CtrlAQUA

Importance of computer modeling in aquaculture (supported by examples)

Aquaculture industry is progressively interested in producing and utilizing larger land-based (RAS) and semi-closed containment systems (S-CCS) to accomplish high production goals and economy-of-scale. Consequently, bigger size and complexity of the systems have high degree of turbulence, and even distribution of gasses, feed and fish and self-cleaning is a challenge. The overall hydrodynamic performance of the system is influenced by inflow characteristics, i.e. turbulence produced by inlet orientations, inlet (nozzles) and outlet positioning and internal structures. An actual experimental study on such a high flow condition that involve velocity, uniformity, vorticity and swirl number changes is not feasible. Therefore, computational fluid dynamics modeling (CFD) is considered as the most appropriate tool to investigate the hydrodynamics of such a large and complex system.

Methods

The hydrodynamics of the system is evaluated using different flow field indicators, such as flow velocity, distribution of vortices, turbulence in the system and vorticity. Flow rate through the inlet pipes at both sites is measured using a transit-time type, Portaflow 300 ultrasonic flowmeter. Water rotational velocity measurements are collected using a Nortek Acoustic Doppler Velocimeter, which determines the instantaneous velocity vectors of local flow. The measuring head of the instrument contains the bistatic acoustic system, which emits short acoustic pulses at a frequency of 6 MHz. The three transducers, placed around the transmitter with 120o azimuth interval, receive the echo, which undergoes digital signal processing in the conditioning module to measure the Doppler shift. This processing module is a low power, standalone component, intended for underwater applications.

Modeling configuration

Naiver Stokes equation for incompressible fluids is solved with SIMPLE algorithm, which is Semi Implicit Method for Pressure Linked Equations. Where initially pressure and velocity values are estimated by algorithm and later pressure-correction equation $\nabla^2 p' = 1/(\Delta t\,(\nabla \cdot V)$ is solved to obtain a corrected value of pressure and velocity field and at the solution convergence is checked (figure 1). A k-omega SST turbulence model with first order accuracy in space and time is used to solve Turbulence Kinetic Energy (k) and Specific Dissipation Rate (ω).

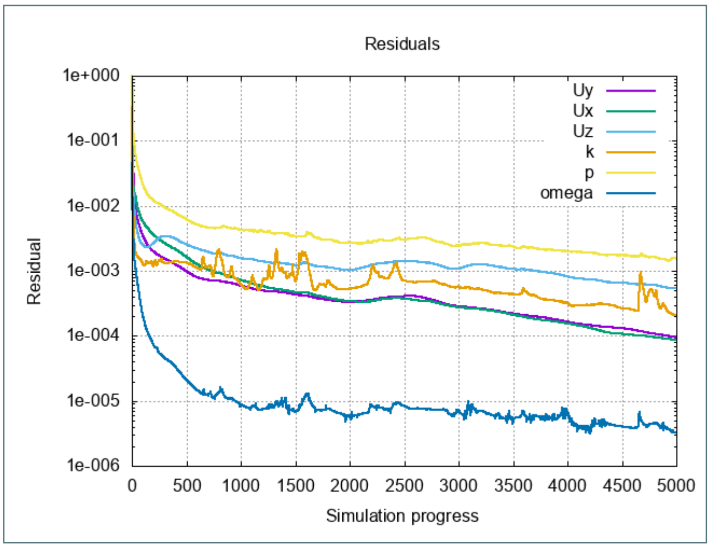


Figure 1: Residuals graph for Simulation Convergence check (Velocity (Ux, Uy, Uz), Turbulence Kinetic Energy (k), pressure (p), Specific Dissipation Rate (ω).

Examples and discussion

All land-based (RAS) or semi-closed containment systems (S-CCS) are equipped with numerous inlet columns. The designing of those inlet columns plays a vital role for achieving a more uniform mixing and flow pattern across the tank. Some inlet column designs are built with either single large inlet face or with numerous small nozzles. The effect of inlet column can be seen in figure 2, where half of the nozzles are aligned toward the center of the tank. Those minor change in inlet column will impact the whole system by removing velocity dead zones plus tank self-cleaning is improved, respectively.

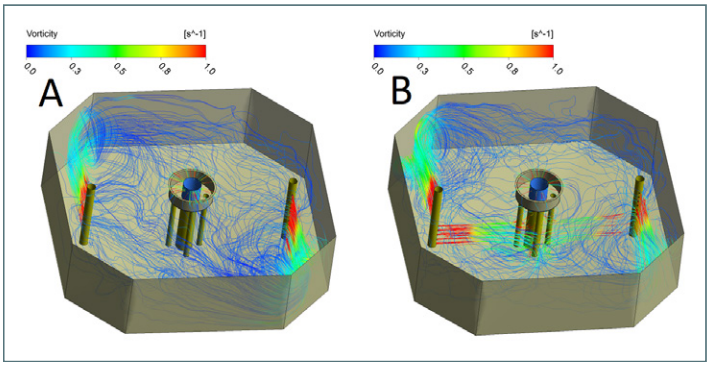


Figure 2: Comparing Two Octagonal tanks with two inlet columns and elevated central outlet. Each inlet column is designed with numerous small nozzles (a) All the nozzles are directed toward the center of opposite small wall (b) Half of the nozzles are directed toward the center of opposite small wall and remaining half toward the center of the tank.

In another example, when all nozzles of inlet column are moved toward the center of the big wall side (figure 3 (A), a huge velocity drop is generated in center region, as compared to the case when all nozzles of inlet column are moved toward the center of small opposite wall figure 3 (B).

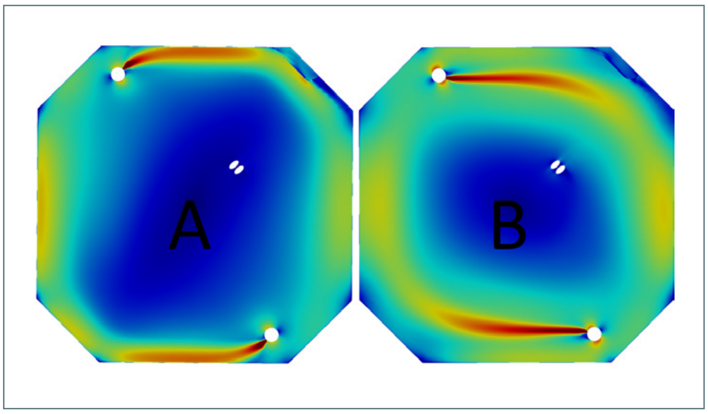


Figure 3: Comparing Two Octagonal tanks with two inlet columns and side outlet. Each inlet column is equipped with numerous small nozzles (a)All the nozzles are directed toward the center side big wall (b)All the nozzles are directed toward the center small wall.

Figure 4 shows another case of octagonal tank, where 25% more inflow from Inlet 1 than Inlet 2 are modeled. The stream line results are quiet astonishing, when outlet flow is closed and open in figure 4 (a,b), respectively. The slice shown in figure 4 (c,d) is the cross-sectional region of the tank with velocity mapping. When the central outlet is closed the velocity in central region is low with no mixing pattern seen across the tank as compared to the case, when the central outlet is fully open and very nice mixing pattern is produced along with tea-cup effect which helps in self-cleaning of the tank.

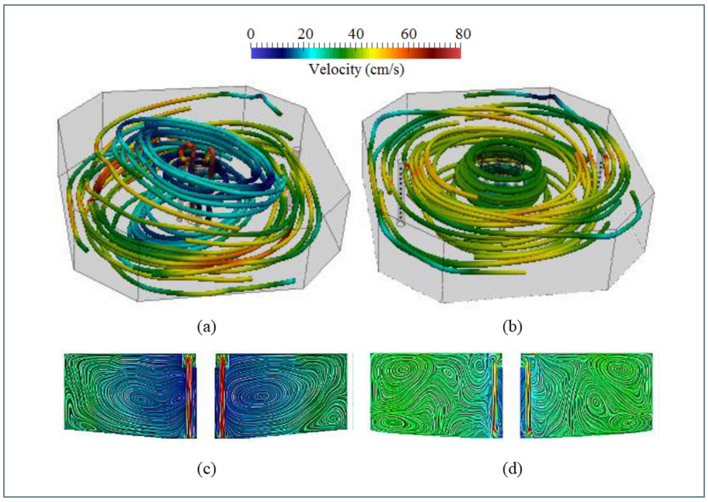


Figure 4: Streamline pattern in the tank with 25% more inflow from Inlet 1 than Inlet 2. Figures show 3D streamlines without (a) and with (b) flow through the outlet casing, and sectional streamline distribution across the central vertical plane without (c) and with (d) flow through the outlet casing, respectively.

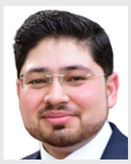
With the help of CFD, we can predict the tank hydrodynamics (water velocity/flow patterns) which is beneficial for fish welfare and tank self-cleaning. CFD can help designing optimal systems and is far cheaper than building before physical testing. Therefore, the new mega structures in aquaculture industry which are in building phase need computer modeling to improve the system performance in efficient and cost-effective ways.

Over the past years, Nofima is helping industry with computer modeling, to improve hydrodynamic conditions and fish welfare in different shapes of tanks.

About the research

CtrlAQUA project: HYDRO
Partners: Nofima and industrial partners in CtrlAQUA

Contact



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This is CtrlAQUA
CtrlAQUA is a centre for research-based innovation (SFI) doing research on closed-containment aquaculture systems on land and at sea. The main goal is to develop technological and biological innovations that will make closed systems a reliable and economically viable technology. Nofima AS is the host institution of CtrlAQUA, and is collaborating with several partners from research, the supplier industry and salmon farming companies