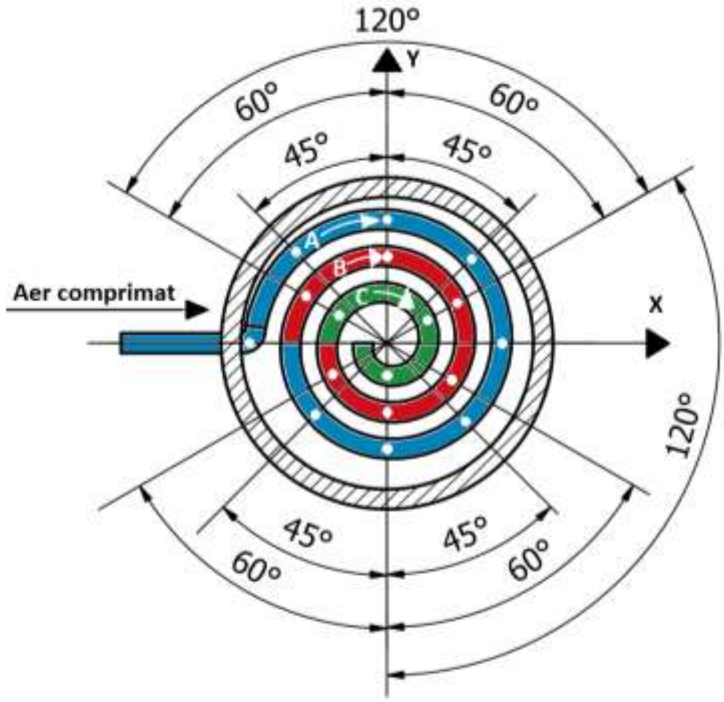

Fig. 4. Location of the 17 holes on the coper pipe $\emptyset\, 3 \times 1$ spiral

- on the first section of the spiral (green color) 3 holes at 120˚ are located [13];
- on the second section (red color) 6 holes at 60˚ are located;
- on the last section of the spiral (blue color) 8 holes at 45˚ are located.

The compressed air follows the ABC path. At a scale of 1:1 the spiral can be seen in figure 5.

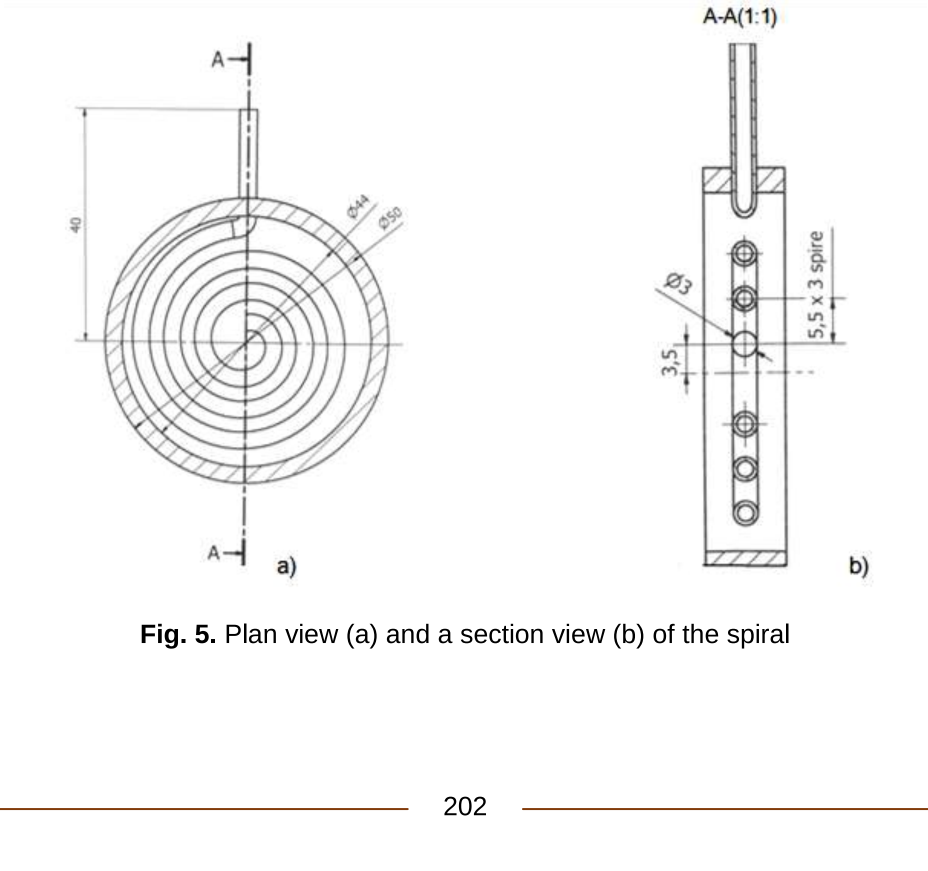

Fig. 5. Plan view (a) and a section view (b) of the spiral

An axonometric view of the spiral can be seen in figure 6.

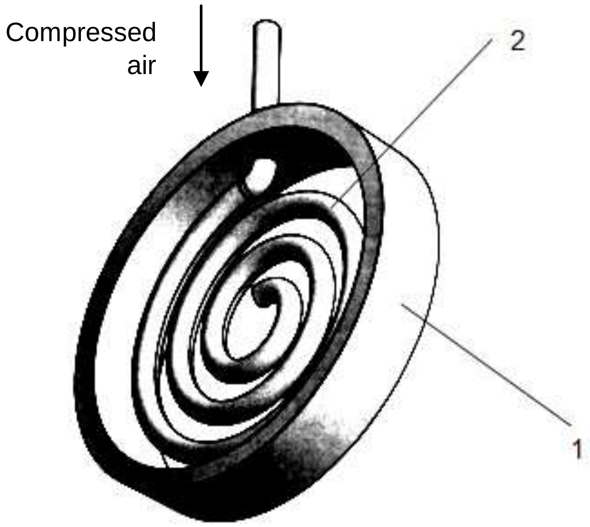

Fig. 6. Axonometric view of the spiral
1-pipe $\emptyset 50 \times 3$; 2-pipe spiral $\emptyset\ 3 \times 1$.

The water flows in the interior of the pipe through the spaces between the constructive elements of the spiral; the compressed air gets out of the holes of the spiral and flows in same direction as the water flow does.

5. Construction of a device where 17 syringe needles $\emptyset\ \mathbf{0.25}\ \boldsymbol{mm}$ are located in the pipe's section

In the 7th figure it can be observed that the compressed air from the tank (1) is assigned to the 17 syringe needles that generate holes where the air is introduced into the water; the air jets generate a movement into the water that creates meaningful turbulence [14].

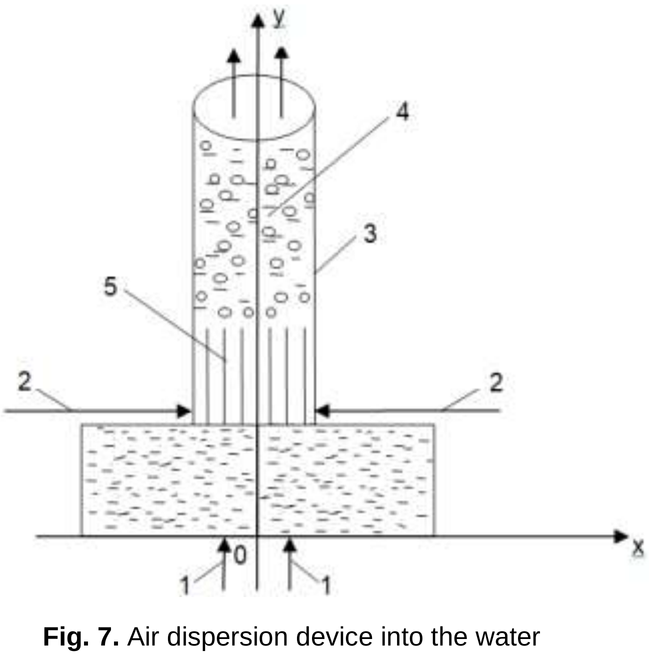

Fig. 7. Air dispersion device into the water

1-coupling for compressed air; 2-water inlet; 3-pipe $\emptyset 50 \times 3$; 4-biphasic mixture (air+water); 5-syringe needles with $\emptyset\ 0.25\ mm$.

The air gets in the tank through the inlet couplings (1), then in the syringe needles and flows in the same direction with the water flow in vertical direction.

6. Conclusion

All three devices assure the immersion into the water of fine air bubbles which in fact can be translated as transfer of the oxygen into the water.
The devices can be mounted on vertical pipes as well as on horizontal pipes.
In the experimental researches that will be presented in a future paper the following points will be taken into account:

- Measurement of the concentration of dissolved oxygen into the water at different lengths along the pipe
- Air flow or water flow's influence on the variation of the concentration of dissolved oxygen into the water

Acknowledgements

This work was supported by a grant of the Romanian National Authority for Scientific Research and Innovation, CCDI – UEFISCDI, project number Manunet – MNETI/ENER2307-CEBIOTREAT within PNCDI.

References

[1] Oprina, Gariela. "Hydro-gas-dynamic contributions of porous diffusers." PhD thesis, University Politehnica of Bucharest, 2007.
[2] Mateescu, Gabrilea Maria. "Hydro-gas-dynamic of fine bubbles." PhD thesis, University Politehnica of Bucharest, 2011.
[3] Law, C.N.S., and B.C. Khoo."Transport across a turbulent air-water interface." *AICHE Journal* 48, no. 9 (2002): 1856-1868.
[4] Băran, Nicolae, Mihaela Călușaru, and Gabriela Mateescu. "Influence of the architecture of fine bubble generators on the variation of the concentration of oxygen dissolved in water." *Scientific Bulletin of University Politehnica of Bucharest*, *D series, Mechanical engineering* 75, no. 3 (2013): 225-236.
[5] Tănase, Betrice Elena. "Influența compoziției gazului insuflat în apă asupra conținutului de oxigen dizolvat." PhD thesis, University Politehnica of Bucharest, 2017.
[6] Marinescu, Mircea, et al. *Mass and Heat Transfer*. Bucharest, Politehnica Press, 2000.
[7] Dobrovicescu Alexandru, Nicolae Băran et al. *Elements of Technic Thermodynamic*. Bucharest, Politehnica Press, 2009.
[8] Isbășoiu, Gh. C.E. *Fluid mechanics treaty*. Bucharest, AGIR Publishing House, 2011.
[9] Rasha (Cusma), Mlisan. "Influence of the fine bubble generators architecture on the concentration's growth of dissolved oxygen into the water." PhD thesis, University Politehnica of Bucharest.
[10] Vlăsceanu (Banu), Mihaela, Dan Robescu, and Mihaela Călușaru (Constantin). "Theoretical and experimental research concerning the modification of dissolved oxygen concentration in aeration tanks equipped with surface aerators." *Scientific Bulletin of University Politehnica of Bucharest, D series, Mechanical Engineering* 77, no. 1 (2015): 177-184.
[11] Chansonn, Hubert. "Air-Water Interface Area in Self-Aerated Flows." *Water Res*. 28, no.4 (April 1994): 923-929.
[12] Pătulea, Alexandru. "Influence of the functional parameters and the fine bubble generators architecture on the efficiency of aeration installations.",PhD thesis, University Politehnica of Bucharest, 2012.
[13] Radu, Constantin. *Linear algebra, Analytic and differential geometry*. Bucharest, Fair Partners Publishing House, 2008.
[14] Albu, Nicoleta, Nicolae Băran, Mihaela Petroșel, Daniel Besnea, and Mihaela Constantin. "Research Regarding the Execution of a Flat Jet Generator used for Water Aeration." *Hidraulica,* no. 2 (June 2019): 23-28.