RESEARCH REGARDING THE CONSTRUCTION OF A MECHANISM USED FOR THE DISPLACEMENT OF AN OXYGEN METER PROBE

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În lucrare se prezintă necesitatea măsurării concentraţiei de oxigen dizolvat în ape imobile; pentru efectuarea unor măsurători precise sonda oxigenometrului trebuie deplasată în apa cu o viteza mai mare de 0.3 m/s. Se expune soluţia constructivă a mecanismului de acţionare, funcţionarea lui şi rezultatele măsurătorilor efectuate.

The paper justifies the need for measuring the concentration of oxygen dissolved in stationary waters; in order to perform accurate measurements, the oxygen probe must be displaced inside water with a speed greater than 0.3m/s. The constructive solution of the driving mechanism, its functioning and the results of the performed measurements are exposed.

Keywords: Stepping, Microcontroller.

1. Introduction

An important indicator of the water quality is the quantity of dissolved oxygen; among water molecules there are oxygen molecules that constitute the dissolved oxygen DO.

A high content of DO must be preserved in the fish farms; if the DO level decreases below 2mg/l, the fishes start to suffocate. Therefore the need of measuring the content of DO in basins or tanks appears. The measurement of DO concentration is performed using chemical, electric or optical methods. A process of DO measurement using an oxygen meter endowed with a polarographic probe, belonging to the class of electrical methods, will be presented in continuation. The oxygen meter manufactured by Hanna Instruments, Canada, requires a water

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speed of minimum 0.3 m/s in order to perform accurate measurements. During our research, the basin water will be stationary and the probe driven by a stepping motor will be displaced in the water with a speed of 0.39m/s.

2. Description of the do measuring instrument

The oxygen dissolved in water is measured in parts per million (ppm=mg/l) or in saturation percentages (%).

The oxygen meter is composed of a microprocessor (1) (fig. 1) that, through the connection cable (2), establishes the connection with the measurement probe (3) introduced in the water whose DO content must be established [1].

Images from figures 1 and 2 present the component elements of the oxygen meter as well as their assembling manner in order to perform DO measurements.

Fig. 1. General view of the oxygen meter: 1- microprocessor with digital display; 2 – connection cable; 3 – probe body; 4 – temperature sensor; 5 – threaded portion of the probe body where the part 4 (fig.2) is screwed; 6 – anode; 7 – cathode.

A small cylinder (4) (fig.2) that contains an electrolyte solution is screwed on the threaded portion (5) (fig.1). The cylinder base consists of an oxygen permeable Teflon membrane (5) (fig.2).

The functioning principle of the measuring instrument is the following: a d.c. battery is mounted inside the microprocessor (1), thus an electric field where ions migrate is established between the probe electrodes.

A special purpose electrolyte solution, contained in a small cylinder tube (4) (fig.2) isolated to water, lies between the electrodes (anode and cathode). The intensity of the electric current between the anode and the cathode varies in function of the concentration of dissolved O_2, therefore the value of the O_2 concentration displayed by the oxygen meter also changes.

Fig. 2. Assembly view of the oxygen meter prepared for measurements. 1- microprocessor; 2 – connection cable; 3 – probe body; 4 – small cylinder that contains an electrolyte solution; 5 – oxygen permeable Teflon membrane; 6 – solution vail.

3. The experimental stand for the measurement of the oxygen dissolved in water

The experimental stand (Fig. 3) consists of:

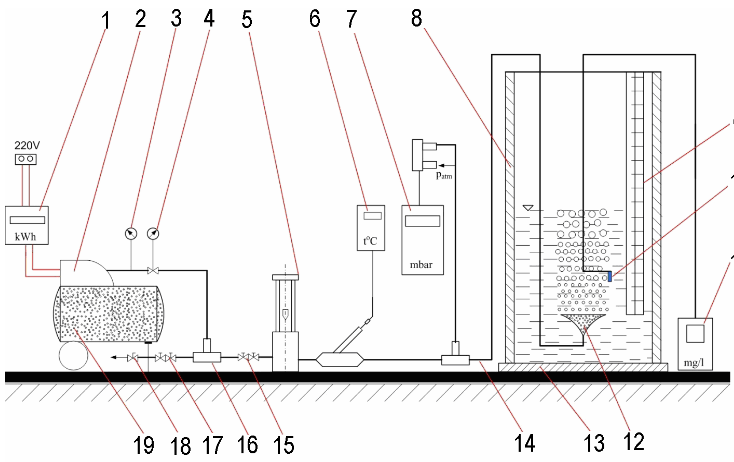

Fig. 3. Sketch of the stand for experimental researches regarding the water oxygenation. 1 – energy meter; 2 – compressor; 3 – manometer; 4 – pressure reducer; 5 – rotameter; 6 – digital thermometer; 7 – digital manometer; 8 – plexiglas basin; 9 – graduated scale; 10 – polarographic sonde; 11 – oxygen meter; 12 – rectangular FBG; 13 – support plate; 14 – compressed air pipe; 15 – valves for regulating the air flow to FBG; 16 – branch pipe; 17 - valves for regulating the discharged air flow; 18 – closing valve; 19 – compressed air tank.

a. An air electro-compressor (2) with the following main parameters:

- maximum discharge pressure: p = 8[bar];
- admission flow rate: $\dot{V} = 200$ [dm^3/min];
- electrical motor power: P = 1.2[kW];
- rotation speed: n = 2850[rpm];
- tank volume: V = 24[dm^3].

The compressor is endowed with a manometer (3) and a pressure reducer (4) that assure the required work pressure.

b. a rotameter (5) for air flow rate measuring;

c. a digital thermometer (6) for measuring the air temperature;

d. a digital manometer (7) for measuring the air pressure at the entrance of the fine air bubble generator (FBG);

e. a tank (8) filled with water from the plant supply, where the FBG is immersed [2; 3];

f. the measurement probe (10) and its driving mechanism.

An energy meter (1) was used in order to measure the electric energy consumption.

The air discharged by the compressor covers the following path:

- through the rotameter, where its pressure is measured (5);
- the temperature (6) and pressure (7) of the air current are subsequently measured;

- finally the air enters the FBG (12) that emits air bubbles;
- the increase of O_2 concentration is measured using the oxygen meter (11).

Measures will be taken that the air pressure in the tank (8) remains constant during the measurements. The pressure reducer (4) allows keeping a constant pressure at the entrance of the air in FBG.

4. Device for the displacement of the polarographic probe

The instruction and operation manual of the oxygen meter specifies that, in order to obtain accurate measurements, water must flow with a flow speed of minimum 0.3 [m/s]. In our case, the water is stationary in the water tank, thus we will displace the probe on a circular path in the horizontal plane.

A circle with a diameter of D = 0.25m is chosen. Accordingly, the length of the path is equal to:

$$L = \pi \cdot D = \pi \cdot 0.25 = 0.78\,[\mathrm{m}] \tag{1}$$

If the circle is travelled in two seconds, it results a probe speed equal to:

$$v_s = \frac{L}{\tau} = \frac{0.785}{2} = 0.3925\,[\mathrm{m/s}] \tag{2}$$

thus upper than the minimum speed of 0.3 [m/s].

The displacement device of the oxygen meter probe is mounted on the upper part of the water tank (fig. 4), being fixed on a support plate.

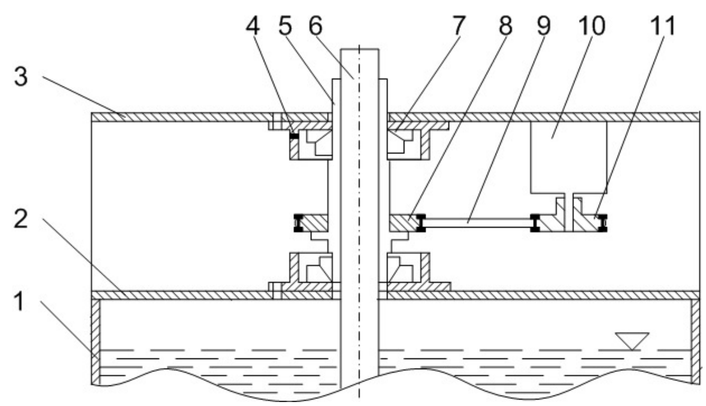

Fig. 4. Device for driving the oxygen meter probe in a circular movement. 1 – water tank; 2 – base plate; 3 – upper plate; 4- conical bearing case; 5 – central bushing; 6 – carrier rod of the probe; 7 – conical bearings; 8 – gear wheel; 9 – gear belt; 10 – stepping motor; 11 – gear wheel coupled on the motor shaft.

The electric motor drives the rod (6) (fig. 4) carrying the probe in a rotation movement on a circle Ø250 with a speed of 0.39 m/s.

A detailed representation of the driving mechanism of the oxygen meter probe is presented in figure 5.

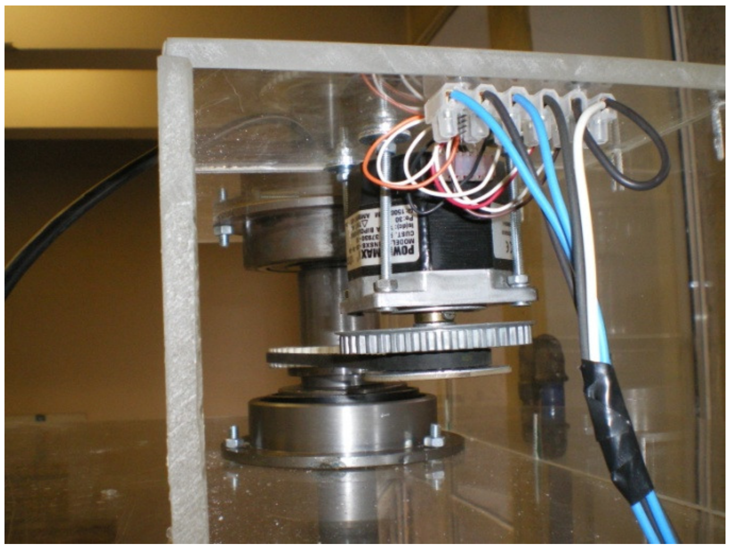

Fig. 5. Driving mechanism.

The mechanism provided for driving the probe consists of: stepping motor (10) that drives the gear wheel (8) joint to the central bushing (5) through a gear wheel (11) and a gear belt (9). The central bushing is mounted on a pair of conical bearings (7) and allows the fixing of the carrier rod (6). The movement is therefore transmitted from the motor to the carrier rod, assuring the rotating movement of the oxygen probe.

A POWERMAX II type P21NSXS-LSS-NS-03 stepping motor, manufactured by ScientificPacific, was chosen. The motor features a step of 1.8° and a maximum torque of 1.2Nm.

The control electronics of the positioning system of the oxygen probe must guarantee the correct step sequence of the stepping motor in order to achieve the rotating movement of the probe. The electronic system can be controlled through a number of knobs that allow the accomplishment of a pre-established rotation sequence in both directions, with a speed of 0.5 rps, or the positioning of the probe by the operator in the desired position 2 [4].

5. Measurement results

In the experimental stand, a column of water of height H = 500mm H_2O lies above the perforated plate. The pressure generated by the surface tension is equal to, [5]

$$p_{ts} = \frac{2\sigma}{r_0} = \frac{2 \cdot 8 \cdot 10^{-2}}{0.25 \cdot 10^{-3}} = 620\ \mathrm{N/m^2} \tag{3}$$

$$\Delta h_{ts} = \frac{p_{ts}}{\rho_{H_2O} \cdot g} = \frac{620}{10^3 \cdot 9.81} = 0.063\mathrm{mH_2O} \tag{4}$$

Hereupon the first gas bubbles will appear if the digital manometer will display:

$$\Delta h_1 > H + \Delta h_{ts} \Rightarrow \Delta h > 563\ \mathrm{mmH_2O}\,. \tag{5}$$

Fig.6. FBG in function; Δh1=60 mbar=611mmH2O.

Previous researches [6; 7], proved that the air pressure at the entrance to FBG had to be equal to 611 mm H_2O > 563mm H_2O, therefore the FBG functioned normally (fig. 6).

The measurements are performed in four stages.

I) The first measurement is illustrated in figure 6, where the water column above the FBG is of h_{H_2O} = 500 mm and the probe situates at h_{probe} = 250 mm, the initial concentration of DO being c_0 = 5.12mg/l and the water temperature t = 19.5℃. The pressure and the rate of the air flow that enters the FBG are measured.

p_1 = 611mm H_2O, $\dot{V}$ = 540 l/h, values that are maintained constant during the measurements. After the FBG functions for a time period of $\Delta\tau_1$ = 15', it is stopped and the O_2 concentration is measured by rotating the probe in a horizontal plane in the water.

II) The FBG is started again. Air is introduced in water during 15', leading to a total functioning time of $\Delta\tau_2$ = 30'. The O_2 concentration is measured in the same plane.

III) Similarly we arrive at $\Delta\tau_3$ = 45'.

III) Similarly we arrive at $\Delta\tau_4$ = 60'.

Finally the concentration of the O_2 dissolved in the water is measured after a functioning time of the FBG of one hour. The measured values are presented in table 1.

Table 1

O2 concentration in function of the duration of FBG functioning

Concentration of O2 dissolved in water				
$\tau = 0'$	$\Delta\tau_1 = 15'$	$\Delta\tau_2 = 30'$	$\Delta\tau_3 = 45'$	$\Delta\tau_4 = 60'$
5.12	6,57	7,16	7,63	7,97

Data presented in table 1 allow constructing the graph $C_{O_2} = f(\tau)$ for a height of the water column equal to 500mm and for a temperature t_{H_2O} = 19.5℃.

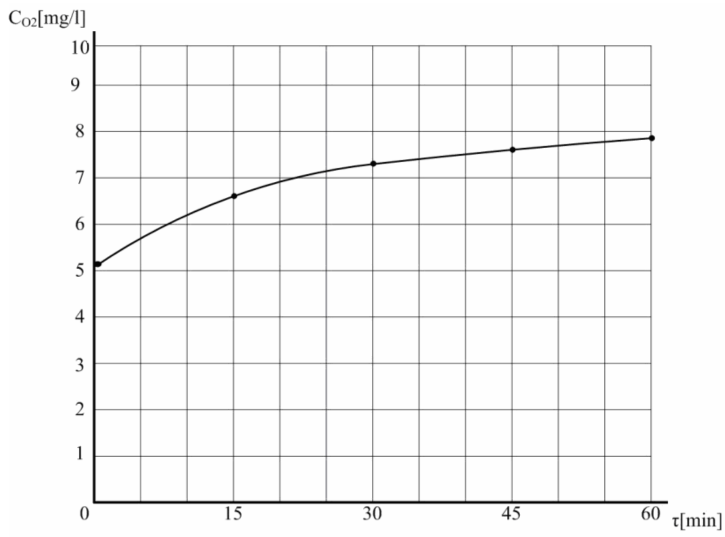

Fig. 7. Graphical representation of the function $C_{O_2} = f(\tau)$.

The shape of the curve presented in figure 7 is similar to the one that can be found in specialty literature [8].

The oxygen transferred to the clean water (from the plant supply) was not consumed either as consequence of the microorganism metabolism (see reactors, water treatment plants) or by the fishes, thus the concentration of oxygen in water increased in proportion as air was blown in the water tank.

6. Conclusions

1. The driving mechanism of the oxygen meter probe performs a 360° rotation of the probe in 2 seconds; the movement is transmitted from the stepping motor, through a gear belt, to the probe carrier rod. An accurate trajectory covered in a well determined time is thus guaranteed.

2. The electronic system of the driving mechanism can receive instructions through the knobs from the control panel; the knobs allow the accomplishment of a pre-established rotation sequence in both directions, with a speed of 0.5 rps.

3. The performed experimental researches proved the accuracy of probe displacement and the reliability of the driving mechanism.

4. The driving mechanism allows the horizontal and vertical displacement of the probe, observing pre-established conditions.

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