EFFECT OF DELTA WINGS AND DEFLECTORS TO IMPROVE THE PRODUCTION IN ALGAL

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Abstract

In-order to meet the increasing demand of energy people are switching over to renewable source of energy. Bio-fuels to a larger extent has proven to be a very effective replacement to fossil fuel and hence stress is given on its production. Algal culture is gaining prominence. These algae are cultured in open raceway ponds and studies are being carried out to improve its efficiency. Hydrodynamics of water like vertical mixing, dead zone formation are few of the important parameters affecting the efficiency of raceway. Herein, study on the improvement of the hydrodynamics of a raceway from CFTRI has been done. Effectiveness of Delta wing (DW) in improving vertical mixing of pond was studied, furthermore parameters like DW angle of attack and number of DWs were optimized. In addition effectiveness of deflectors in solving the issue of dead zones at bends was studied.

Keywords: *Algal pond, Delta Wings, Deflector, Vertical Mixing, Deadzones.*

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1. INTRODUCTION

Increase in demand for renewable energy has drawn attention towards biodiesel [1]. Algae being the source of biodiesel are being cultured. Biodiesel from algae has high potential to replace fossil fuels. Furthermore it can be grown in non-arable land and even reduces greenhouse gas in environment as it takes in carbon-dioxide for photosynthesis [2, 3].

Algal growth is carried out in two types of facilities they are open raceway (RW) and photo- bioreactors. RW is comparatively simple and cost effective, wherein water is circulated using paddlewheel and is exposed to nature. In contrast photo- bioreactor are closed container containing algal solution [1]. In our studies we have considered open raceway ponds.

Exposing algal cells to alternating period of light and darkness helps in improving the efficiency of algal growth. This process is being termed as Flashing Light Effect. Vertical mixing is one of the way to improve FLE [4, 5]. With an objective to improve vertical mixing vortex generators like delta wings (DW) are used [6, 7]

Formation of dead zones at bends are detrimental to the growth of algae. Stagnated water may become breeding ground for unwanted microbes thereby affecting the efficiency of raceway. Installation of deflectors do resolve the issue to some extent [8, 9].

2. MATERIALS AND METHOD

Effect of Delta Wings and Deflector was studied for an algal pond in CFTRI.

2.1 Geometry and Dimensions of Raceway Pond

An algal raceway pond of total length 3.7m with operating depth of 0.375m was simulated. Wherein 8 blade paddlewheel is used for keeping the water in motion. Dimensions are mentioned in Table 1.

Table -1: Dimensions for raceway

Part Name	Dimensions (cm)
Depth	37.5
Length	370
Breadth	145
Baffle length	370
Baffle thickness	16
Blade Length	60
Blade breadth	19
Distance between the propeller tip and the base of the floor	3
Propeller RPM	15

2.2 CFD Modelling and Solver Settings

Geometric model construction and meshing is performed using ICEM CFD (meshing tool in ANSYS Fluent). The U-RANS equation is solved using ANSYS fluent 16.2. It has been found that k-ω SST model has the tendency to provide better result [10] and has also been found to be a right modelling choice for the flow over delta wings [11]. So, here we used k-ω model with standard wall functions, in order to handle the near wall regions.

The top of the raceway pond is model as zero shear stress rigid lid boundary condition. By using this boundary condition we can get rid of multiphase modelling which is computationally expensive [12].And all other solid regions are treated as rigid walls with no slip boundary condition.

Propeller region is modelled as a Plane with fan boundary condition having a discontinuity in pressure across it and transient simulation [12].

Power required by the paddlewheel is one of the essential flow parameter which is to be considered. Power required to run the water in the raceway is given by:$P= Q*\Delta p$, *where* Pis the power required for an ideal paddle wheel with 100% efficiency, Q is the volumetric flow rate, and $\triangle p$ is the pressureloss in the channel. Installation of delta wings would result in resistance hence change in the power consumption.Hence, with an objective to nullify the effect of power on our result all the simulations were carried out such that power remains equal. Through iterative process pressure and flow rate were so chosen that power remained same for all the simulations [12, 13]. Fig 1 is the geometry of the simple raceway pond, wherein vertical plane in the channel represents a paddle wheel and the flow is in clockwise direction.

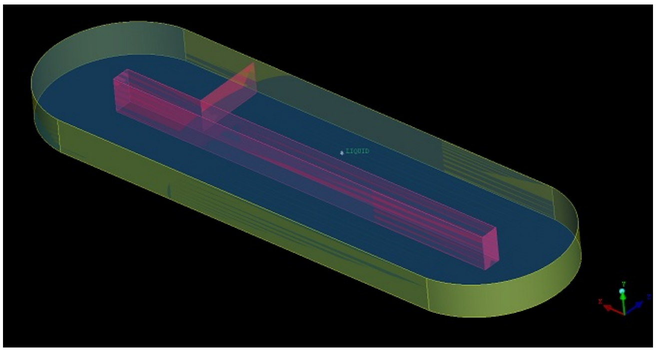

Fig -1: Geometry of simple raceway pond

Fig 2 is the geometry of the raceway pond with delta wing (DW). DW herein, used is an equilateral triangle of length 0.54m. CFD simulations were done to optimize the angle of attack for improving the efficiency of the raceway. Different angle of attacks of: 10, 20, 30 degrees were considered. Angle of attacks above 30 degree would project the DW tip, out of the liquid hence were not considered.After optimizing the angle of attack, minimum number of DWs, with the optimized angle, required for the pond was found. Number of DWs for the pond was optimized by finding out the distance up to which DW has increased the vertical velocity of the flow. Three imaginary planes a, b, c were created after the DW respectively along the flow direction. Vertical velocities of the simple raceway pond and that of raceway with DW at these planes were compared.

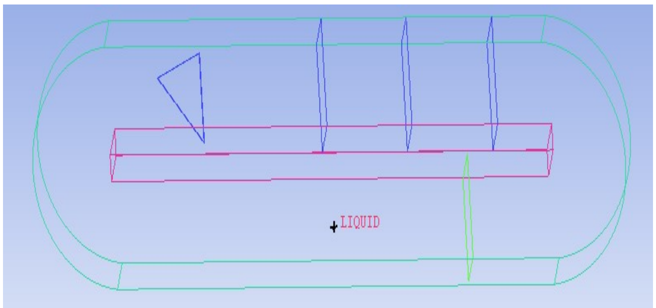

Fig 2: Geometry of raceway pond with DW

Fig 3 is the geometry of raceway pond with deflectors installed at bends. These deflectors are semi-circular in shape which are parallel to walls at bends. Their effect on minimizing dead zone formation at bends was studied.

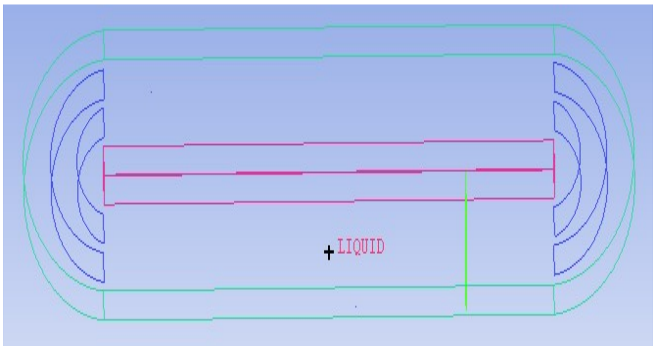

Fig -3: Geometry of raceway pond with deflectors

3. RESULT AND DISCUSSION

Fig 4 is the velocity contour for the simple raceway pond, wherein it can be observed that at the bends there are dead zone formation where the velocity is almost zero. Moreover, from Ansys post analysis software, it was found that the average vertical velocity for the pond is 0.03 m/s, which is low.

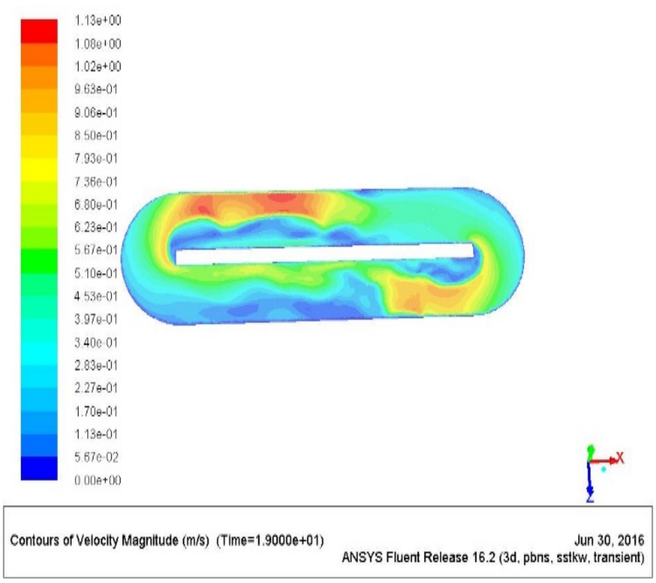

Fig -3: Velocity contour of simple raceway pond.

3.1 Optimizing Angle of Attack

10, 20 and 30 degrees were considered as angle of attack for the simulation wherein power consumption was kept same for all the simulations. Effectiveness of the DW was judged based upon the increase in the vertical velocity of the fluid flow [4]. Table 2 shows the average vertical velocity of stream at different angle of attack.Installation of DW did improve the vertical mixing of the pond as the vertical velocity has increased. From Table 2 it is clear that angle of attack of 30 degree is more effective compared to other.

Table -2: Average vertical velocity for different Angle of Attack

Variation	p (Pa)	Q (m3/s)	P=Q*△ p (W)	Vertical Velocity (m/s)
Without DW	440	0.087	38.2	0.03
10 degree	460	0.083	38.18	0.035
20 degree	470	0.081	38.07	0.047
30 degree	485	0.078	37.7	0.087

3.2 Optimizing Number of DWs

Table 3 gives the vertical velocity at the planes a, b, c for the simple raceway and raceway with DW (DW is at optimized angle of attack).

Table -3: Vertical velocities at various planes

Plane	Simple Raceway	Vertical Velocity (m/s)	DW with 30 degree	Vertical Velocity (m/s)
a		0.015		0.0533
b		0.0047		0.036
c		0.0025		0.0415

It can be clearly observed that the vertical velocity has increased such that DW which is being installed at one end of the raceway has its effect on the vertical velocity till plane 'c' which is located at the other end of the raceway. Hence, one DW on either side of the baffle would be sufficient for improving the vertical velocity of whole raceway.

3.3 Effectiveness of Deflectors

Fig 4 is the velocity contour for the raceway pond with deflector. A comparison of Fig 4 against Fig 3 shows that dead zone formation at bends has decreased with the installation of deflectors at bends. Moreover, velocity distribution along the pond has become uniform.

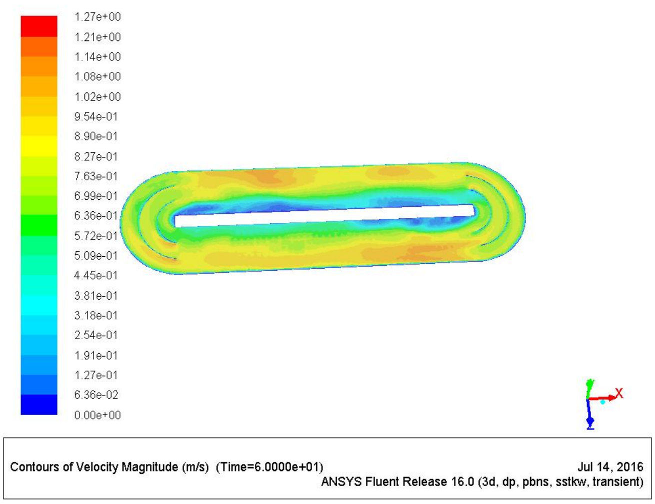

Fig -3: Velocity contour of simple raceway pond.

The simulation has been carried out such that the power consumption for that of simple raceway is equal to that of raceway with deflectors.

Table -4: Power Consumption for simple raceway and that of raceway with deflectors

Variation	p (Pa)	Q (m3/s)	P=Q* △ p (W)
Simple Raceway	440	0.087	38.2
With Deflectors	300	0.127	38.1

Moreover, it can be observed from Table 4, that the pressure drop in the stream along the flow has decreased with the installation of deflectors at bends. Hence, installation of deflectors at bends does help in curtailing some of the fluid frictional loss at bends.

4. CONCLUSION

Delta wings did increase the vertical mixing of the raceway. An angle of attack of 30 degree was found to be more effective and total of two DWs, one on each side of the baffle are sufficient for improvement in vertical mixing for the given raceway. Deflectors are very effective in solving the issue of dead zones at bends.

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BIOGRAPHIES

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