

Design and Construction of an Installation for Testing Bubble Generators Used for Water Aeration

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ABSTRACT

The paper presents an installation comprising four fine bubble generators each with a circular perforated plate with \varnothing 0.2 mm orifices. There is a water tank inside the installation in which compressed air is introduced. The installation is designed so as to ensure the monitoring of the following parameters: 1 - The size of the air bubbles; 2 - The appearance of bubble coalescence; 3 - Increasing the dissolved oxygen concentration in water; 4 - The amount of pressure loss that occurs when air passes through the bubble generator; 5 - The efficiency of the aeration process; 6 - Efficacy of the aeration process; 7 - Air consumption; 8 - Electricity consumption; 9 - Air temperature; 10 - Water temperature; 11 - Compressed air pressure; 12 - Hydrostatic load (H).

Keywords: Bubble generator, Water aeration, Oxygen dissolved in water.

1. Introduction

Water aeration systems are highly efficient if the dispersion of air into water is carried out in a controlled and uniform manner. The use of fine bubble generators ensures this and, in addition, creates a small pressure loss as air passes through it.

Water aeration can be done in three ways [1], [2] namely:

-by *mechanical aeration*;

-by *pneumatic aeration*;

-by *mixed aeration*.

Pneumatic aeration is more efficient and consists of introducing pressurized air bubbles into the aeration tank.

According to the way the air bubbles are obtained, the aeration installations are classified as follows [3], [4]:

- *Aeration installations with porous diffusers made of ceramic elements or elastic membranes*;

- *Aeration installations made of pipes provided with orifices; these pipes are mounted on the radiator of the water tank*;

- *Aeration systems with fine bubble generators*.

Fine bubbles are bubbles created by orifices with $\varnothing < 1\text{mm}$. Currently, fine bubble generators (FBG) are made in the form of glass, ceramic, etc. diffusers. These diffusers have the disadvantages [5]:

- *does not provide bubbles of equal diameter*;

- does not provide fine bubbles on the entire surface of the diffuser;
- pressure losses when air passes through it are large;

To eliminate these disadvantages, a team of researchers from the department of Thermotechnics, Engines, Thermal and Refrigeration Equipment's researched [6], [7]:

- the construction of FBGs by using a laser;
- the construction of FBGs by EDM;
- the construction of FBGs by micro-drilling with special work machines.

Thus, the following types of FBG were performed [8]:

- FBG with 0.5 mm orifices, the orifices plate being made of aluminum;
- FBG with 0.3 mm orifices, the orifices plate being made of transparent plexiglass;
- FBG with 0.1 mm orifices, the orifices plate being made of aluminum.

2. Experimental Bubble Generator Test Installation

The experimental installation was conceived, designed and constructed so as to allow the testing of several types of fine bubble generators (FBG).

Figure 1 shows two fine bubble generators (9) located on the radius of the water tank (8).

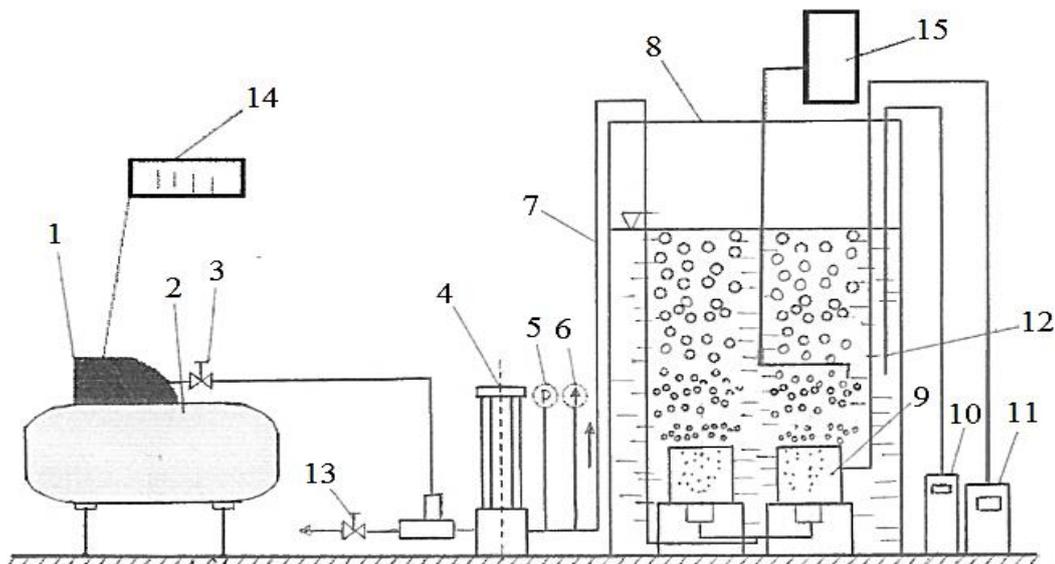


FIG 1: THE SCHEME OF THE EXPERIMENTAL INSTALLATION FOR TESTING FINE BUBBLE GENERATORS

1-air compressor; 2- compressed air tank; 3-pressure reducer; 4-rotameter; 5-manometer; 6-thermometer; 7-compressed air pipe for feeding fine bubble generators; 8-water tank with transparent plexiglass walls; 9-fine bubble generator; 10-electronic thermometer; 11-manometer with digital indication; 12- electronic thermometer probe; 13-valve for evacuating excess air from the pneumatic circuit; 14-electricity meter; 15- oxygenometer.

The main element of the fine bubble generator is the plate (figure 2) which ensures the uniform dispersion of the compressed air in a certain volume of stationary water.

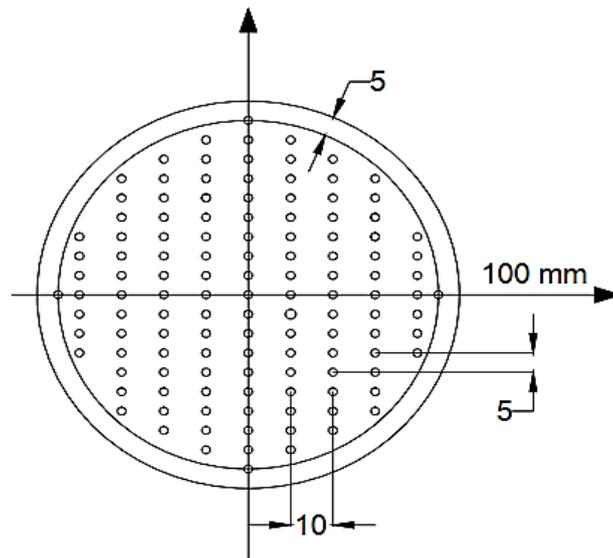


FIG 2: THE CONSTRUCTION SCHEME OF THE FINE BUBBLE GENERATOR PLATE

The perforated plate contains 129 orifices \varnothing 0.2 mm; a metal ring is fixed on the surface of $\pi R^2 = \pi \cdot \left(\frac{100-10}{2}\right)^2 = 6358,5 \text{ mm}^2$ which allows the plate to be changed, i.e. its replacement with another plate with other orifices diameter.

Figure 3 shows the structure of the fine bubble generator (FBG); it comprises a base plate on which four cylinders of transparent plexiglass are fixed. Each cylinder is closed by the orifice plate.

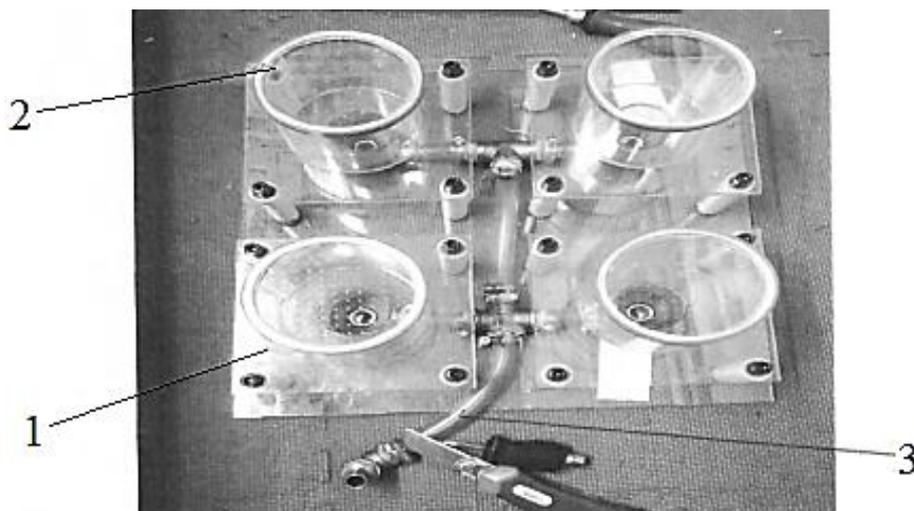


FIG 3: GROUP OF FOUR FINE BUBBLE GENERATORS WITH AIR MOUNTED DISPERSION PLATES

1-cylindrical body of the fine bubble generator; 2-ring fixing orifices plate; 3-compressed air pipe.

The experimental installation works as follows: the air taken from the atmosphere is compressed by the compressor (1) (figure 1) and then enters the tank (2) with a pressure of 2 - 4 bar. With the help of the pressure reducer, the

pressure decreases to the value of 0.6 bar, necessary for the operation of the fine bubble generators (FBG) (9). The air flow rate in the pneumatic circuit is measured with the rotameter (4), then the pressure (p) and temperature (t) of the air are measured with the devices (5) and (6) so that through the pipe (7), enters the FBG (9).

The air pressure in the capsule (9) is measured with the digital manometer (11) and the water temperature is measured with the electronic thermometer (10).

The electric method is used to measure the dissolved oxygen concentration in water [2]. In order not to complicate the figure, the actuation mechanism of the oxygenometer probe and the probe itself were not represented, these being presented separately in figure 4.

The oxygenometer has a polarographic probe that must be moved during the measurements; the displacement consists in a rotational movement with a speed of 0.3 m / s (value required in the oxygenometer leaflet). The radius of the probe is 0.125 m.

The speed provided by the mechanism is established as follows:

$$w = \omega \cdot r [m/s] \quad (1)$$

$$\omega = \frac{w}{r} = \frac{0.3}{0.125} = 2.4 \left[\frac{rad}{s} \right] \quad (2)$$

$$\omega = \frac{2\pi \cdot n}{60} \quad (3)$$

$$n = \frac{60 \cdot \omega}{2\pi} = \frac{60 \cdot 2.4}{2\pi} = 22.92 [rot/min] \quad (4)$$

Figure 4 shows a general view of the actuation mechanism of the oxygenometer probe.

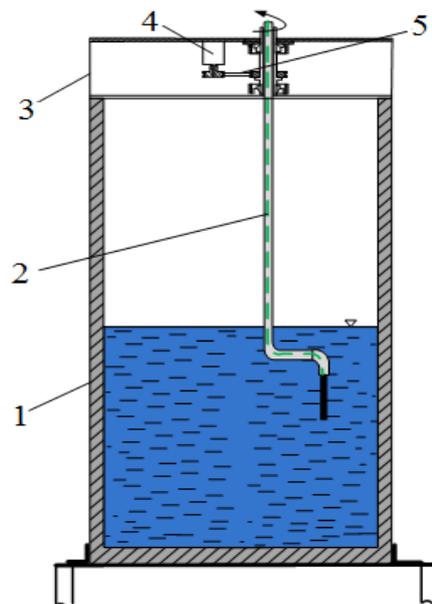


FIG 4: OXYGENOMETER PROBE ACTUATION MECHANISM

1-water tank; 2-oxygenometer probe; 3-box with the rotating drive mechanism of the oxygenometer probe; 4-electric motor; 5-toothed belt.

3. Devices Used in the Fine Bubble Generator Test Installation

The main devices used to perform the measurements in the FBG test installation are presented [9] [10].

3.1 Electronic Thermometer

The air temperature is measured using a digital thermometer (figure 5). The device has a measurement scale between -50.0 and 150.0 °C with a resolution of 0.1 °C and an accuracy of ± 0.3 °C (between -20 and 90 °C) / ± 0.5 °C (output). The sensor is made of stainless steel with a wire length of 1m.



FIG 5: ELECTRONIC THERMOMETER

3.2 Manometer

The pressure at the inlet to the fine bubble generator is measured using a Digitron PM 20 manometer (figure 6). It consists of a piezoresistive transducer and an electronic microprocessor with digital display; the device has a sensitive element of high fineness and precision, of piezoresistive type, which takes the measured quantity and transforms it into electrical quantity. This quantity is passed on to the microprocessor which picks up, processes and displays the electrical signal on the display.

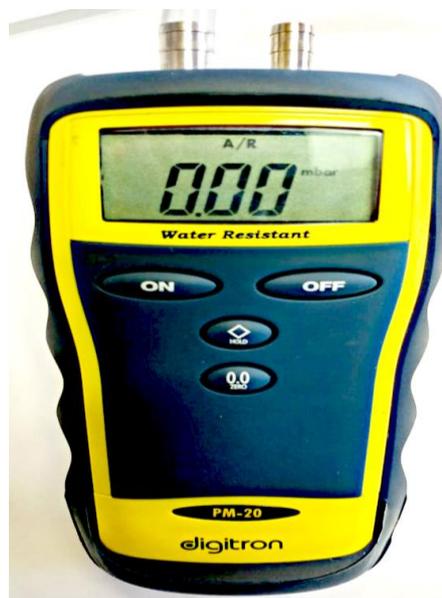


FIG 6: MANOMETER WITH DIGITAL INDICATION

3.3 Rotameter

Using a rotameter (figure 7) the air flow introduced into the fine bubble generator is measured, the device is based on the movement of a float inside a graduated frustoconical tube, arranged vertically with variable section. The rotameter is a flow meter with constant pressure difference and rotating float.

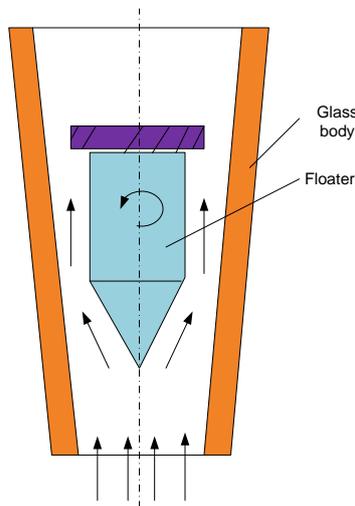


FIG 7: ROTAMETER

3.4 Oxygenometer

The dissolved oxygen in water following the oxygenation process is measured using a polarimeter oxygenometer probe. The oxygenometer is manufactured by HANNA Instruments, Canada, and consists of a microprocessor (Figure 8) that connects the connection cable to the measuring probe that is inserted into the water. The polarographic probe contains a small cylinder containing an electrolyte solution, two electrodes and a temperature sensor. The base of the cylinder consists of a Teflon membrane that is permeable to oxygen.



FIG 8: OXYGENOMETER

1-microprocessor; 2-cable connection; 3-probe body; 4-small cylinder containing the electrolyte solution; 5-Teflon membrane Oxygen-permeable; 6-ampoule with electrolyte solution; 7-temperature sensor.

4. Monitoring the Parameters that Occur during FBG Testing

These parameters will be analyzed in the successive order presented in the article summary.

- The measurement of the air bubbles (parameter 1) and a possible coalescence (parameter 2) of the bubbles are determined with a high-performance camera.
- The increase of the dissolved oxygen concentration in water (parameter 3) is evaluated with the oxygenometer (15) (figure 1) [9].
- The magnitude of the pressure loss (parameter 4) of the FBG is evaluated as follows:

In dynamic mode, the air flows through the pipe (7), enters the FBG and through the orifices enters the water tank. The air pressure at the entrance to the FBG body (p_1) must overcome the hydrostatic load, the surface tension and the pressure losses that occur when the air passes through the FBG:

$$p_1 = \rho_{H_2O} \cdot g \cdot H + \frac{2\sigma}{r_0} + \Delta p \left[\frac{N}{m^2} \right] \quad (5)$$

From this relation, one can find its value, by measuring the pressure with the device 11 (figure 1).

$$\Delta p = p_1 - \rho_{H_2O} \cdot g \cdot H - \frac{2\sigma}{r_0} \left[\frac{N}{m^2} \right] \quad (6)$$

σ - surface tension coefficient.

The pressure $p_1=0.6 \text{ m}_{H_2O}$ was measured and it results:

$$\Delta p = 0.6 \cdot 10^3 \cdot 9.81 - 10^3 \cdot 9.81 \cdot 0.5 - \frac{2 \cdot 73 \cdot 10^{-3}}{0.2 \cdot 10^{-3}} = 251 \frac{N}{m^2} \quad (7)$$

$$\Delta p = 0.0251 \text{ m}_{H_2O} = 25.1 \text{ mm}_{H_2O}$$

Aeration process efficiency (parameter 5):

$$\eta_{ox} = \frac{8.4H(C_s - C)}{\alpha_0} \quad (8)$$

Where:

- H - tank depth (hydrostatic load);
- C_s - Saturation concentration of dissolved oxygen in water.
- The oxygenation process efficacy (parameter 6) specifies the amount of oxygen transferred to the water for an electricity consumption of 1 kWh.

$$E = \frac{V}{P_c} \cdot \frac{dC}{d\tau} = \frac{V}{P_c} a k_L (C_s - C) \left[\frac{kg O_2}{kWh} \right] \quad (9)$$

Where:

V - the tank volume;

P_c - power required for air compression;

dC/dt - air to water transfer speed.

- The air consumption (parameter 7) is measured with the rotameter (4) (figure 1).

- Electricity consumption (parameter 8) is measured with the meter (14) (figure 1) [10] [11].

- Air temperature (parameter 9).

- The water temperature (parameter 10) is measured with the electronic thermometer (10) in figure 1.

- The compressed air pressure (parameter 11) is measured with the manometer (5) in figure 1.

- The hydrostatic load (parameter 12) is measured using a strip attached to the transparent wall of the water tank.

5. Conclusion

- For a good test study of an FBG, a number of 12 parameters must be followed, during which the initial dissolved oxygen concentration in water reaches saturation.

- The stand made in the laboratory of the department of Thermotechnics, Engines, Thermal and Refrigeration Equipment's is equipped with modern devices, most of them having digital indication.

- By changing the orifices plate (figure 2), different FBGs can be tested in which the orifices architecture can be different from one case to another; the other elements of the installation remain the same.

- An original constructive solution consists in the realization of the driving mechanism of the oxygenometer probe which, during the measurements, rotates in the water tank with a constant speed of 0.3 m/s.

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