Numerical modelling of the hydrodynamics of a semi-submersible offshore fish farm in waves and currents

Gang Wang, Yong Cui, Lin Wang and Changtao Guan

Yellow Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences
266071 Qingdao, China

ABSTRACT

With the marine ranching projects gradually extending from the nearshore regions to the open ocean areas, aquacultural cages tend to be large-scale and more intelligent. Offshore fish farms are usually set in open ocean areas along with the extreme wave-current loadings from high-energy sea states resulting in increased fatigue and unpredictable structural damages, thus the safety issues in the extreme sea states have attracted widespread attention in the aquacultural industries. Offshore fish farms are generally composed of frames, nets, and mooring systems, the flow fields around and the hydrodynamic loadings on the nets, as well as the stability of the structure in the non-linear waves and currents, are the critical issues related to the safe operations of aquacultures. An advanced understanding of waves and currents through aquaculture structures is required to quantify the hydrodynamics loads as well as dynamic responses and, thereby, optimize future aquaculture structures designs. With the improvement of computational resources, the numerical simulation techniques based on the fluid structure interaction (FSI) has become a promising strategy to study the hydrodynamics of offshore fish farms. It includes a CFD fluid solver for the three-dimensional numerical wave tank (NWT), a novel continuous direct forcing approach for coupling three-dimensional moored floating bodies with a net solver [1,2]. To couple with NWTs, a Lagrangian approach for nets is implemented in an Eulerian fluid model, and hydrodynamic loads on nets are determined using screen force models [3]. The integrated numerical framework has been implemented in the REEF3D open-source hydrodynamics software, thereby the hydrodynamics of a typical semi-submersible offshore fish farm “Ocean Farm 1” [1], a submersible offshore fish farm “Shen Lan 1” [2], as well as vessel-type “HavFarm 1” [1] are investigated and well validated with the physical measurement data. The results are primarily illustrated in waves, the dominance of currents was however overlooked.

In this study, high-fidelity and efficient FSI simulations using the aforementioned REEF3D are utilized to study the hydrodynamics of a semi-submersible offshore fish farm in waves and currents. The generation of inputs conditions and the wave absorption are dealt with the relaxation method and the active wave absorption (AWA) methods, and the accuracies of NWT are validated with the published data. The flow fields around the semi-submersible offshore fish farm in pure currents are initially revealed. The impacts of Reynolds numbers and bio-fouling are considered, of which the latter are modelled through net solidities. Secondly, the regular and irregular waves combined with currents are included to examine response motions, wave loadings, mooring line tensions and offset distances. This study has provided the scientific references for the designs and optimizations of semi-submersible offshore fish farms.

REFERENCES

[1] Martin, T., Tsarau, A., Bihs, H., 2020. A numerical framework for modelling the dynamics of open ocean aquaculture structures in viscous fluids. Appl. Ocean Res. 106, 102410.

[2] Wang, G., Martin, T., Huang, L., Bihs, H., 2022. Numerical investigation of the hydrodynamics of a submersible steel-frame offshore fish farm in regular waves using CFD. Ocean Eng. 256, 111528.

[3] Wang, G., Martin, T., Huang, L., Bihs, H., 2022. An improved screen force model based on CFD simulations of the hydrodynamic loads on knotless net panels. Appl. Ocean Res. 118, 102965.