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A Fluid-Structure Interaction (FSI) Numerical Model for Aquaculture-Related Structures in Offshore Environment

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ABSTRACT

Offshore aquaculture structures encounter significant engineering challenges due to complex fluid-structure interactions (FSI) in harsh marine environments. A FSI numerical model has been developed to solve the engineering problems of aquaculture-related structures in offshore environments. The two-way coupling model in this work combines the open-source Computational Fluid Dynamics (CFD) code OpenFOAM (Jasak, 2009) to solve the fluid flow, and the Finite Element Analysis (FEA) code Project Chrono (Tasora et al., 2016) to solve the structural dynamics. The model employs the Finite Element Method (FEM) to simulate flexible components such as mooring lines, seaweed, and net structures. The Immersed Boundary Method (IBM) is employed for the interactions between the fluid and all the aquaculture-related structures (Mi et al., 2022, 2024). Fig. 1 shows the snapshots of an aquaculture system in regular waves, demonstrating the capability of current model for simulating the free surface and each component of the aquaculture system.

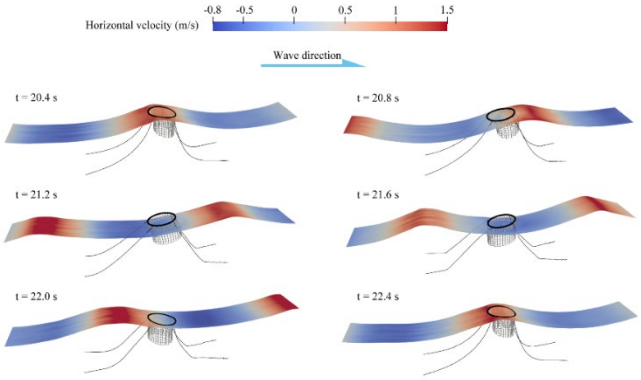

Figure 1: Snapshots of the aquaculture system in regular waves.

Rigid body dynamics are incorporated to model rigid man-made components such as platforms and frames of an aquaculture system, as well as natural structures like mussel and scallops. The Non-Smooth Contact (NSC) method (Pazouki et al., 2017) is considered to account for the collisions between net structures and rigid bodies. As shown in Fig. 2, nine scallop-shaped rigid bodies contact with the flexible net structure, leading to deformation of the net structure. Therefore, this numerical model can be used to simulate the state of scallops within the net cage and the dynamic response of scallop aquaculture cages under different flow conditions. The model has been extensively validated against published experimental data and is demonstrated to be a robust tool for simulating the complex fluid-structure interactions of aquaculture-related structures.

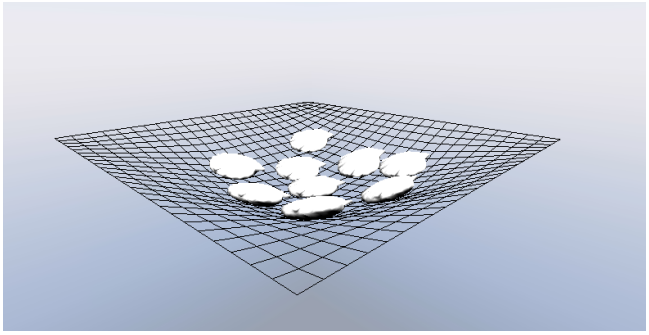

Figure 2: Contact of scallops and flexible net structure.

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