Simulation of a paddlewheel aerator in an aquaculture tank

João P. Marques[1,2], Rita F. Carvalho[1], Pedro M. Pereira[2]

Department of Chemical Engineering, University of Coimbra, Portugal

MARE – Marine and Environmental Sciences Centre

CERES – Chemical Engineering and Renewable Resources for Sustainability

Index

1. Overview

Population increases → Increasing demand for seafood → Overfishing → Aquacultures

- Depletion of fish stocks;
- Disruption of marine ecosystems;
- Threat to livelihoods;
- Habitat destruction.

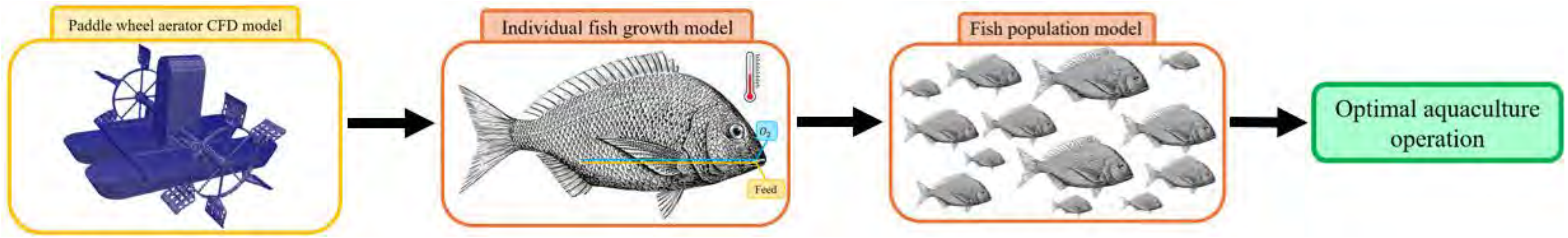
1. Overview

Large amounts of fish reared lead to large oxygen needs!

Aeration devices (paddlewheel aerators)

2. Motives

SISdATA project - Aiding in the creation of a new information system to support aquaculture all across the Atlantic Area



3. Problem Statement

- Aquaculture operation control is based only on diffused oxygen levels measurements;
- Improper control over paddlewheel aerators could lead to energy waste and be counterproductive;

3. Problem Statement

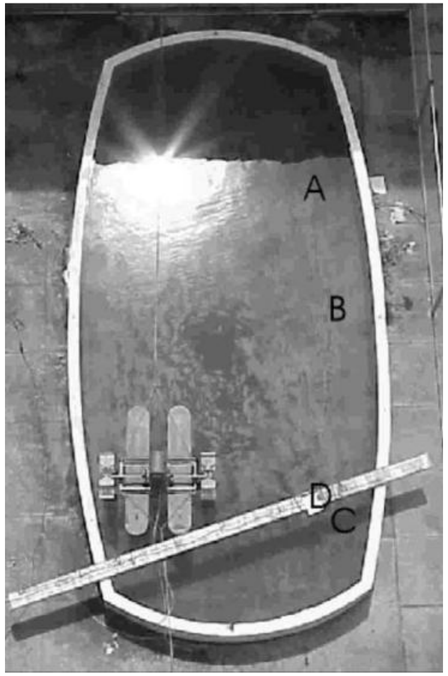
- Acording to Peterson et al. (2001), “backsplashing dilutes the oxygen-starved water entering the paddlewheel, thereby degrading the operational efficiency”.

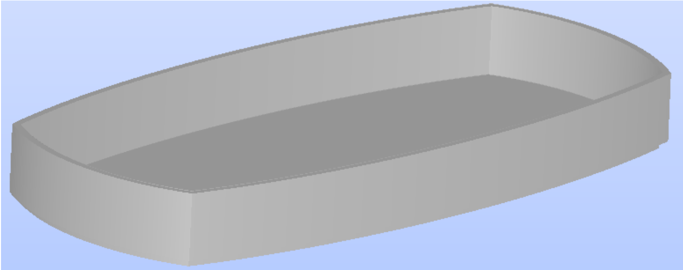
4. Objectives

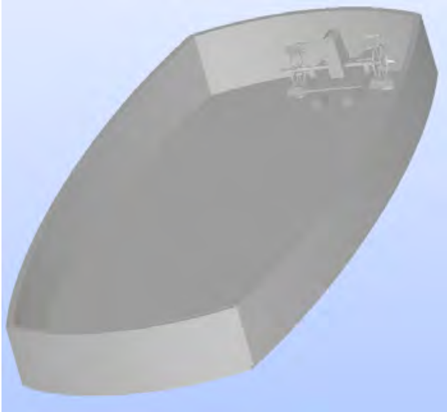
- Verify if, in fact, if more backsplash happens in higher aerator rotational speeds (recreation of paddlewheel aerator from Peterson et al. (2001));
- Access whether, through OpenFoam, we are able to verify stationarity in this system.

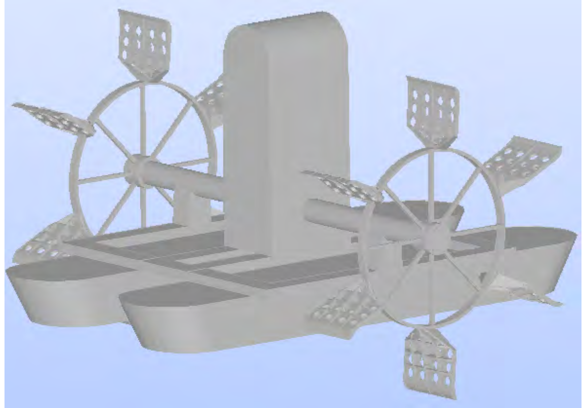
5. Simulation setup

5.1. Geometry creation - **SALOME**



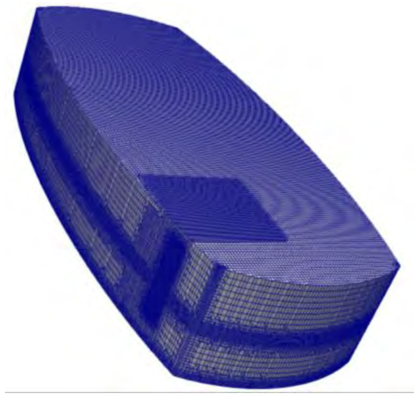




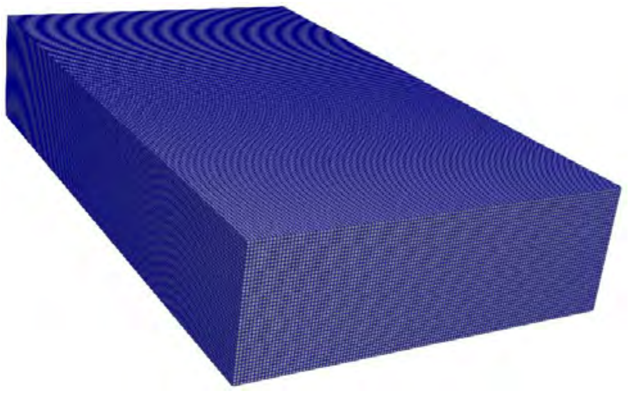


5. Simulation setup

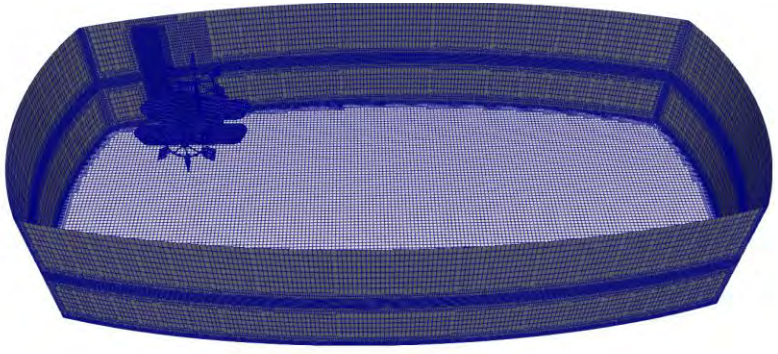
5.2. Mesh creation

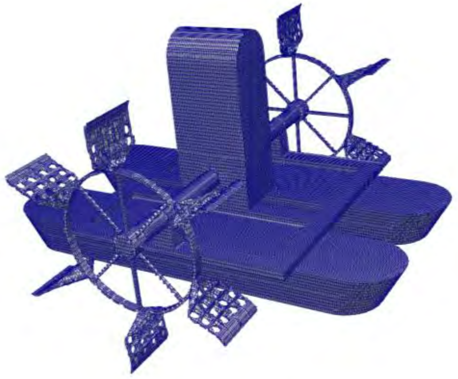


blockMesh



snappyHexMesh





Number of cells: **6, 694, 388**

5. Simulation setup

5.3. Solver

interfoam solver: solves the Navier Stokes equations for two incompressible, isothermal immiscible fluids.

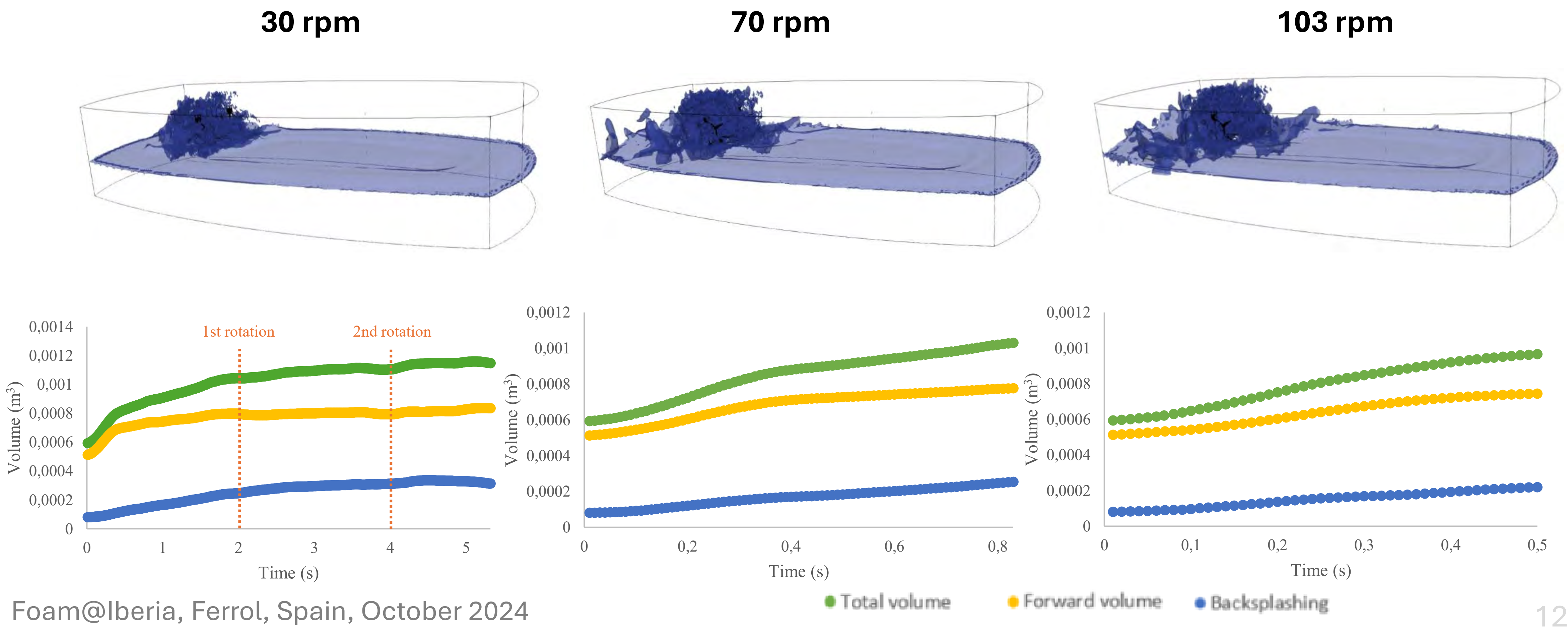
Continuity equation: $$\frac{\partial_{u_j}}{\partial_{x_j}} = 0$$

Momentum equation: $$\frac{\partial(\rho u_i)}{\partial t} + \frac{\partial}{\partial x_j}\left(\rho u_j u_i\right) = -\frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j}\left(\tau_{ij}\tau_{t_{ij}}\right) + \rho g_i + f_{\sigma i}$$

Equation for the interphase: $$\frac{\partial \alpha}{\partial t} + \frac{\partial(\alpha u_j)}{\partial x_j} = 0$$

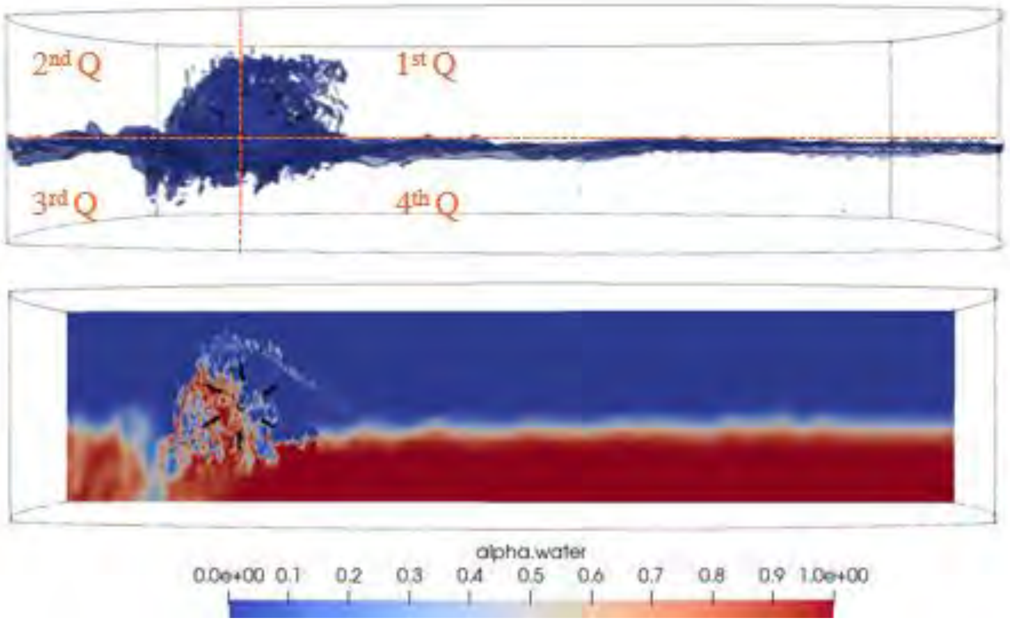
6. Results and disussion

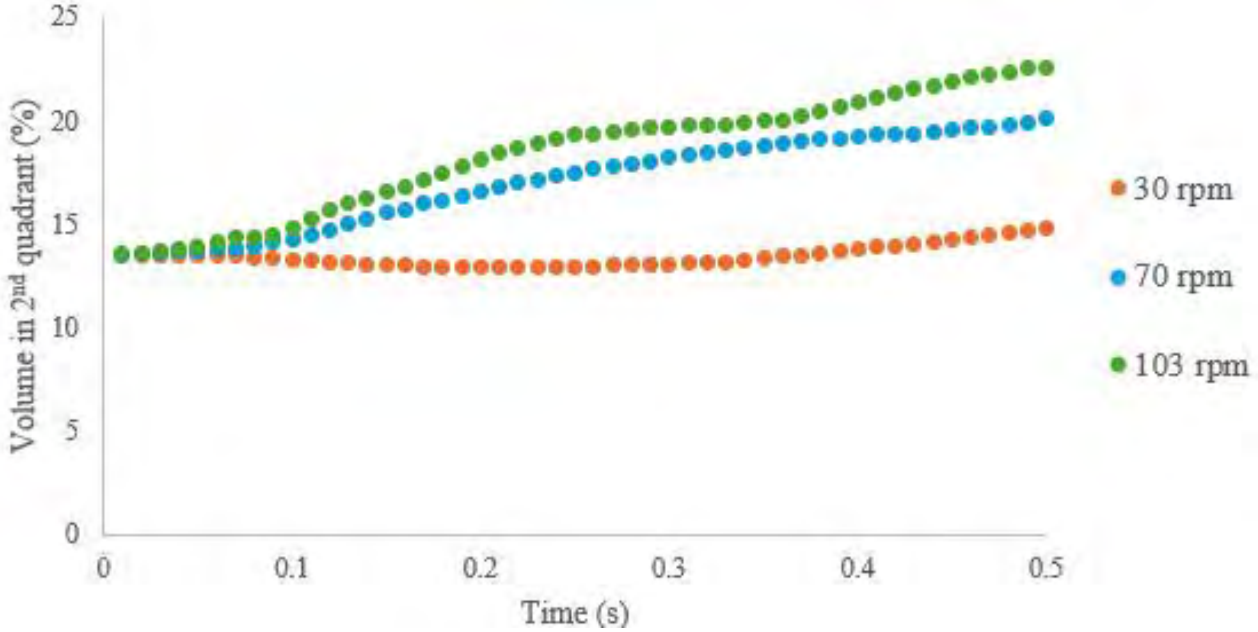
6.1. Near stationarity



6. Results and discussion

6.2. Comparison of volumes lifted

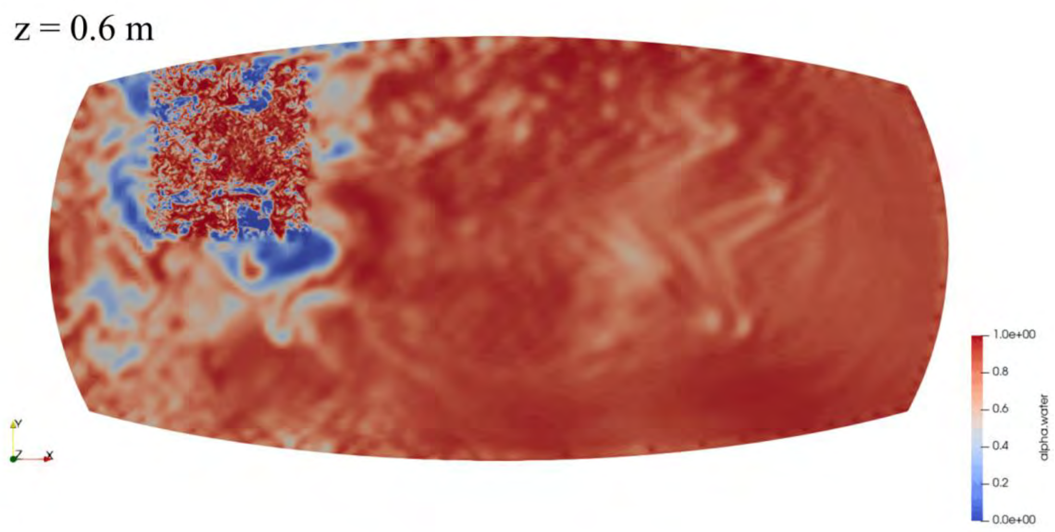




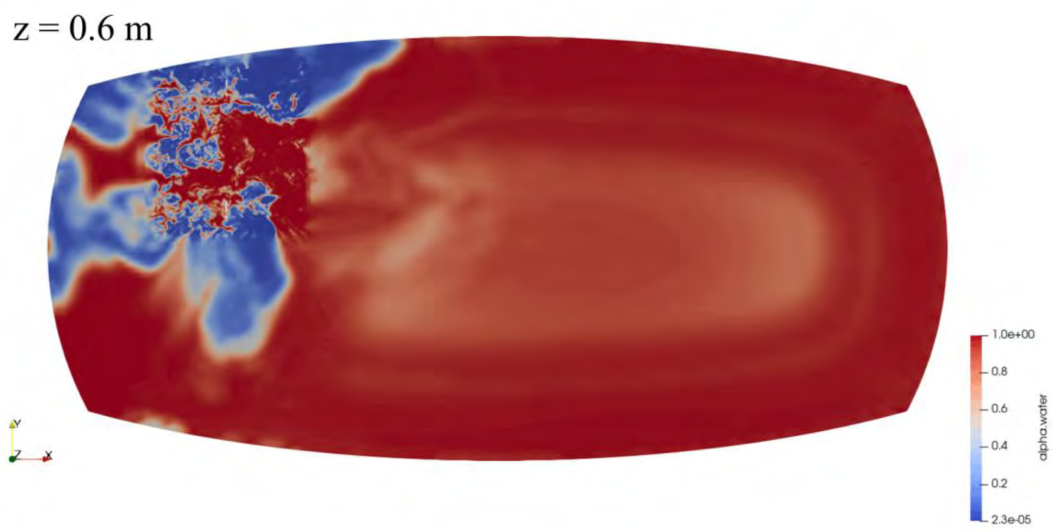
6. Results and discussion

6.3. Air entrainment

30 rpm



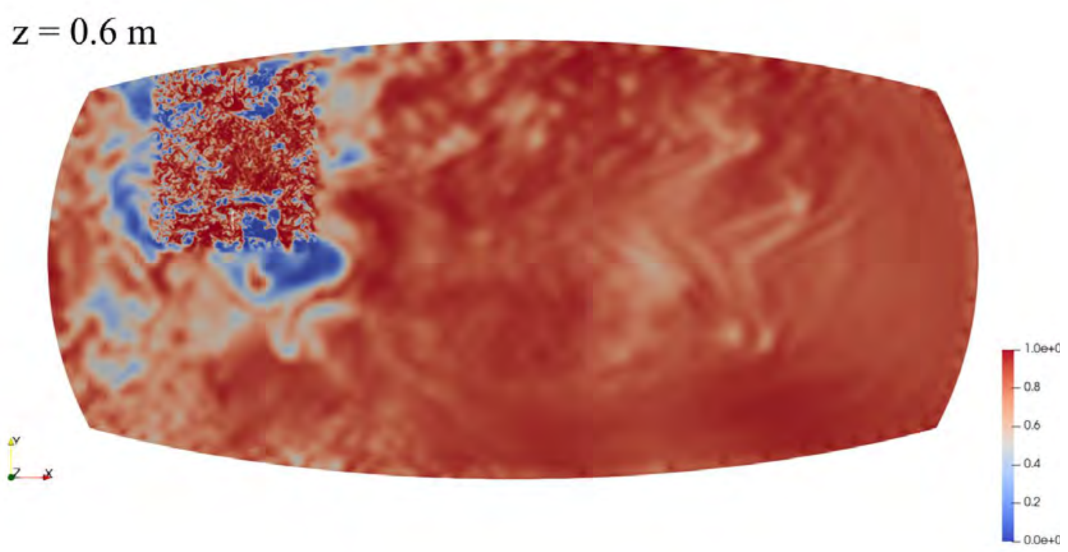
103 rpm



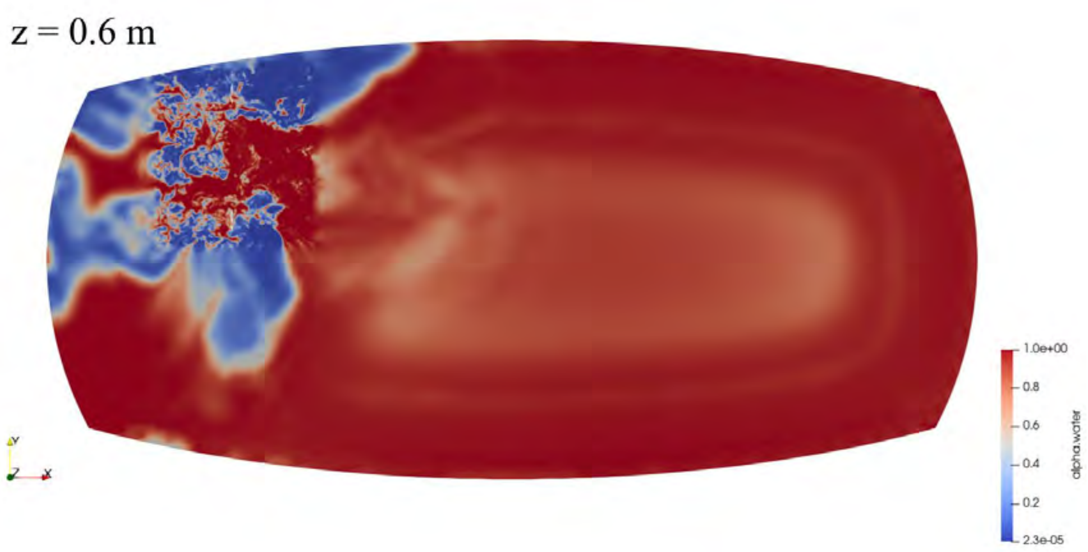
6. Results and discussion

6.3. Air entrainment

30 rpm



103 rpm



7. Conclusion and next steps

- Higher rotational speeds do lead to more volume of water in the second quadrant (possibly more inefficient);
- The simulations are able to reach a stationary/ near stationary state for paddlewheel aeration;
- Gas entrainment in the fluid is happening, as would be expected.

- Decrease the domain for further studies;
- Validate the results;
- Include an oxygen transference equation in OpenFoam solver.

Thank you for your atention!

Acknowledgement/Funding: This study had the support of national funds through Fundação para a Ciência e Tecnologia, I. P (FCT), under the projects UIDB/04292/2020, UIDP/04292/2020, granted to MARE, LA/P/0069/2020, granted to the Associate Laboratory ARNET and UIDB/00102/2020, UIDP/00102/2020 granted to CERES, and is part of SISdATA – EAPA_0040/2022 – System to Increase Security / sustainability in the domain of Atlantic Traditional Aquaculture (natural tanks and cage nets), project funded by Interreg Atlantic Area. Cluster computing system used in this study is supported by the Laboratory for Advanced Computing of the University of Coimbra.