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# Simulating the hydrodynamic response of a floater–net system in current and waves

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ABSTRACT

We present a novel numerical model for simulating current and wave interaction with a floater–net system. The main contribution of the paper is the integration of the floater motion and the fluid–structure interaction analysis of the net structure in the same modelling framework via the computational fluid dynamic approach. The sinker and the mooring lines were not directly resolved, but their effects were partially modelled. The model couples a hydrodynamic solver, a rigid body motion solver, a mesh motion solver and a structural solver in a segregated manner. In the numerical model, the net structure was modelled as a set of dynamic porous zones. A lumped mass model was coupled with it to realize fluid–structure interaction analysis for the net structure. The floater was treated as a rigid body, which was resolved by the body-fitted computational mesh in the fluid domain. The motion equation for the floater was set up based on the principle of linear and angular momentum balance. Different motion integration schemes were implemented and tested in the numerical model. The numerical model was validated against three sets of available experimental data in the open literature. The first set of validation cases treated the floater motion in regular waves. The second set of validation cases focused on the fluid–structure interaction analysis of the net structure. The final one was related to the whole floater–net system in regular waves, and combined current and wave condition.



## 1. Introduction

Hydrodynamic analysis on the floating fish cages for offshore aquaculture has been presented during the past few years. This comes with the fast development of aquaculture industry in the world. With the growing demand of food due to increasing population over the world, aquaculture is expected to continue making important contributions on world food security and nutrition supply.

The fish cage itself is a compliant and flexible system, whose components interact with each other. It usually contains four important components, namely the net cage, the floater, the mooring system and the sinker system. Each of them plays an important role and has its unique functionality. It is in general not straightforward to perform global analysis on the floating fish cage system. Some simplifications and assumptions are needed in order to set up a realistic numerical model. For instance, there exist a large number of twines and knots for a net cage, which are usually grouped together into fewer meshes in the numerical model. The floater may contain several tori, but it is usually simplified into a circular cross section in the numerical model. However, on the other side one still needs to properly take the effects of all the components into account, although sometimes it may be not necessary to model all of them.

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## Nomenclature

| | |
|---|---|
| $\boldsymbol{u}$ | fluid velocity field |
| $U_c$ | magnitude of steady current velocity |
| $U_w$ | magnitude of horizontal wave velocity |
| $V_w$ | magnitude of vertical wave velocity |
| $T_w$ | wave period |
| $\omega_w$ | wave circular frequency |
| $f_w$ | wave frequency |
| $k_w$ | wave number |
| $H_w$ | wave height |
| $\boldsymbol{x}$ | Cartesian coordinate system |
| $\rho$ | density field |
| $p_d$ | excess pressure field |
| $\mu$ | dynamic viscosity |
| $p$ | total pressure field |
| $\alpha$ | volume fraction field |
| $\boldsymbol{u}_r$ | compression velocity field |
| $\boldsymbol{g}$ | gravitation acceleration |
| $C_n^m$ | added mass coefficient of the net |
| $\boldsymbol{S}$ | porous resistance due to net |
| $\langle p_d \rangle^f$ | intrinsic volume averaged pore pressure field |
| $n$ | porosity of the net |
| $C$ | quadratic porous resistance coefficients |
| $V_P$ | volume of the porous zones |
| $\boldsymbol{u}_n$ | velocity field for the net structure |
| $\boldsymbol{F}_n^{wave}$ | wave force on each panel element in the lumped mass model |
| $\boldsymbol{F}_n^{struct}$ | structural force on the node in the lumped mass model |
| $\boldsymbol{F}_n^{grav}$ | gravitation force on the node in the lumped mass model |
| $\boldsymbol{F}_n^{buoy}$ | buoyancy force on the node in the lumped mass model |
| $S_n$ | solidity ratio of the net cage |
| $d_{twine}$ | diameter of the twine of the net |
| $\boldsymbol{T}_n$ | tension force of the net |
| $C_n^{twine}$ | drag force coefficient of the twines of the net |
| $\boldsymbol{u}_c$ | The convective velocity field in arbitrary Lagrangian–Eulerian formulation, defined as $\boldsymbol{u}_c = \boldsymbol{u} - \boldsymbol{u}_m$ |
| $\boldsymbol{u}_m$ | The mesh velocity field |
| $\boldsymbol{x}_m$ | mesh cell position |
| $\boldsymbol{q}_m$ | rotation quaternion for the mesh cells |
| $\langle \boldsymbol{u} \rangle$ | volume averaged velocity field |
| $\boldsymbol{F}_f^{wave}$ | wave force on the floater |
| $\boldsymbol{L}_f$ | angular momentum |
| $\boldsymbol{Q}_f$ | altitude of the floater |
| $\boldsymbol{u}_f$ | linear velocity of the floater |
| $\boldsymbol{x}_f$ | centre of mass of the floater |
| $\boldsymbol{F}_f^{wave}$ | wave force on the floater |
| $\boldsymbol{F}_f^{net}$ | force on the floater due to the connecting net cage |
| $\boldsymbol{F}_f^{moor}$ | mooring line force on the floater |
| $\boldsymbol{F}_f^{grav}$ | gravitation force on the floater |
| $\boldsymbol{F}_f^{buoy}$ | buoyancy force on the floater |
| $\boldsymbol{a}_f$ | linear acceleration of the floater |
| $\boldsymbol{\tau}_f$ | torque on the floater |
| $m_f$ | mass of the floater |
| $m_{f,a}$ | added mass of the floater |
| $\boldsymbol{q}_f$ | rotation quaternion for the floater |
| $\boldsymbol{F}_s^{cur}$ | current forces on the sinker |
| $\boldsymbol{F}_s^{wave}$ | wave forces on the sinker |
| $C_s^d$ | drag force coefficient of the sinker |
| $C_s^L$ | lift force coefficient of the sinker |
| $C_s^m$ | added mass coefficient of the sinker |