SUBMERGED AERATION SYSTEM IN AQUACULTURE

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ABSTRACT

The requirement of aeration in aquaculture became crucial in deciding the productivity of total shrimp. However, the natural aeration provided by atmosphere should not compensate the actual need of oxygen in real time aquaculture practice. For that, various kinds of aeration systems were being emerged in recent years irrespective of their air supplying mechanism. As the biomass under water demands more amount of oxygen for their survival, the need of aeration made compulsory for aquafarm where the aquaculture of shrimps is abundantly nurtured or cultivated. These demands resulted in evolving more aeration technologies to meet the various aeration requirements in aquafarming. Diffused Aeration systems were also emerged as more prominently used aeration techniques in it. This project is mainly concerned with the design of diffuser module which was going to be installed in a diffused Aeration system. We designed a required product in the CATIA V5 software along with its required dimensions. Further the experimentation is done with a scale version of the product (diffuser) by using the 3D printer. Therefore, based on working of the diffuser we concluded that submerged aeration system will improve the productivity of the shrimps.

Keywords: Aeration, Aquafarming, CATIA V5, 3D Printer, Shrimps.

I. Introduction

Aeration is the process of mixing atmospheric oxygen into water of pond or lake. Shrimp yields per unit of production pond area have steadily intensified during recent years. The essential factors allowing intensification are greater feed inputs allowed by higher rates of mechanical aeration. Dissolved oxygen (DO) is one of the most important water quality parameters affecting the quality of aquaculture pond water. Dissolved oxygen is a measure of the amount of gaseous oxygen (as O2) dissolved in water. Aquaculture is termed as farming of shrimps and fish in large sized tanks for commercial purposes. The aquaculture is rapidly increased from past 10 years. Generally a single crop takes two and half or three months to its successful completion. Oxygen transfer rate describes the rate at which oxygen is transferred to the pond water at gas – liquid interface. The more the agitation and spilling of water occur, the more the oxygen transfer rate. All human beings on the planet need oxygen to survive. On earth, living organisms receives oxygen from photosynthesis of plants and trees. In the same way aquatics pecies receives oxygen from aquatic plants by same mechanism. But growing aquaculture intensified the production of shrimps yield per unit area, so that additional amount of Dissolved oxygen is required to the successful completion of a shrimp crop. This emerges the need of Artificial/Mechanical aeration mechanisms to develop. The most common mechanisms of aeration are paddle wheel aerator, Diffuser aerator, and Venture aerators. By using mechanical aeration mechanisms we can supply the dissolved oxygen demanded. Aerators are the devices which are fully equipped with mechanical components aimed to mix the atmospheric oxygen into the pond water by agitating the surface water of pond. Aerators increase the interfacial area between surface water and atmosphere so that more oxygen molecules come in contact with the water drops thus enhancing the overall oxygen transfer rate. Aeration can be done in two modes, based on the requirements of dissolved oxygen we can choose the following modes of oxygen transfer mechanisms. Generally Plants grow in an atmosphere where sufficient water, soil and sunlight available. In water bodies also plants will grow and we call them as Aquatic Plants. Plants and trees on earth releases oxygen to the atmosphere as a byproduct by doing photosynthesis process. In the same way Aquatic plants also releases oxygen molecules in the form of bubbles into the water at submerged levels by doing photosynthesis in day time. 11 In this way mixing of oxygen will takes place in water bodies and it is necessary for fish to live and aerobic bacteria to break down excess nutrients. In case of aqua ponds shrimp yield per unit pond area is intensified in recent times and Dissolved Oxygen from natural mode is not sufficient for the survival, growth, metabolism of living masses. There is an immediate demand of high Dissolved Oxygen rate. To fulfill the requirements we need to go for Artificial/Mechanical mode of aeration. Sometimes the oxygen level in the pond water is not sufficient for the survival of shrimps. When the dissolved oxygen level (D.O) falls below 2mg/l anaerobic activities starts. This leads to failure of overall crop and resulting huge losses to the aqua farmer. Under the poor aeration conditions water bodies experiences various problems such as formation of gases and metals, unstable PH levels, reducing alkalinity and carbon dioxide levels. In artificial mode of aeration a mechanically equipped system will be installed in/on the pond so that it will uses the basic principle of aeration i.e., agitation of surface water or diffusing fine bubbles into the water medium. But here the Dissolved Oxygen rates will be very high when compared with the Natural Mode of aeration. By having the high Dissolved oxygen rates aqua farmers can avoid the previously discussed problems and financiallosses. The most commonly used mechanical aerator system is paddle wheel aerator system. It is a form of water wheel or impeller in which number of paddles is attached around the wheel. It is a surface operating mechanism. The foresaid set up is collectively called as a Fan or Turbine. These turbines are attached to the shaft which is connected to a driving source like electrical motor or diesel/petrol the rotary motion of the shaft is turned into the linear motion of the water. The set of turbines are made to float on the surface water of pond by using thermocol supports. When it is operated on surface water, the rotating turbines splashes the water and split into the air, this phenomenon increases the contact between surface water and oxygen molecules in the atmosphere which increases the Dissolved oxygen concentration in the pond water. The necessity of aeration in aquaculture laid its ways to improve significantly from past few years. Many renowned scientists and scholars initiated their research works in developing different kinds of aeration system and worked to improve the oxygen transfer efficiency of fine pored diffused aeration systems by taking energy intensity as unifying evaluation parameter. He researched and developed fundamental relations by making use of different approaches like oxygen transfer modeling approach, Volumetric oxygen transfer rate as a function of Aeration intensity and Volumetric Energy input as a function of Aeration intensity [1]. Research on arrangement of aerators in an intensive shrimp grows out pond having a rectangular shape. They worked on arrangement of aerators in series (inline), parallel (side by side) and diagonal (diverting apart) and model 15 results were obtained based on the benthic shears tress by classifying the regions of pond like red zone, green zone and dead spots [2]. The researchers published a journal on performance evaluation of propeller-aspirator pump aerator. They proceeded with some theoretical considerations and formulated relations using dimensional analysis. Since diffusers were made in variety of sizes due to availability of different criterions, they used different experimental methods for a variety of propeller-diffusers [3]. They observed various parameters like management of stocking density, Pond size, starting time of aeration, and duration of cultivation for intensive commercial production of shrimp in August, 2010. Prior to the observation of parameters, they conducted a data survey and made linear regression analysis based on the obtained data and formulated the results accordingly [4]. The treatment of sewage water in gigantic water bodies' results in making use of aspirator enhanced in developing the efficiency and their capacity of oxygen transfer rate in waste water treatment plants and produced their research paper stating oxygen transfer rate, efficiency, capacity and their kinetic energy on Aeration system in activated sludge process of sewage treatment plant. They studied about oxygen and its efficiency parameters at various conditions viz. mass transfer coefficient, oxygen at ion capacity and oxygen transfer efficiency at unsteady state in aeration tank for activated sludge process and dependency of sludge retention time and oxygen uptake transfer on waste water treatment [5]. In2017, from Department of Aqua cultural Engineering published an article on importance of Aeration in aqua cultural pond and where the aeration systems must be placedto have stream like flow of water and types of aerator systems [6]. In 2019, many researchers worked on automated Aeration control by improving the accuracy of dissolved oxygen in an automated aerator control system for shrimp farming by Kalman filtering technique. This comprises of many sensors for the measurement of dissolved oxygen. Kalman filtering can be done in two stages in the algorithm. It predicts the estimated value and finds the correction value by measuring through sensors [7]. In 2021, focused on continuous statistical monitoring of various parameters of shrimp culture and published a journal on monitoring shrimp growth with the help of control charts in the aquaculture. Primarily, they collected the shrimp farm data and from that obtained data, they have drawn related graphs of various parameters. Later, the correlated that data with control charts and concluded with the results. The developing trend of Aquaculture has been tremendously increased from past few years. Many of the aquaculture practices involved in using paddle wheel Aerators. Despite having advantages, it became power consuming aeration practice and requires continuous monitoring and maintenance. So we were focused on diffused aeration system and concerned with the design of diffuser and to know how it actually alters the performance of Aeration of diffuser system and environment of shrimps in the pond [8]. Paddle wheel Aerators are the most commonly used aerators in intensive shrimp culture farming but they consume much fossil fuels like petroleum, diesel and requires regular maintenance of the motor. Ultimately it requires high maintenance cost. As it was a surface operating aeration mechanism, it doesn't create much movement of water all over the pond (i.e., from bottom to top) causes bubbles to pop up very quickly without facilitating more oxygen transfer rate and considerable turbulence all over the pond. If paddle wheel aerators were installed in a large rectangular pond, it would definitely require more number of units over the tank causes more number of sets running at same period of time. Even though, there is a chance of setting large diffusers which eliminates more sets or units of aerators reduces consumption of power. This demands the need for an alternative aeration system (Diffuser) which consumes very less power and holds the bubble in water for more amount of time besides creating turbulence over the water of pond.

II. Methodology

To develop a diffuser which ultimately deliver better performance under low cost conditions. The following are the considerations that have taken into account for the development of diffuser; the primary considerations are highly perforated tubular diffuser to get high concentration of bubbles, giving taper to the design to avoid the collisions between air bubbles which ultimately reduces the performance, to place one tubular diffuser by replacing two or more paddle wheel sets, to create turbulence and achieve high mixing ratios at a time, to develop a model which costs very less amount compared to paddle wheel aerators. Based on the above primary considerations, have designed a tubular diffuser with some taper angle and analyzed it as shown in figure 1(a) and 1(b).

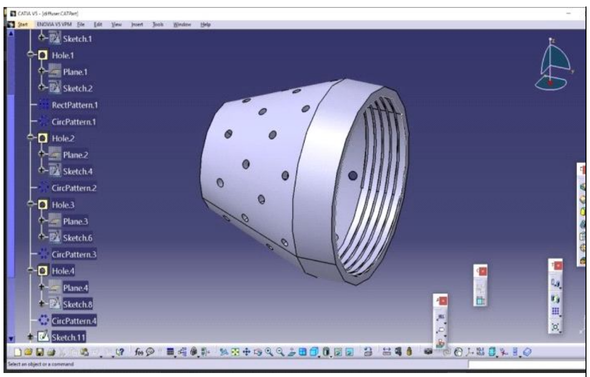	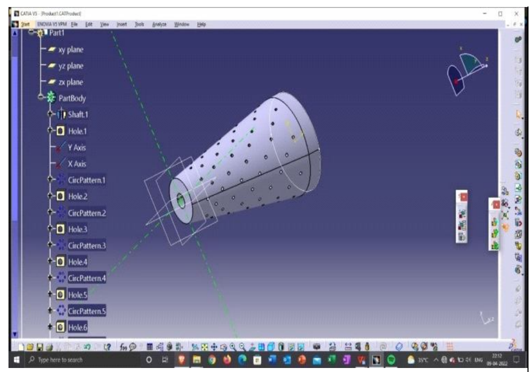
➢ Input Diameter of the diffuser = 50cm ➢ Output diameter of the diffuser = 5cm ➢ Length of the diffuser = 50cm ➢ Taper angle of the diffuser = 110degrees	➢ Input Diameter of the diffuser =10cm ➢ Output diameter of the diffuser = 3cms ➢ Length of the diffuser = 100cm ➢ Taper angle of the diffuser = 100degrees

Fig. 1: (a) Primary Design (b) Secondary Design

The respective dimensions, have designed a tapered tubular diffuser. Here the compressed air input mouth is very large in diameter which provides practical conditions. A 50 cm input of compressed air is not possible while considering this particular aquaculture, it causes rapid pressure drop due to large area, economically it costs high amount, handling issues rises which we cannot prevent etc. To avoid all these problems we have designed a model which is quite different from the above one. The revised dimensions of the diffuser: increase in diffuser length, decrease in output diameter which produces 3 cm coarse bubble usually creates turbulence in the pond water, decrease in input mouth diameter to 10 cm which is practically possible to deliver the compressed air supply at a decent rate. But in this design also some problems still exist and these can be overcome by optimizing the dimensions and parts of the geometry. The bubbles will get collide with each other at very beginning they are produced. This reduces the bubble size which automatically decreases the mixing performance because there is no additional area exposing to atmosphere. When a bubble popped out from the diffuser it travels all the way and reaches surface water of the pond. By reaching the surface water of the pond the bubble tries popup by splashing the water droplets into the atmosphere. All this is possible when the bubble size is considerable and large in diameter. But due to early collisions between the bubbles the Dissolved oxygen (DO) mixing performance will gradually decreases. This phenomenon decreases the overall performance of the aerator and low efficiency. To overcome this effect we went through several practical problems and understand the aerating mechanism basics. Now optimized the design parameters again and created a new geometry as shown in figure 2(a) and 2(b).

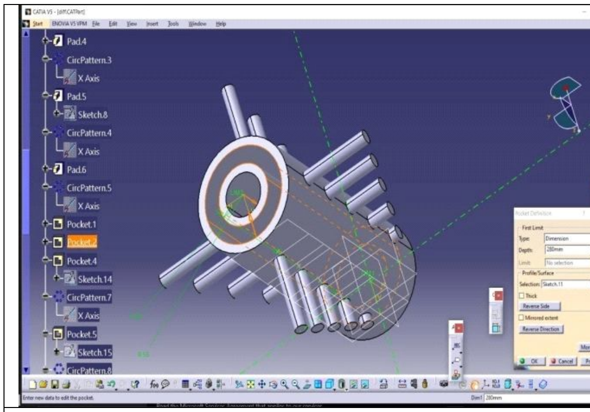	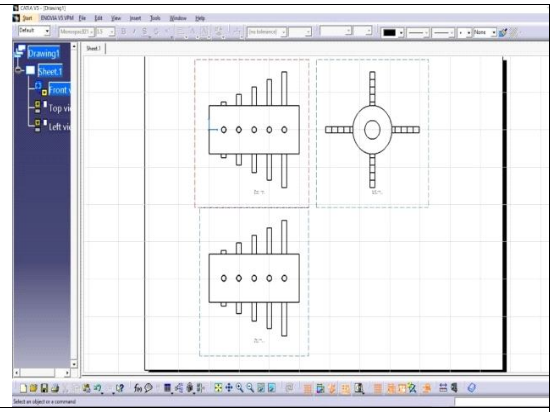
➢ Outer diameter of diffuser = 10cm ➢ Inner chamber diameter of diffuser = 4cm ➢ Hollow chamber final dimensions (radius) = 3cm ➢ Length of the diffuser = 100cm ➢ Extruded pipes diameter = 1 cmeach ➢ Extruded pipes length = 2, 4, 6, 8, 10 cm respectively.	➢ Outer diameter of diffuser = 10cm ➢ Inner chamber diameter of diffuser = 4cm ➢ Hollow chamber final dimensions (radius) = 3cm ➢ Length of the diffuser = 100cm ➢ Extruded pipes diameter = 1cm ➢ Extruded pipes length = 2, 4, 6, 8, 10 cm's

Fig. 2: (a) Optimized Design (b) Scale Version of Design – 2D Image

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The above design has a mouth of 10 cm diameter which is divided into two chamber one is to create turbulence by generating a coarse bubble of minimum 3 cm and another chamber is to facilitate fine bubble delivery through extruded pipes which have direct connection to compressed air from the outer periphery of the diffuser. Some amount of compressed air is bypassed to hollow chamber to generate fine bubbles to achieve high DO mixing ratios and some amount of air is forced to travel to the direct outer end to a through hole with minimum bubble diameter of 3 cm turbulence facilitate active metabolism to the shrimps which directly helps in increasing feed intake efficiency of shrimps which automatically increases the count. Once the count is increased, the farmer will get high crop yields and results in huge profits. That is why, focused on turbulence aspect also in a single design.

III.Fabrication of diffuser in 3D Printer

3D printers, sometimes known incorrectly as "3D printing machines", are additive manufacturing machines that specialize in making custom parts with accuracy. Fused deposition modeling (FDM) is an extrusion-based 3D printing technology. The build materials used in fused deposition modeling are thermoplastic polymers and come in a filament form. In fused deposition modeling, a part is manufactured by selectively depositing melted material layer by layer in a path defined by the CAD model and The components used are shown in table 1

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➢ **Characteristics and application of FDM:** When using fused deposition modeling as the manufacturing process, a designer should keep its capabilities and limitations in mind to produce the best results. Fused deposition modeling requires iterative design through prototypes as features do not usually print correct the first time.

➢ **Temperature and build speed:** The nozzle and build platform temperature, build speed, layer height and cooling fan speed are all adjustable in most fused deposition modeling systems. This are often set by the printing service provider and varies with the material. The nozzle and build platform temperature, build speed, layer height and cooling fan speed are all adjustable in most FDM systems. This are often set by the printing service provider and varies with the material.

➢ **Build volume:** It is the biggest part the machine can build. A DIY 3D printer's build volume is typically 200x200x200mm, while industrial machines can have built volumes as large as 1000x1000x1000 mm. Consider the build volume of the printer you will be using during the design. Remember larger model can also be printed in smaller chunks and might be better in terms of cooling

Table 1. Specifications of air pump

FREQUENCY	VOLATAGE	POWER	FLOWRATE	OUTPUT	PRESSURE
50HZ	AC 220V	6W	0.076A	30L/min	28kpa
60HZ	AC 220V	4.2W	0.055A	21l/min	35kpa

IV. Experimentation

An air pump is a pump for pushing air. All air pumps contain a part that moves (vane, piston, impeller, diaphragm etc.) which drives the flow of air. When the air gets moved, an area of low pressure gets created which fills up with more air. When the piston is pulled up, air gets sucked into the pump through the inlet. The pump chamber depressurizes as it fills with air. When the piston is forced down, the air becomes compressed and closes the inlet. Then the air flows out from the outlet. Air hoses are used to convey compressed air for pneumatic systems. These air hoses must have high strength to handle high pressures in order to prevent leakage and damage. In addition, oil-based lubricants are sometimes added to the compressed air for smooth running of the equipment. A container Such as glass tank or an artificial pond in which living aquatic animals or plants are kept in establishment where aquatic organisms or kept and exhibited. So this type of tank for this experimentation is used as shown in figure 3.

Fig. 3 Final diffused aeration system

Diffused aeration is a sample concept the pumping air through a pipe or tubing and releasing this air through a diffuser below the water surface. Diffused aeration systems come in two main types such as fine bubble and coarse bubble. Fine bubble aerator diffusers produce a smaller-diameter bubble for the aeration process. These bubbles typically measure 1to3mm in diameter. This fine bubble aeration usually provides 2% or more Standard Oxygen Transfer Efficiency during aeration. Coarse bubble system is a secondary treatment phase .Coarse bubble sizes ranges from 3 to 50 mm*. When gas enters into the diffuser coarse bubble is produced .It will flow from the bottom to surface of the water and produce the turbulence on the water. It will leads to increasing the digestion of shrimp.

V. Results and Discussion

- **Characteristics of Bubble:** Formation is generally accomplished by passing air through an orifice. Bubble volume has been empirically determined as

$$Vb = 2\pi R\sigma / g\Delta p$$

Where Vb = bubble volume, cm^3
a = bubble radius, cm
R = orifice radius, cm
σ = surface tension, dynes/cm
g = gravitational constant, cm/sec^2
Δρ = difference between ρ, density of liquid in $gram/cm^3$
ρ = density of the bubble.

Accordingly, the radius of a bubble is directly proportional to the surface tension and the radius of the orifice, and inversely proportional to the difference in densities between the liquid and gas. Temperature and viscosity have only marginal effects on bubble diameters.

➢ **Bubble shape:**
Bubble shape varies with the diameter and this is caused by the varying drag forces. Radius <0.01 cm (solid spheres)
Radius 0.01 to0.1 cm (deviational from spherical)
Radius >0.1 cm (ellipsoidal)

➢ **Coarse bubble:**
Diameter d = 1cm; Pressure P = 28kpa; Radius r = 0.5cm;
Area of the pipe$A=\pi r^2 = \pi (0.5)^2 = 0.785 cm^2$
Volumetric flow rate Q = V x A
Where: Q = Volumetric flow rate; V = Velocity of the bubble
Density of air Þa = 1.293 kg/m3
Density of water Þw = 103 kg/m3
Coefficient of viscosity of water = 10^{-3}Nsm^{-2}
$V = (2\times r^2\times [Þa-Þw]\times g)/9\times\eta$
$V = (2\times (5\times10^{-3})^2\times [1.293-103]\times 9.8)/9\times10-3$
$V = 54.37\times10^{-3}$m/sec.
Q = $V\times A = 54.37\times10^{-3}\times0.785\times10^{-4} = 4.26\times10^{-6} m^3/sec.$

Mass flow rate m = $Q \times Þ = 4.26\times 10^{-6} \times 10^3 = 4.26\times 10^{-3} kg/sec.$
Air flow rate $V = 4005\times \sqrt{\Delta p}$
V = Flow velocity in ft. /min
Δp = Change in pressure.
$\Delta p = p_2 - p_1 = 0.35 - 0.28 = 0.7$ kpa
V = 4005 x √0.7 = 4005 x 0.836 = 3,350 Ft/Min

Flow Velocity = 3350 Ft/Min.
Time for the coarse bubble = D/V
D = Distance travelled
V = velocity
T= D/V =$5.5\times10^{-2} / 54.37\times10^{-3}$ = 1.01sec

➢ **Fine bubble**:
Diameter d = 0.5cm; Pressure P = 28kpa; Radius r = 0.25cm
Area $A = \pi r^2 = \pi(0.25)^2 = 0.196 cm^2$
Volumetric flow rate Q = V×A
Q = Volumetric flow rate;
V = Velocity of the bubble;
A = Area of the pipe
Density of air $Þ_a$ = 1.293 kg/m^3;
Density of water $Þ_w$ = 103 kg/m^3
Coefficient of viscosity of water = 10^{-3}Nsm^{-2}
$V = 2 \times r^2 \times [Þ_a - Þ_w] \times g \;/\; (9 \times \eta)$
$V = 2\times (0.25\times10^{-3})^2\times [1.293-10^3]\times 9.8 \;/\; (9\times10^{-3})$
$V = 13.59\times 10^{-3}$m/sec.
Q = $V \times A = 13.59\times 10^{-3} \times 0.196 \times 10^{-4} = 2.66\times 10^{-7} m^3/sec.$

Mass flow rate m = $Q \times Þ = 2.66\times 10^{-7} \times 10^3 = 2.66\times 10^{-4} kg/sec.$
Time for the fine bubble = D/V
D = Distance travelled;
V = velocity
$T_1 = D_1/V = 6.5\times10^{-2} / 13.59\times10^{-3} = 4.78$sec
$T_2 = D_2/V = 7.5\times10^{-2} / 13.59\times10^{-3} = 5.51$sec
$T_3 = D_3$/V=$8.5\times10^{-2} / 13.59\times10^{-3} = 6.25$sec
$T_4 = D_4/V = 9.5\times10^{-2} / 13.59\times10^{-3} = 6.99$sec.

$T_5 = D_5/V$ =10.5×10^{-2} / 13.59×10^{-3}= 7.72sec.

VI. Conclusions

In diffusion aeration system there are different types of aerations are used .while comparing of other aeration systems like paddle wheel aeration system and diffusion aerations system, choose the submerged aeration system in the aqua culture to increasing the productivity of shrimp. Production of shrimp is mainly depending on the turbulence and rate of dissolved oxygen in the water. Based on these two considerations were searched on different types of submerged aerations systems and their designs. Finally, the required product was designed in CATIA V5. Further, experimentation was done on a scale version of the product (diffuser) by using the 3D printer. Therefore, based on working of the diffuser, concluded that submerged aeration system will improve the productivity of the shrimps.

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