Modelling of floating fish cage dynamics with computational fluid dynamics - DTU Orbit (28/07/2019)

Modelling of floating fish cage dynamics

The present thesis considers modelling of the dynamic response of floating fish cages in current and wave conditions. The numerical model was developed based on the computational fluid dynamic (CFD) approach. The modelling framework is OpenFOAM, an open source CFD toolbox. A two-phase flow solver provided in official OpenFOAM software has been adopted as the foundation of the present numerical model. The solver treats the water and air as a mixture fluid, and solves mass and momentum conservation equations for the whole mixture system. The volume of fluid (VOF) method was applied to track the free surface.

A floating fish cage usually contains a net cage, a floater, a sinker and mooring lines. The focus of the present work is on modelling of the floater and the net cage. The sinker and the mooring lines were not explicitly modelled. Only the constant forces were added to the relative equations for the motion/deformation of the floater and the net cage.

A net cage contains a large number of twines and knots. Therefore, a detailed modelling of the geometry of the net cage is not possible yet. In the present work, it was modelled as a sheet of porous media with very thin thickness. Volume averaged Navier-Stokes equations were applied as the governing equations for the porous media flow. Due to the volume averaging process, a resistance term appears in the governing equations, representing the viscous force of the net cage on the fluid flow. The force was usually expressed as the sum of a linear drag force and a quadratic drag force. But it was found that for a net cage, the quadratic drag force completely dominated over the linear drag force. Therefore, the linear component was neglected. An analytical expression was derived to relate the quadratic force coefficients with the physical parameters of the net cage, e.g. the length of the mesh bar, the solidity ratio, the drag force coefficient for the twins etc. The derivation indeed was based on the transformation from Morison type load model. Two new parameters were introduced to account for the interaction effects between the twines, and they were calibrated based on the available experimental data. The proposed expression was validated against model test results for current and wave interaction with fixed plane net panels and circular net cages.

Considering the flexibility of the net cage in response to the current and waves, the porous media model was further coupled with a lumped mass structural model. A new coupling scheme was implemented in the numerical model. The coupling scheme was based on the static mesh, therefore the mesh does not need to conform the deformed geometry of the net cage. Instead, the geometry of the deformed net cage was approximated by several dynamic porous media zones, corresponding to the panel elements in the lumped mass model. At every time step, the cells in the porous media zones were updated based on the transferred nodal positions from the structural model. This coupling scheme was validated against experiments for top fixed and bottom weighted plane net panels and circular cages in current and waves.

In general, for a fish cage in steady current flow, the net cage is the main part to stand the drag force on it. However, when modelling the floating fish cage in wave conditions, the motion of the floater is the main contributor to the forces on the net cage. Hereby in the numerical model it should be considered. Presently a body-fitted computational mesh was applied, and the geometry of the floater was resolved by the mesh. A six degree of freedom motion solver was applied to solve the motion equations of the floater with different motion integration methods. Careful validations were performed first on wave loads on the fixed floater, and motion responses of the floating floater. It was decided to apply the explicit-implicit Adams-Bashforth-Moulton scheme as the motion integration scheme for the floater. This floater model was successfully coupled with the above described model for the net cage, hereby is capable to model the responses of the whole floating fish cage system. This integrated numerical model was validated against the experimental data on snap loads of the net cage in regular waves, which is due to the relative motion between the sinker and the floater, and the mooring loads in combined current and wave conditions.

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