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The Design and Construction of an Electro-mechanical System for the Movement of Fine Bubbles Generators

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Abstract
The paper presents the design and operation of a mobile platform that is used to move a fine air bubble generator in order to increase the dissolved oxygen concentration in water. It is worth noting the advantages of fine, mobile bubble generators, compared to the fixed immobile (fixed) bubble generators.
Keywords: *Water oxygenation, Mobile fine bubble generator.*

1. Introduction

In water treatment and purification processes, aeration is the basic operation in ensuring proper water quality. Aeration is used in the following areas:

- in water treatment processes for the removal of dissolved inorganic substances or chemical elements such as iron, manganese, etc., by oxidation and formation of sedimentable compounds or which may be restrained by boiling;
- in the biological treatment of wastewater either by the activated sludge process or bio filters;
- in the processes of disinfection by ozonisation of raw water taken from a source for the drinking purpose;
- in separating and collecting emulsified fats from wastewater.

Water oxygenation is a mass transfer process with wide application in water treatment. The oxygenation equipment's are based on the dispersion of one phase into the other, for example, gas into liquid, consuming energy. Dissolved oxygen is an important parameter in assessing water quality due to its influence on living organisms in a volume of water. In Limnology (the study of lakes), dissolved oxygen is an essential factor [1]. A height or low dissolved oxygen level can affect water life and quality. Non-compound oxygen, or free oxygen (O_2), is the oxygen that is not bound to any other element (Figure 1). Dissolved oxygen is the presence of those free O_2 molecules in water. The water-bound oxygen molecule (H_2O) is a compound and is not considered in the determination of the dissolved oxygen level [2][3].

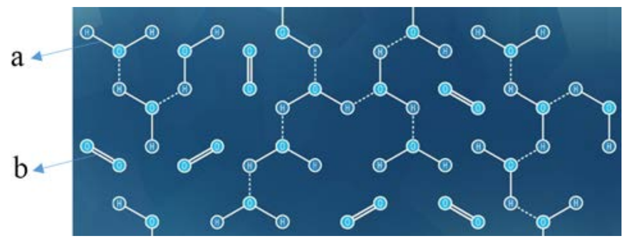

Fig. 1 Free oxygen molecules dissolved in water
a) H_2O molecules; b) dissolved O_2 in water.

2. Presentation of the installation for moving the fine bubble generator

The installation comprises a plastic tank of 4 x 0.5 x 0.5 = 1 m^3 in which water is introduced. Above the tank there is a platform that moves a fine bubble generator (FBG) in direction A → B and vice versa (figure 1) [4]. On the platform there are two step by step electric motors that provide:

- moving the platform (3) on the distance A → B and B → A;
- rotating with 180 ° at point B so that the air bubbles leave the FBG in the opposite direction to the movement.

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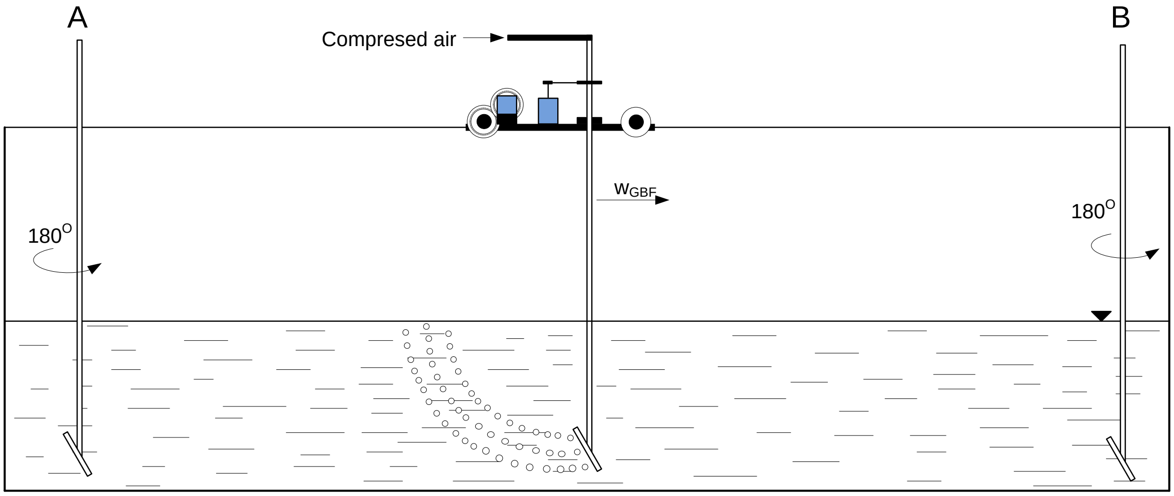

Fig. 2 Sketch for the measurement of the concentration of dissolved oxygen for mobile FBGs
1– water tank; 2– A-B: the displacement distance of a mobile FBG; 3– mobile platform; 4– electric engine for the displacement of the platform; 5–mechanical system for the 180° rotation of the FBG at the points A and B; 6–FBG, with 17 holes, Ø 0.5 mm

The FBG (5) is supported by a rod through which the compressed air supplied by an electro compressor enters through an elastic hose; this makes it possible for the FBG to be supplied with air over the entire distance between A → B and B → A.

3. Calculating the power of the electric motor that moves the platform

To be moved, the platform must overcome:
a) Water resistance (R_f) resistance of the mobile FBG;
b) Friction force (R_{fr}) between the platform wheels and the contour of the tank; the platform moves on four Ø 5 mm wheels.
The forward resistance of the FBG in water, is calculated with relation [5]:

$$= R_f = \frac{1}{2} C_x \rho_{H_2O} A w^2 \qquad (1)$$

where:
C_x - dimensional coefficient that depends on the Reynolds number, body shape, location of the body in the fluid stream;
ρ_{H_2O} - density of the fluid [kg / m3];
A - area of the body section projected on a plane perpendicular to the motion direction [m^2];
w - the displacement speed of the FBG [m / s].

3.1 Problem formulation

a) A cylinder of Ø 22 mm and l = 250 mm is given; the cylinder contains orifices through which the air enters the water.
It must be moved to a water tank with different speeds: 0.2 m / s; 0.4 m / s; 0.6 m / s; 0.8 m / s.
The forward resistance must be determined in order to determine the power of the electric motor to move this cylinder which is part of a fine bubble generator.
For water is known: kinematic viscosity: $\upsilon = 1.15 \cdot 10^{-10}\ m^2/s$, ρ_{H_2O} = 103 kg / m^3. Since C_x is a function of the Reynolds number, the Reynolds flow rate on the cylinder is calculated:

$$Re = \frac{w \cdot d}{\upsilon} = \frac{0.8 \cdot 22 \cdot 10^{-3}}{1.15 \cdot 10^{-10}} = 15304 \qquad (2)$$

The flow is turbulent because Re> 2320.
From [6], Figure 3 shows the diagram C_x = f (Re).

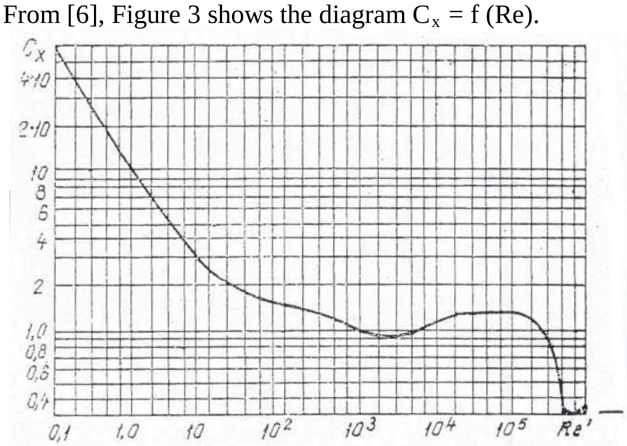

Fig. 3 The graphical representation of the function C_x = f(Re)

From figure no. 3 results in $C_x = 1.2$.
The value of A will be:

$$A = d \cdot l = 0.022 \cdot 0.25 = 0.0055 m^2 \quad (3)$$

it results:

$$R_f = \frac{1}{2} C_x \rho_{H_2O} A w^2 = \frac{1}{2} \cdot 1.2 \cdot 10^3 \cdot 0.0055 \cdot 0.2^2 \quad (4)$$
$$R_f = 0.132 \ N$$

Similarly, the speeds are 0.4; 0.6; 0.8 m / s. The values are listed in Table 1.
b) For the determination of the frictional force between the platform and the frame of the tank it is known:
- the platform weight: m = 12 kg → $G = m \cdot g = 12 \cdot 9.81 = 117.72 \, N$;
- the platform moves on four wheels, so a force apears on each wheel:

$$G_{r,1} = \frac{117.72}{4} = 29.43 N \quad (5)$$

- the frictional force between a wheel and the frame of the basin will be: $F_{r,1} = G_{r,1} \cdot \mu$ [N]
where μ - coefficient of friction; from [7] $\mu = 0.008$:

$$F_{r,1} = 29.43 \cdot 0.008 = 0.23 N \quad (6)$$
$$R_{fr} = 4 \cdot F_{r,1} = 0.94 \ N$$

Total forward resistance will be:
$R = R_f + R_{fr} = 2.11 + 0.94 = 3305$ N (7)

The power of the motor to move the platform will be [8]:

$$P = \frac{dL}{dt} = \frac{R d\vec{r}}{dt} = \vec{R} \cdot \vec{w} = R \cdot w (\cos \vec{R} \cdot \vec{w}) \quad (8)$$
$$\cos \vec{R} \cdot \vec{w} = \cos 0^\circ = 1$$

For the 4 speed values the calculation results are shown in Table 1.

Table 1: Electrical motor power values

w [m/s]	0.2	0.4	0.6	0.8
R_f [N]	0.13	0.52	1.18	2.11
R_{fr} [N]	0.94	0.94	0.94	0.94
R [N]	1.07	1.46	2.12	3.05
P [W]	0.21	0.58	1.27	2.44

4. Constructive details of the electromechanical system for moving the fine bubble generator

To move a FBG along the tank a mobile platform is considered, and in order to keep the same air bubble trajectory at each end of the tank, the fine bubble generator has to be rotated 180 °. Thus, two electromechanical systems powered by step by step electric motors are needed; the systems are schematically shown in Figures 5 and 6.
- One to move the mobile platform; such a system consists of a mobile platform on wheels (1), a step by step electric motor (2) and a transmission system of the rotation movement from the motor shaft to the wheels of the platform consisting of two gear wheels (3) (4) and the other with an intermediate shaft (5) and an elastic coupling (6) to reduce vibration and motor positioning errors, an control motor driver (7) and a hardware software system programming on the PC personal computer the driver (8) with integrated software [9].
- In the second system for rotating the FBG at the two ends of the tank, consisting of a step by step electric motor (9), an integral FBG (10) rod through which the compressed air circulates and a rotation movement system from the motor shaft to the FBG rod consisting of two gears (11), a toothed belt (12) and an electronic motor driver (7).
These two systems have been designed and built to be as light as the platform will move along the edge of the aeration tank as reliable and easy to control. That's why step by step electric motors were chosen.

Fig. 4 step by step electric motor

Characteristics:
- standard Nema 23 flange (56.4 x 56, 4 mm);
- Axle size 8 mm;

- static torque: 3 Nm;
- rated current: 6 A;
- motor inertia: 680 g / cm2;
- resistance 0.4 Ω, inductance 1.5 mH;
- bipolar command;
- motor length: 100 mm.

Figure 5 shows a plan view of the platform driven mechanism.

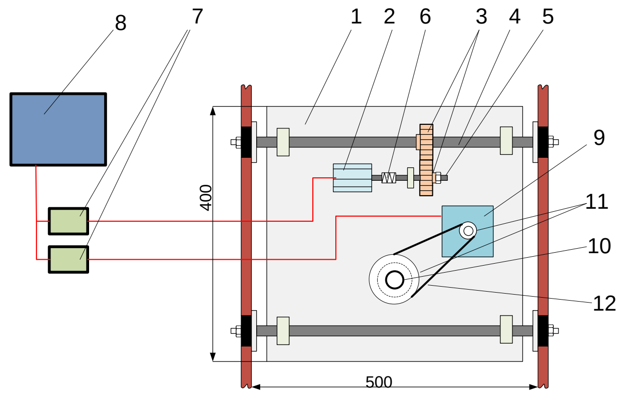

Fig. 5 The displacement systems of mobile FBG (upper view): 1–mobile platform on wheels; 2–electric stepping motor; 3–gear wheels; 4–platform wheeles axle; 5–intermediary axle; 6–elastic coupling; 7–motor driver; 8–personal computerl; 9–stepping motor; 10–rod solidary with the FBG; 11–gear wheeles; 12–gear belt

Figure 6 shows a cross section through the water tank in which a mobile FBG moves.

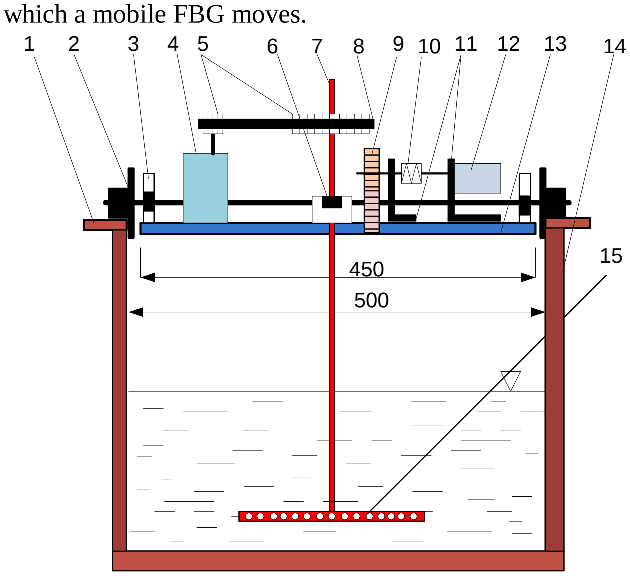

Fig. 6The displacement system of a mobile FBG (front view) 1–guide way; 2–wheel; 3–holder for the axle with bearing; 4–electric motor; 5–wheels for the gear belt; 6–holder with bearing; 7– FBG rod; 8– gear belt; 9–gear wheels; 10– elastic coupling; 11–holders; 12– electric motor; 13–plexiglass plate; 14–tank; 15–FBG

5. Conclusions

By using of fine bubbles generators with perforated plates the following advantages results [10] [11] [12] [13]:
- a uniform distribution of the orifices on the plate surface is ensured, as indicated by the designer;
- the diameter of the orifices being equal, the air bubbles of the same shape and diameter are provided; air flow control is ensured;
- there is no risk of clogging the perforated plate;
- because the loss of pressure is low, significant energy savings occur in their operation;
- the trajectory of the air bubble in water is a curve, so the contact time between the air bubble and water is higher, which leads to an increase in the oxygen transfer rate to the water; thus reducing the time required to aerate the volume of water.

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