Application of CFD (Computational Fluid Dynamics) to optimization (energy consumption and productivity) of an open pond raceway used to microalgae cultivation

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Abstract
Using Computer Fluids Dynamics (CFD) and experimentation, the company Drops & Bubbles Tecnología, a spin-off from the Fluid Mechanics Department in the University of Seville, has developed and patented a new system for algae cultivation in open ponds (raceways). The system is based upon the traditional paddle wheels tanks but with substantial changes both in the geometry of curve zones and the driving procedure.
Optimization of geometry and functioning of these cultivation tanks was undertaken with a twofold objective: reduction of the energy consumption needed for stirring the medium and the concentration of the solid decantation particles in one or several previously fixed points.

Introduction
Drops & Bubbles Tecnología SL was born 4 years ago as a spin-off from the University of Seville. One of its business branches is the CFD (Computational Fluid Dynamics) consultancy. This tool uses advanced numerical simulations programs in order to anticipate the behavior of the most significative parameters related to productive operations where fluids are involved. On the other hand, the technical Department in the company has been working since the beginning of activities in the development of high efficiency aerators to be used in aquaculture. The connection between microalgae cultivation and aquaculture has inspired the work we are presenting in this communication.

Material and methods

As an example of the CFD technique (ANSYS Workbench), Fig 1 shows an image of the meshing in the areas of suction and thrust; in Fig 2 there is a representation of the velocity vectors in a perpendicular plane to the propellers necessary to move the liquid (water + algae + salt, etc.) inside the raceway.

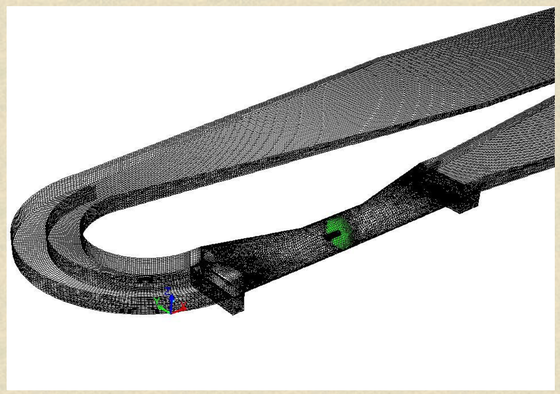

Fig 1. Geometry in the suction zone

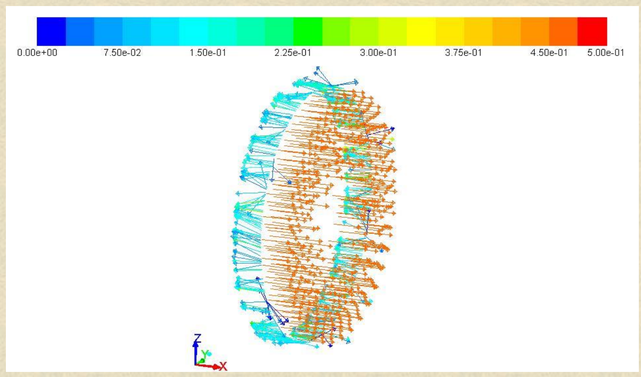

Fig 2. Velocity vectors in the plane transverse to thrusting propellers

Parameters and phenomena related to the hydrodynamic behavior: head losses, backwater areas, inside velocities and on the surface of the flow, flow rate (effective/provided), pumping power, vortex formation, etc. may be estimated with a high degree of accuracy before building the real model.

Results and discussion

In Fig 3 it is shown a real design of a tank which incorporates the mentioned optimization. It belongs to a collaborative project with the IBFV (Institute of Vegetal Biochemistry and Photosynthesis) in which the most important parameters in algae cultivation were compared between a traditional raceway using paddle-wheels and the optimized design by D&BTech. A summary of the most significative results are shown in Table 1.
Algae used in this project were Chlorella vulgaris, Monoraphidium Circinale and cyanobacteria Anabaena ATCC33047.

The most outstanding aspects of this new cultivation tank are:
- Hydrodynamic design: central wall, lateral walls and guidance-deflectors
- Decantation zone to facilitate maintenance tasks
- Thrusting turbine and gas injection system specially adapted to cultivation operations

Fig 3. Raceway built for the R&D Project in the IBVF

	Productivity biomasss (mg l^{-1} d^{-1})	Produced biomass / injected CO_2 (gl^{-1})	Energy consumption (W)
Tank designed by D&BTech	77 ± 32	0,42	24
Traditional paddle-wheels tank	46 ± 26	0,47	178

Table 1. Main results obtained in the two tanks where tests were performed.
Data are the media of three replications. For Productivity results, standard deviation is also included

References
ANSYS Workbench / Fluent 14.5, ANSYS Inc., USA. 2013

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