FLEXIBLE LINK AERATOR FOR DISSOLVED OXYGEN GENERATION IN TIGER PRAWN POND

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"*Special dedication to my beloved family, Aiman Fahmi, and Asri, to my fiancé Azila, and to all my friend, thanks for everything."*

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ABSTRACT

In the aquaculture industry, the dissolved oxygen is one of the important parameters that need to be monitored seriously. Aerator is normally used to increase the level of dissolved oxygen in water. It functions to circulate or mixes the water top to bottom to ensure that the oxygen content is uniform throughout the pond. It also exposes the water surface to absorb oxygen from atmosphere. This aerator uses a new concept by using flexible link to generate dissolved oxygen. The advantages that have in flexible link were used as an actuator to generate and distribute dissolved oxygen in water. Three type experiments were done to find out and verified the optimum parameter setting for this aerator. The best result of dissolved oxygen level were found during run the flexible link aerator at full power with 0.65m length of flexible link and immerses 25% in water. As a result, the flexible link was successfully implemented as a new aerator concept where it is able to generate oxygen up to 8.6mg/L with the average Standard Oxygen Transfer Efficiency 1.84 $kgO_2/kWhr$ and suitable to used in the shallow pond. The key success factor in developing this method is due to the characteristics that are available on flexible link where it length can be extended to cover the surface of the water without burdening the motor. More water surface area exposed to the atmosphere it will encourage the absorption oxygen into water.

ABSTRAK

Dalam industri akuakultur, oksigen terlarut adalah salah satu parameter penting yang perlu dipantau dengan serius. Mesin pengudaraan biasanya digunakan untuk meningkatkan tahap oksigen terlarut di dalam air. Ia berfungsi untuk mengedarkan atau mencampurkan oksigen terlarut dari permukaan hingga ke bawah dan memastikan bahawa kandungan oksigen terlarut adalah seragam kolam. Ia juga berfungsi mendedahkan permukaan air ke atmosfera supaya oksigen dapat diserap ke dalam air. Mesin pengudaraan dalam kajian ini mempamirkan satu konsep pengudaraan baru dengan menggunakan kepingan fleksibel untuk menjana oksigen terlarut. Kelebihan yang ada pada kepingan fleksibel ini telah digunakan sebagai penggerak untuk menjana dan mengedarkan oksigen terlarut di dalam air. Tiga eksperimen jenis telah dijalankan untuk mengenalpasti dan mengesahkan parameter yang optimum. Ujikaji yang telah dijalankan adalah ujian kelajuan mesin pengudaraan, panjang kepingan fleksibel dan tahap rendam yang berbeza di dalam air. Bacaan oksigen terlarut yang terbaik didapati ketika menjalankan mesin pengudaraan ini dengan menggunakan kuasa penuh, berserta panjang kepingan fleksibel 0.65m dan tahap rendaman 25% di dalam air. Hasilnya mesin pengudaraan ini mampu menjana oksigen terlarut sehingga 8.6mg/L dengan purata Kecekapan Piawai 1.84 kgO_2/kWj dan ianya sesuai digunakan pada kolam yang cetek. Faktor utama kejayaan dalam membangunkan kaedah ini adalah disebabkan oleh ciri-ciri yang terdapat pada kepingan fleksibel ini yang mana ia tidak membebankan motor walaupun menggunakan kepingan fleksibel yang lebih panjang. Lebih luas permukaan air terdedah kepada udara ia akan menggalakkan penyerapan oksigen kedalam air.

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LIST OF SYMBOLS AND ABBREVIATION

SAE	-	Standard Aerator Efficiency
SDTR	-	Standard Oxygen Transfer Rate
N/A	-	Not Available
kgO_2	-	Kilo gram oxygen
kW	-	Kilo Watts
kWh	-	Kilo Watts hour
V	-	Voltage
$\frac{d(m)}{dt}$	-	Mass transfer rate
D_m	-	Coefficient of the gas in square centimeters per second (cm^2/sec)
A	-	Area
$\frac{d(C)}{dt}$	-	Concentration gradient of the gas
mg/l	-	Milli gram per liter
τ	-	Torque
E	-	Young's modulus
I	-	second moment of inertia
ρ	-	Density
l	-	Length
δ	-	Deflection
θ(t)	-	Radian angle
PDE	-	Partial Differential Equation
M_p	-	Mass at end point

F_d	-	Drag force
C_d	-	Drag force coefficient
ν	-	Velocity
DC	-	Direct current
Nm	-	Newton Meter
m	-	Meter
ω	-	Angular velocity
b	-	Width
d	-	Thickness
%	-	Percentage
D.O	-	Dissolved Oxygen
^oC	-	Temperature in Celcius
i	-	Current
K_La_{20}	-	The Oxygen Transfer Coefficient At 20^oC
C_{s20}	-	Dissolved oxygen (DO) concentration at saturation, 20^oC (mg/L)
V	-	water volume in m^3
C_m	-	Measured DO concentration
rad/s^2	-	Angular acceleration in Radian per second square
a.m	-	*Ante meridiem* mean before midday
p.m	-	*Post meridiem* mean after midday
Hr	-	Hours
C_{ss}	-	Saturated dissolved Oxygen
A	-	Ampere

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CHAPTER 1

INTRODUCTION

1.1 Research Background

This research is about the new aerator concept that is suitable for shallow pond which can perform as well as common aerator. The concept that was used by this aerator has not been practice yet. It will overcome the limitation of popular mechanical aerator, which is the paddlewheel. Paddlewheel is not suitable to use in shallow pond, where the downward water force movement can disturb the bottom of the pond and make the pond muddy. Meanwhile, other aerators such as diffuser type aerators are inefficient as compared to paddlewheel because it consumes more power to operate.

Dissolved oxygen level increases as wider water surface were exposed to the atmosphere. By implementing the mechanical contact along the water surface, it will increase the area of water exposed to the atmosphere and simultaneously increase the absorption of oxygen. Currently, only the paddlewheel use this concept. However, it has some limitation as mentioned above.

The new concept used by this flexible link aerator is by moving the flexible link as an actuator that contact with the water surface without creating downward force inside the pond. It was achieved by designing an aerator that have a long plate at the hub and driven at horizontal axis using high torque motor. High torque motor are preferable compared to high speed motor, because it has the capability to handle more load such as water drag force and actuator weight.

Flexible link aerators were chosen based on length to weight ratio factor. It is commonly used to improve the speed of operation and handling larger payloads compared to rigid link aerators. Longer plate allows the aerator to cover wider water surface area to generate dissolved oxygen and circulate the water. As mention by Vidoni et al. (2013) in their research, the heaviness of flexible link will decrease speed and the system required more energy to operate. The demand for better performances and higher speed make it necessary to consider lightweight manipulators because they required less energy to move and have more maneuverability. At the same time, the weight will not burden the driver motor and can increase the speed of movement of the aerator. These characteristics could lengthen the durability and lifetime of the driver motor.

The existing mathematical model of flexible link had been synchronized with the new boundary condition, where the flexible link now implements at water surface. The finite different method was used to develop mathematical model for flexible link aerator. The mathematical model was then simulated using Matlab SIMULINK. Observation was made on the effects of deflection behavior of flexible link aerators towards the level of estimated dissolved oxygen. Simultaneously from this simulation, the optimum parameters were defined such as the length of flexible link aerator plate, voltage to control motor speed, and the percentage of immerse flexible link in water.

All parameters obtained from the simulation were used on actual model which were designed and fabricated. The actual model were used on clean water reservoir to find out the level of dissolved oxygen generated and the efficiency were calculated and compared to other types of aerator.

1.2 Problem Statement

Oxygen is the most important element to sustain our life. Animals and human being cannot survive without oxygen. Carbon dioxide exhale from animals and human being were used by plants for photosynthesis which will produce oxygen. Lack of oxygen will disrupt this life cycle will disrupt and could cause fatality to living creatures. Oxygen is not only important for respiration, but also to destroy harmful bacteria in human and animal body without affecting the beneficial bacteria.

Bugbee and Blonquist (2006) stated that, about 20.95% oxygen can be found in the atmosphere. Oxygen can also be found in water molecule. Aquatic animals require oxygen in water to survive just like land animals. Oxygen in water is called dissolved oxygen. Even though oxygen can be found in water molecule, these aquatic lives are unable to separate the oxygen gases. Due to that, they require pure oxygen gases. Shortage of dissolved oxygen indicates existence of pollution and can be harmful to the aquatic animals.

In aquaculture industry, dissolved oxygen is one of the major parameters need to be monitored seriously. Aerator is normally used to increase the level of dissolved oxygen in water. The function is to circulate or mix the water from top to bottom to ensure that the oxygen content is uniform within the entire pond. Aerator also helps to expose the water surface to absorb more oxygen from the atmosphere.

Paddlewheel is one of the most popular aerator machines to generate dissolve oxygen. The latest improvement of existing adjustable impeller is water breaking impeller, designed for power saving and high aeration. It contributes to lower power consumption due to the professional water breaking and parabolic design. However, it is not suitable to use in shallow pond. Due to the rotation force of water that created from the movement of the paddlewheel, the bottom of pond is disturbed and causes the pond to become muddy.

Shallow pond is required for bottom dwelling animals and animals that are difficult to move to the surface such as tiger prawn. Because of the constraint of financial resources and to minimize the operating cost, the pond designed was exceeding the depth that required. This is to suit the paddlewheel circumstances. To ensure the dissolved oxygen circulate and arrive to the bottom of the pond, paddlewheel need to operate more than it should to prevent the shortage of dissolved oxygen.

1.3 Objectives

A study proposed in this research is to developing a new concept of aerator using flexible link to generate dissolved oxygen. The specific objectives of this study are carried out are described below:

i. To investigate new concept of aerator with lower initial and operating cost with better performance compared to existing aerator.
ii. To develop model with finite different simulation algorithm of the flexible link aerator
iii. To test and evaluate the performance of actual model.

1.4 Importance of the Study

This research is important to encourage the tiger prawn agriculture industry as the aquaculture industry in Malaysia and give opportunity to choose a suitable mechanical aerator. Level of dissolved oxygen is one of the most influential factors to be considered in term of the technical aspect in aquaculture farming. It will determine the quality of water. Water quality plays an important role in hatchery, farming and distributing activity especially in intensive farming. However, cost in operating the aerator become the burden and reduce the profit. Thus, aerator with lower operating cost, easy to maintain and good durability is highly recommended. Basically, it combines several engineering disciplines such as engineering control, material science and fluid engineering to handle a problem in design and control system in those activities.

Significant of this research will develop a new technology and concept of aerator in aquaculture engineering. In this research the movement of flexible link is implements in water to become an aerator and there is no aerator concept yet as in this research. Thus, it will add more option of aerator especially the mechanical aerator type in the aquaculture engineering. This research also develops a new knowledge. The mathematical model development by using the finite different method can be use as a reference in future to any related research especially to conduct the flexible link experiment in different boundary conditions.

1.5 Scope of Study

Scope of study in this research is within the limited range of the engineering field area. It limited to find suitable design concept which is suitable to use in shallow pond such as tiger prawn pond. The concept of aerator movement was implementation from the flexible link movement. The flexible link aerator model developed using the existing mathematical model with water boundary condition. The mathematical model was developed using partial differential equation and was then transfer into a block model in Matlab SIMULINK.

The simulation model is limited to find the optimum parameters and to observe the end point angular overshoot effect to the estimated dissolved oxygen level. The optimum parameters that need to be clarified in this research are the voltage used which it related to the speed of the movement, the suitable length, and the percentage immerse of flexible link in water. These parameters are important because it will affect the amount of dissolved oxygen generated.

In this research, the simulation model is important for future research, where it can be altered or modified to be used in other related experiment. Dissolved oxygen level can be estimated without consuming time and money on fabricating new aerator machine for the experiment. Since current flexible link aerator machine uses only basic aerator design, a lot of part can be upgraded in future as cited in the recommendation section later in this thesis.

Later, actual aerator model is fabricated for the experiment. Then the experimental results compared with simulation results to verify the optimal parameters of aerator. The final step is to calculate and compare the flexible link aerator efficiency with other aerators.

1.6 Flowchart of research

There are 4 phases had been through to perform this research. Figure 1.1 shows a brief phase of research that encountered in this research. It starts with finding a suitable design concept and translated into engineering design drawings. The next phase was simulating the developed mathematical model of flexible link in boundary condition of water. The simulation result were use to prepare the actual flexible link. Actual flexible link aerator machine then fabricated according to the drawing concept made in the first phase. Experimental have been conducted to verify the simulation result. Finally, the parameters used by the flexible link aerator have been analysed and aerator efficiency was calculated to compare its performance with other aeration.

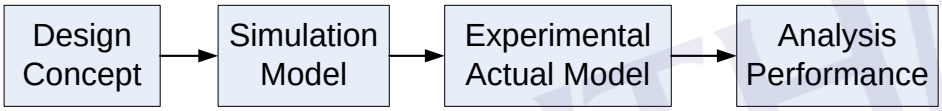

Figure 1.1 : Research Phases

1.7 Organisation of the thesis

A brief outline of the contents of the rest of the thesis is given below:

Chapter 2 present a literature review about the prawn farming, how aerators work in producing the dissolved oxygen in the pond. The next literature review is regarding the advantages of flexible links and some relevant research that have been made. These important topics are very necessary to understand in order to facilitate proper aerator machine design that meets the needs to breeding tiger prawns. Literature review on the effectiveness of the other aerator machine is also made as a benchmark so that the flexible link aerators designed can achieve a good level.

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