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New Design Flexible Link Aerator to Generate Dissolved Oxygen in Water

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Abstract- This paper presents the findings of new design of flexible link plate as an aerator to generate dissolved oxygen. An aerator is one of water treatment methods. Using aerator as water treatment can improve dissolved oxygen rate in water. Low dissolved oxygen content can be fatal to certain aquatic species. The application of flexible links manipulators is worldwide trending in technologies nowadays. Thus, application of flexible link as an aerator is studied to improve the dissolved oxygen content in water and reduced cost of manufacturing for an aerator machine. Results show that the flexible link with proper shape and design is able to generate more dissolved oxygen rate which is good to increase the production rate in aquaculture sector. The new value of the calculated SAE is 2.7 kgO_2/ kWhr

Introduction

The level of dissolved oxygen in water is one of the most important parameters in determining water quality indirectly gives indication to the existence of pollution [1]. The dissolved oxygen (DO) is oxygen that is dissolved in water by diffusion from the surrounding air; aeration of water that has tumbled over falls and rapids; and as a waste product of photosynthesis. Fish and aquatic animals cannot split oxygen from water (H_2O) or other oxygen-contained compounds. Only green plants and some bacteria can do that through photosynthesis and similar processes. Virtually all oxygen that we inhale is produced by green plants. A total of three-quarters of the earth's oxygen supply is produced by phytoplankton in the oceans [2].DO comes from many sources; the largest is absorbed from atmosphere. Wave action and splashing allows more oxygen to be absorbed into the water [3].

The main focus of this research is generating DO and designs a new flexible link using as an aerator to generate dissolved oxygen. The vibration generated from the movement of the flexible plate will generate waves and bubbles in water thus generating dissolved oxygen. Oxygen is continuously moving between the water and the surrounding air. The direction and speed of this movement is dependent upon the amount of contact between the air and water. The more of the water's surface is exposed to the air; it will absorb more oxygen from the atmosphere than a calm, smooth body of water. This is the idea behind aerators; by creating bubbles and waves the surface area is increased and more oxygen can enter the water [3].

Literature Review

A. Flexible link

Flexible link are known to offer several advantages in comparison to their rigid counterparts. Lightweight elastic single-link manipulator is capable of improving the speed of operation and handling larger payloads in comparison to rigid manipulator with the same actuator capabilities.

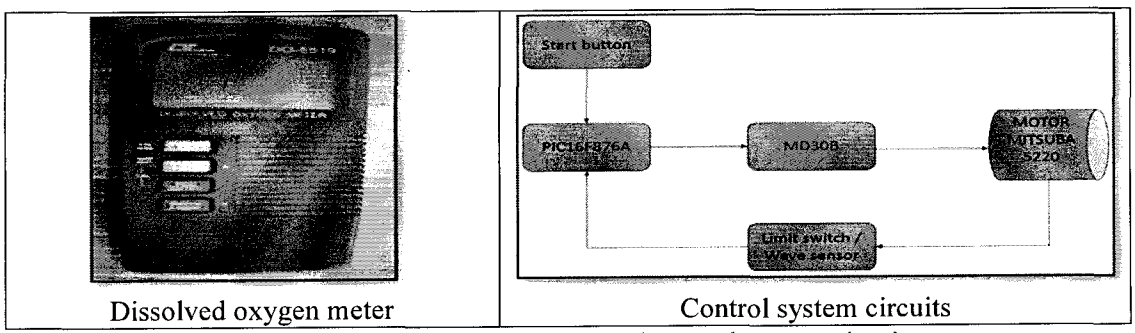
Therefore, lots of research was done in flexible manipulators for industrial applications. This is due to several advantages associated with the flexible link. These include higher gross motion speeds, reduced cost for mechanical subsystem, energy efficiency due to smaller actuators for the same cycle times, portability and improved mobility of manipulator arms, safety due to reduced moving mass, and reduced mounting requirement [4].

B. Dissolved oxygen

Dissolved oxygen is O2 molecule that is dissolved into the water. It is invisible and is not the water bubbles, nor the oxygen component of the water molecule H2O. All animals need oxygen to survive. Dissolved oxygen is the necessity for aquatic life. Changes in oxygen concentration may affect species dependent on oxygen-rich water, like many macro-invertebrate species. Without sufficient oxygen they may die, disrupting the food chain. All terrestrial and aquatic animals need oxygen to survive. Many aquatic macro-invertebrate species depend on oxygen-rich water. Even a small change in dissolved oxygen concentration can affect the composition of aquatic communities. Many types of fish require a certain dissolved oxygen range in order to survive [5]. Dissolved oxygen level will be measured by water proof dissolved oxygen meter as shown in Figure 1. The rate of dissolved oxygen that is generated is measured in order to analyse the data for comparison with the previous research results.

C. Control system

The previous research for flexible link plate as an aerator control system will be reviewed. The conceptual design model is developed by considering some factors. The factors that need to be considered are the capability of the motor driver, power supply and the controller. The selected motor and motor driver is based on the power supply suitability and maintainability to find it in the common market. To get an overview of the previous research, the illustration is provided in Figure 1. In this research, notice the reaction of the machine with the water that requires the machine to have the corrosion resistance ability [3].



Dissolved oxygen meter | Control system circuits

Fig. 1: Dissolved Oxygen meter and control system circuits

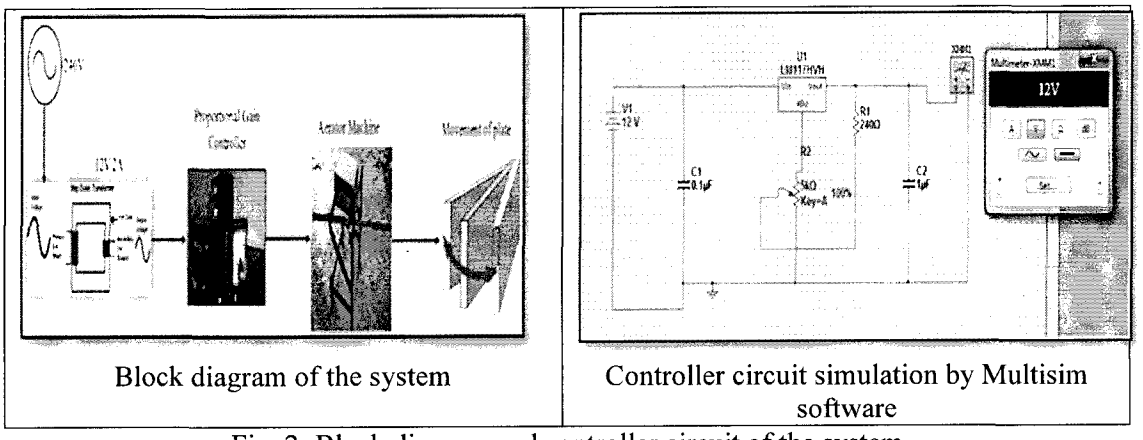
3.0 Methodology

A. Controller circuit design

In order to fulfil the research objectives, the controller circuit for proportional gain is customised. There are many common controller circuits that can be used, but it is decided to use the controller circuit that is step down source from AC (alternating current) to DC (direct current). This is because AC electrical source can provide continuous energy supply for the machine while the machine are working by DC motor that consumed low but continuously electrical power. Before customizing the circuit, simulation of the circuit is done by using Multisim software to make sure the components will perform well. Figure 2 shows the block diagram and the controller circuit of the system, respectively.

B. Concept of movement

The flexible plate is designed to move horizontally, where the attached flexible plate to the motor hub and it move left and right on the water surface. However, this concept prevents the flexible plate to have more contact to the water surfaces, where during the vertical motion, the flexible plate have no contact with the water. Furthermore the surface area of water is limited; it only depends to flexible plate width area [3].



Block diagram of the system

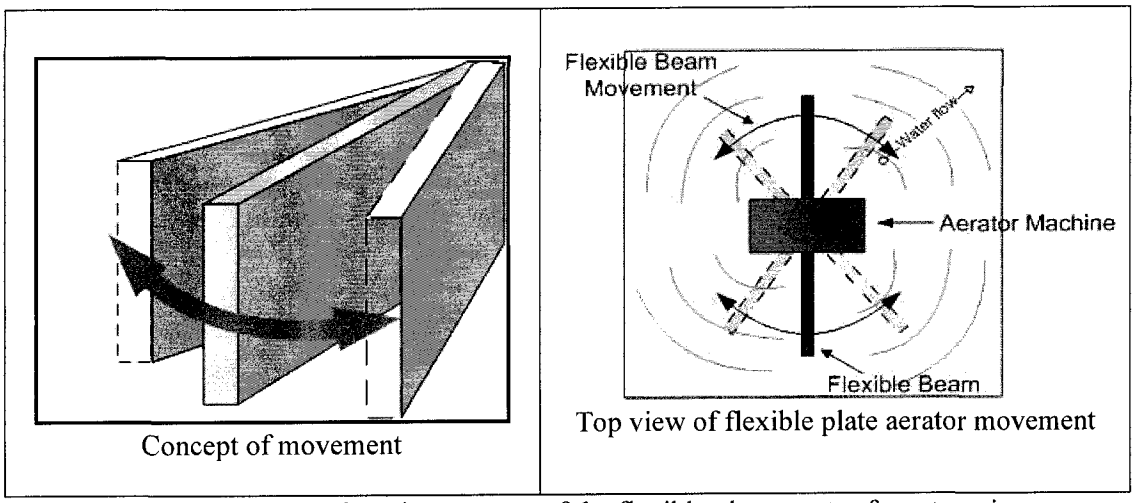
Controller circuit simulation by Multisim software

Fig. 2: Block diagram and controller circuit of the system

By design the flexible plate move with the horizontal movement, the flexible plate will attach to motor hub and it move left and right frequently on the water surface. This concept is more practical because it will have more contact with water surface continuously. This design allows the aerator to cover more pond surface area, from the centre of aerator. As the longer flexible plate is used, more area can be covered and more dissolved oxygen can be generated, and at the same time it enhanced water circulation. However it depends on capability of the motor to hold the load. Longer flexible plate will cause more load need to be implemented due to the water resistance during motion and its own weight [3]. Figure 3 shows the illustration of motion concept of the flexible plate aerator from top view.

C. New concepts design

The new design concept of the flexible plate is based on two factors, the used material and holes shapes design for flexible link plate. Particularly a good method for selection on the most promising design concept is the Pugh concept selection process.

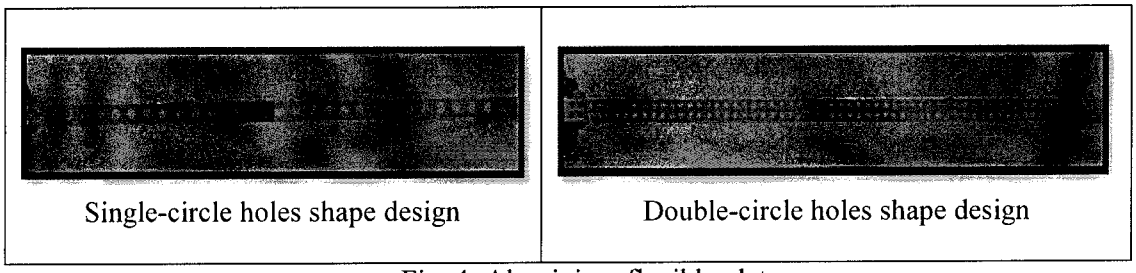


Concept of movement

Top view of flexible plate aerator movement

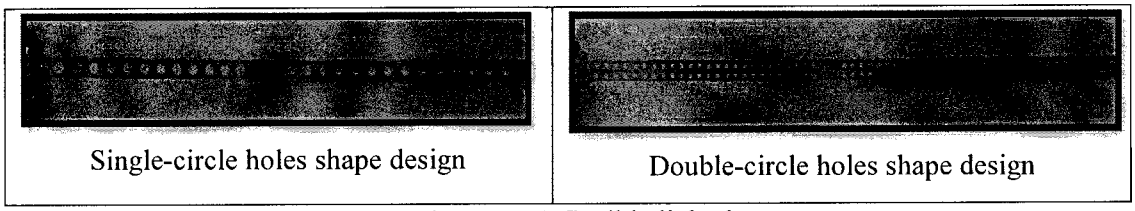
Fig. 3: Illustration of motion concept of the flexible plate aerator from top view

This method compares each concept relative to a reference and for each criterion it determines whether the concept n is better than, poorer than, or about the same reference concept [6]. After the design concept is selected, the designs for flexible plate that is used in this project are as shown in Figure 4 and Figure 5, respectively.



Single-circle holes shape design | Double-circle holes shape design

Fig. 4: Aluminium flexible plate



Single-circle holes shape design | Double-circle holes shape design

Fig. 5: PVC flexible link plate

Result and Discussion

The best length for the flexible link plate is 0.65 metre for one side that makes the actual length of 1.3 metre while the thickness and width being used are 0.003metre and 0.04metre respectively [3]. The next parameter is types of material which is aluminium and Poly-Vinyl Chloride (PVC) with two different shapes circle holes. The design concept uses circle and triangle combined together, although the fabrication needs precise manufacturing process and will cost more. Even though in the previous research states that by using highest 12 volt to operate the aerator machine gives the best result, but for this testing parameter different kind of value 6 volt, 9 volt, and 12 volt are selected but in a more appropriate method where the feedback control system is used as stated in methodology chapter.

The immersed percentage level (25%, 50% and 100%) of flexible link plate is also an important parameter that needs to be tested and so that the aerator machine can give the best performance and better result in generating dissolved oxygen [3]. Apart from the stated parameters, the period of time for this experiment being tested is fixed where there are morning (7.30am – 10.00am), afternoon (12.00 pm – 2.30pm), and evening (4.00 pm – 6.30pm) due to different temperatures.

The duration of each experiment is 15 minutes with each minute the measurement will be recorded. Table 1 shows the data for dissolved oxygen with immersed level (50%) of PVC flexible plate at 12V. Figure 6 shows the graph of dissolved oxygen level against time for operating aerator using Aluminium and PVC flexible link plate with Single-circle holes shape design at 12V.

Table 1: Data of dissolved oxygen with immersed level (50%) of PVC flexible plate at 12V

Period Time	Morning	Afternoon	Evening	Average	Remark
Temperature (℃)	28.9	33.6	31.7	**31.4**	Maximum reading
Time (minute)	Dissolved Oxygen Level (mg/L)				
1	2.9	3.1	2.7	**3.0**	Initial level
2	3.3	3.5	3.1	**3.3**	
3	3.8	4.0	3.6	**3.8**	
4	4.2	4.4	4.0	**4.2**	
5	4.7	4.9	4.5	**4.7**	
6	5.1	5.3	4.9	**5.1**	

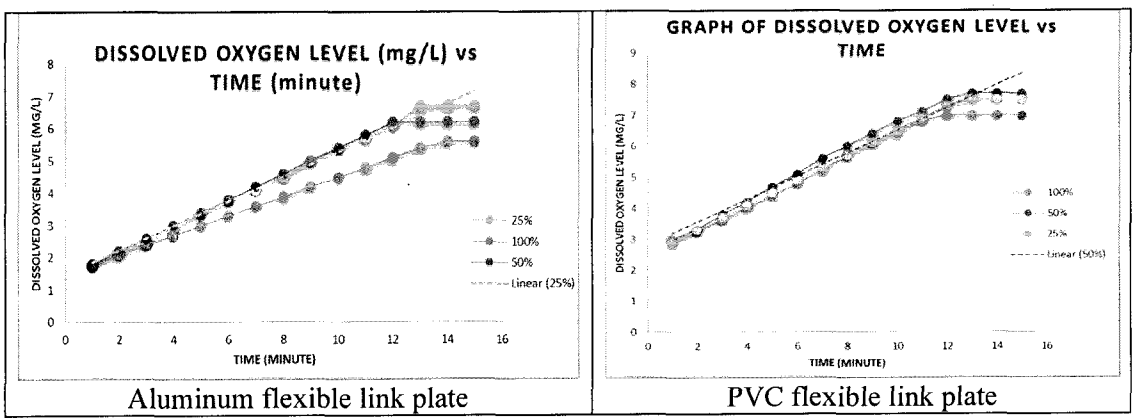
7	5.6	5.8	5.4	**5.6**	
8	6.0	6.2	5.8	**6.0**	
9	6.4	6.6	6.2	**6.4**	
10	6.7	6.9	6.8	**6.8**	
11	7.0	7.2	7.1	**7.1**	
12	7.4	7.6	7.5	**7.5**	
13	7.7	7.7	7.7	**7.7**	Saturated level
14	7.7	7.7	7.7	**7.7**	
15	7.7	7.7	7.7	**7.7**	
ΔD.O.	4.8	4.6	5.0	**4.8**	

A. Standard oxygen transfer rate

Standard oxygen transfer rate (SOTR) is the most important factor when deciding to use an aerator. SOTR will determine whether the selected aerator is efficient compare to other aerator. For this research, the SOTR value will be calculated using the best parameter setting that shows best result and comparison between costs of material. It shows that PVC plate gives lower cost than using aluminium plate as an aerator. Even though both plates give almost the same result, but considering the cost part, it is crucial to choose the cheapest one. Thus the PVC flexible link plate with double-circle holes shape design is selected as the best parameter. Table 2 shows the comparison of aerator efficiency including the research finding.

Table 2: Oxygen Transfer Efficiency of Basic Type of Aerator

Type of aerator	Average Oxygen Transfer Efficiency ($kgO_2/kWhr$)
Paddlewheel	2.75
Flexible Link Aerator with circle holes	**2.70**
Flexible Link Aerator	1.84
Propeller aspirator pump	1.58
Vertical pump	1.28
Pump sprayer	1.28
Diffused air	1.20



Aluminum flexible link plate PVC flexible link plate

Fig. 6: Graph of dissolved oxygen level against time for operating aerator using Aluminium and PVC flexible link plate with Single-circle holes shape design at 12V

Conclusion

The new design of flexible link as an aerator is fabricated based on the previous study of aerator and flexible link. The chosen material for the flexible link plate is also studied carefully. The design of the aerator machine has to go through detailed design and manufacturing process. The aerator machine must need a proper leg design so that it can withstand the movement of flexible link plate that involving friction force in water and weight of motor on top of it. Finally, the aerator machine needs to go through detailed analysis process so that we can determine the machine endurance level. The new value of the calculated SAE is 2.7 $kgO_2/kWhr$.

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